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Atlas of Holocene pollen of Southern Italy (Mar Piccolo, Taranto)

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A R T I C L E I N F O

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A B S T R A C T

There have been plenty of palynological studies on Quaternary from the Mediterranean region in the past decades. However, few focused on the iconographic documentation of pollen grains.

An illustrated, descriptive atlas of pollen from Holocene sediments (S05B core and surface samples) and mosses from Mar Piccolo (southern Italy) was compiled. The pollen atlas includes 143 taxa representative of local (wetlands including both freshwater and salt marshes), regional and extra regional sources as well as some alien taxa (e.g., *Citrus medica* and *Eucalyptus*). A total of 490 light microscopy images are organized in 15 plates concerning 27 species and 75 genera within 26 families. The atlas is intended to serve as practical guide for pollen investigations, aiming at reconstructions of flora and vegetation, as well as environmental and climate changes in southern Italy.

1. Introduction

A detailed knowledge of palaeoenvironmental and palaeoclimate changes during the Holocene is crucial to better understand the response of our planet to both climate changes and increasing anthropic forcings plus associated feedbacks. Nowadays, the Mediterranean region (MR) has been identified as one of the most responsive to Global Warming (e.g., IPCC-AR6, 2023). Higher temperatures and lower precipitation amount (e.g., Cos et al., 2022) have a strong impact on the flora and vegetation enhancing the spread of open vegetation in the MR (e.g., Apulia Region: Ladisia et al., 2012) as well as biodiversity and ecosystem services loss (Danso Appiagyei et al., 2022).

Palynological studies of terrestrial and marine sedimentary successions document the history of floristic, vegetational, and climate changes throughout the Holocene, in the MR (e.g., Magri, 1999; Allen et al., 2002; Mariotti Lippi et al., 2007; Tinner et al., 2009; Vescovi et al., 2010; Di Rita et al., 2011, 2018; Joannin et al., 2012; Combourieu-Nebout et al., 2013; Mercuri et al., 2013; Sadori et al., 2015; D'Orefice et al., 2020; Vignola et al., 2022). Additionally, transfer functions permit to acquire numerical values of climate parameters (e.g., temperature and evapotranspiration) (e.g., Ortu et al., 2008; Martin et al., 2020; Robles et al., 2023) which are crucial for the validation of climatic models. According to the palynological evidence temperate forests spread under warm and humid climate at the beginning of the Holocene (ca. 11.7 ka BP) just after the expansion of steppes under a prevalent cold and dry event at ca. 12 ka BP (Younger Dryas). However, a series of rapid climatic changes (e.g., 8.2 ka BP and 4.2 ka BP events) punctuated the Holocene (e.g., Bini et al., 2019; Di Rita et al., 2022; Bernal-Wormull et al., 2023). The sudden and short-term events of drought caused forest decline and consequent expansion of open vegetation in the MR (e.g., Di Rita et al., 2018; Di Rita and Magri, 2019). The effects of previous factors as well as sea level fluctuations are especially well documented in Holocene coastal wetlands by palynology (e.g., Mariotti Lippi et al., 2007; Bellini et al., 2009; Di Rita and Magri, 2009; Di Rita and Melis, 2012; Azuara et al., 2015; Di Rita et al., 2018; Roner et al., 2021; Susini et al., 2023). However, Holocene pollen atlases for Italy and even MR are quite few (e.g., Chester and Raine, 2001).

The Mar Piccolo (MP, Fig. 1) (southern Italy: 41° – 39° N) is a shallow inland marine basin, straddling the Ionian Sea and the Apulia region, surrounded by extended wetlands. Here palynological investigations on pollen, dinocysts and other Non-Pollen Palynomorphs (NPPs) are in progress in a sedimentary core (S05B), mosses and surface sediments. The abundant preserved pollen grains allow us to realize, in this first step of the research, an atlas of selected pollen taxa from the previous different natural archives. The atlas is intended to serve as a handy and comprehensive reference for morphologically and taxonomically identification of pollen recovered from the Holocene archives of southern Italy, and to support the robustness of the associated pollen-based vegetation and climate reconstructions.

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2. Regional setting

2.1. Physiographic context

The MP (Fig. 1) is a coastal brackish marine ecosystem located along the northern coast of the Gulf of Taranto (40°28′16″N 17°14′35″E, Fig. 1) with a total surface of 20.72 km^2 (Matarrese et al., 2004). In this area, during the last ca. 12 kyr a fluvial incision was followed by the development of a lacustrine environment and then a marine ingression led to the establishment of the present-day semi-closed marine basin (Valenzano et al., 2018).

The basin encompasses two embayments, respectively to the west and to the east, named *Primo Seno* and *Secondo Seno* (Fig. 1). The *Primo Seno* (Fig. 2A) is the smallest embayment and exhibits an average water depth (wd) of 13 m and a maximum wd of 30 m. The *Secondo Seno* has an average wd of 9 m and reaches a maximum wd of 18 m. The MP basin is connected with *Mar Grande* (Fig. 1) by two channels respectively of natural (at north-west) and anthropogenic (at south-west) origin (Mastronuzzi et al., 2013). Freshwater inputs linked to both tributary rivers and at least 34 subaerial/submerged karst springs (locally called '*Citri*', Cerruti, 1938, 1948; Parenzan, 1969; Lisco et al., 2016; Valenzano et al., 2020) influenced the water chemistry. Freshwater inputs along with the effects of low hydrodynamics, geographic confinement, prevalence of uncoherent substrates, eutrophication, and human activities lead the MP to be very close to a brackish lake although its salinity (ca. 36), is consistent with that of seawater (Caroppo and Cardellicchio, 1995; Annichiarico et al., 2009). Near the subaerial *Citri* freshwater marshes expanded (e.g., Galeso, Figs. 1 and 2B) whereas saltmarshes (Palude la Vela, Figs. 1 and 2C) developed in eastern portion of *Secondo Seno*.

2.2. Landscape, climate and vegetation

The terrestrial landscape surrounding the MP basin is mostly characterized by lowland. The Murge (600 m a.s.l; Fig. 3A) are the nearest low reliefs. They are characterized by erosive karst incisions called *gravine* which provide a wide range of habitats and ecological niches for plant and animal species (e.g., Macchia, 1980; Di Pietro and Misano, 2009). Mountain reliefs are far away, over 200 km, with the closest located to the N-NW, in the Dauno Apennines (Monte Cornacchia, 1151 m a.s.l.; Fig. 3A). The MP basin holds a typical Mediterranean climate, with a strong seasonality marked by dry and hot summers and relatively rainy and mild winters (e.g., Macchia et al., 2000). At Taranto the highest temperatures are from June to September while precipitation is abundant from September to April (Fig. 3B). The recent effects of global warming and anthropic exploitation of the territory endanger the floristic-vegetational landscape of the Apulian region. We must report that MP hosting one of the largest and most polluting steel factories in Europe to be included within the contaminated Italian Sites of National Interest (SIN, National law n. 426/, 1998). Pollution of water, soil and air is very high (e.g., Mangia et al., 2019; Trifuoggi et al., 2019; Labianca et al., 2020; Cotecchia et al., 2021; Liberatori et al., 2021; Rizzo et al., 2022; Lisco et al., 2023) and associated with high mortality and morbidity rate (e.g., Bianco et al., 2013; Pirastu et al., 2013; Cazzolla Gatti and Velichevskaya, 2022).

Mesophilous forests with deciduous/semi-deciduous oaks (*Quercus pubescens*, *Q. petraea*, and *Q. cerris*), often associated with *Castanea sativa*, expand between 400 and 600 m a.s.l.. *Quercus trojana* (semi-deciduous oak), a taxon exclusive of the Murge hills, characterizes two main types of forests. The *Q. trojana* forest associated with *Q. pubescens* is present in the Murge hills, although reduced by an intensive cultivation. The shrub layer is highly developed (*Pistacio-Rhamnetalia alaterni* Rivas-

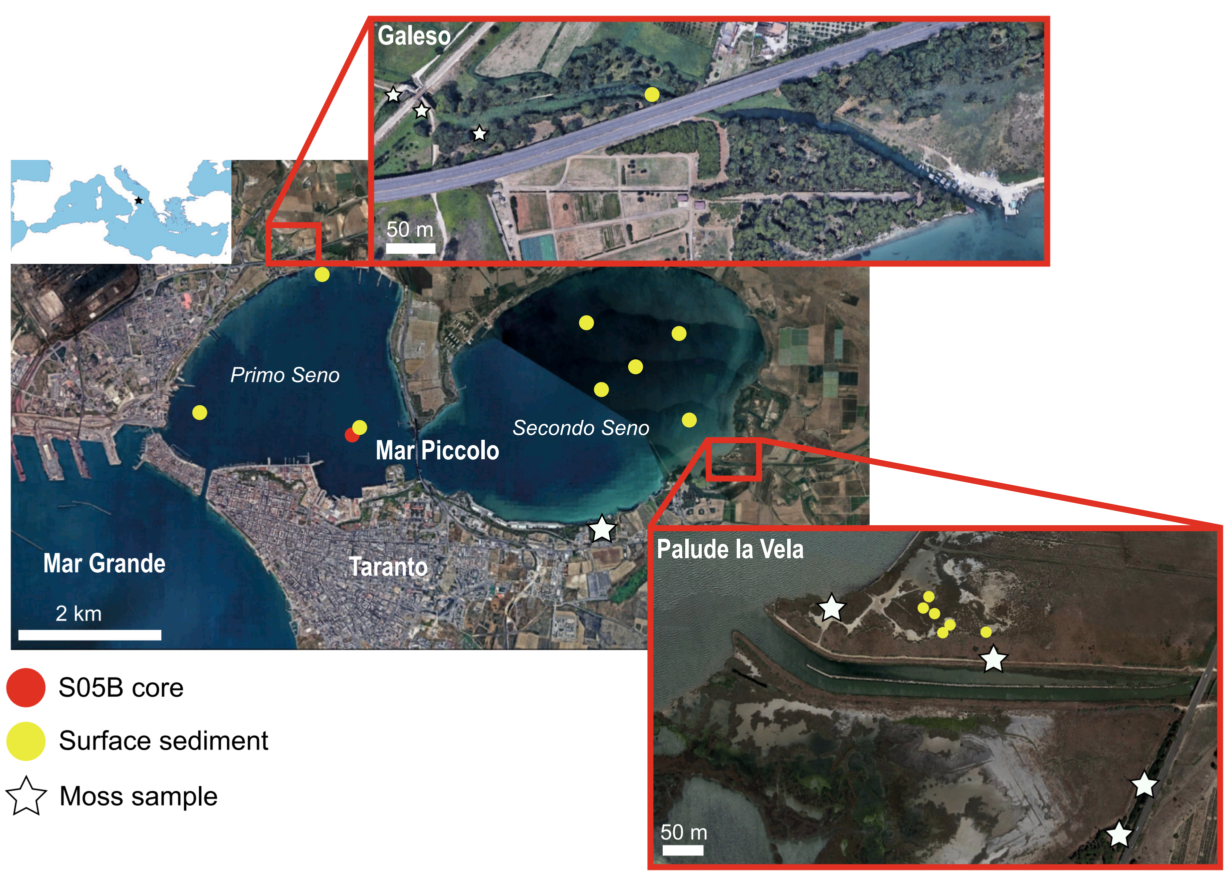

Fig. 1. Location Map (top-left) of the Mar Piccolo in the Mediterranean region. In the Google Earth map the main sites around the Mar Piccolo are specified along with the position of the S05B core, surface sediments, and moss samples.

Fig. 2. Mar Piccolo landscapes. *Primo Seno* (A). Galeso freshwater marsh (B). Palude la Vela saltmarsh (C).

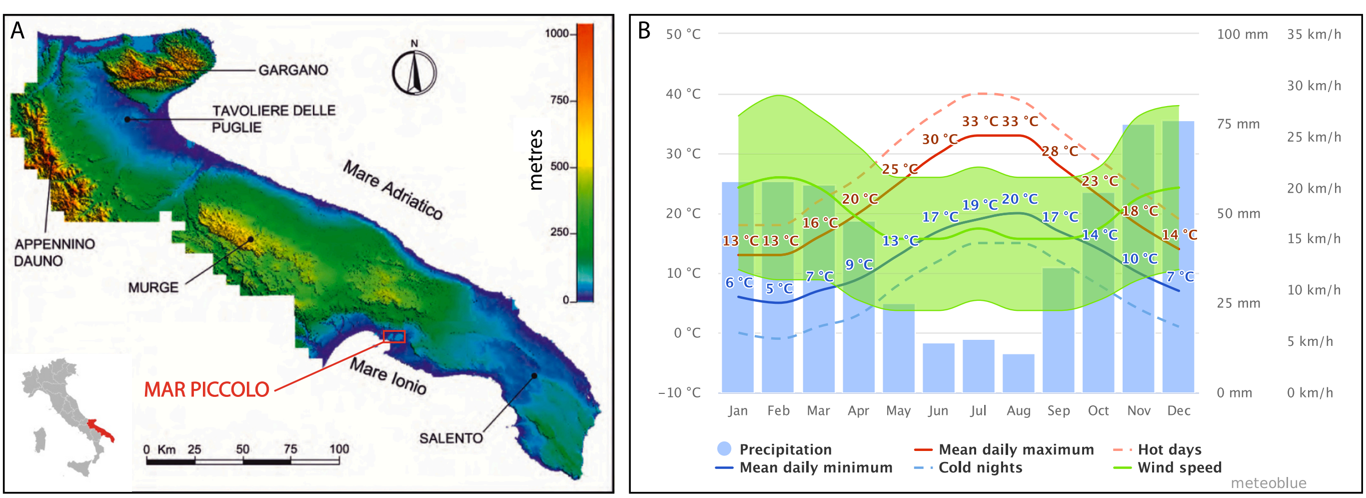

Fig. 3. Altitudinal map of the Apulia region (modified from Cotecchia, 2014) (A). Climogram of Taranto with mean daily maximum/minimum temperatures, numbers of cold nights, precipitation, and wind speed (from www.meteoblue.com) (B).

Martínes 1975) with abundance of *Ruscus aculeatus*. The herbaceous component is also well developed with *Allium subhirsutum* and other nitrophilous entities such as *Asphodelus ramosum* and *Galium aparine* (for more details refer to Di Pietro and Misano, 2009). The highlands are characterized by steppe and garrigue. In the *gravine* the floristic composition and structure of the *Q. trojana* forest is totally different from that thriving on the hills. Here *Q. trojana* forest especially includes *Carpinus orientalis* and *Fraxinus ornus*. *Q. pubescens* is not common and *Quercus ilex* (evergreen oak) is present on rocky outcrops. Shrubs are dominated by *Ruscus aculeatus*. The innermost area of the *gravine* has meso-hygrophilous taxa such as *Festuca drymeja* and *Umbilicus rupestris* or riparian forest with *Fraxinus angustifolia* subsp. *oxycarpa* (for more details refer to Di Pietro and Misano, 2009). Above 900 m a.s.l. *Pinus nigra* subsp. *laricio* dominates associated with *Cupressus sempervirens*. In mountains reliefs, *Fagus sylvatica* is present often associated with *Ilex aquifolium, Alnus cordata* and *Acer cappadocicum*. Sometimes it is also associated with residual/relict forest of *Abies alba*. *Alnus glutinosa* and *Fraxinus excelsior* along with some herbaceous plants (e.g., *Berula erecta*, *Potamogeton natans*, and *Carex distans*) (Wegensommer et al., 2014) grow near rivers and streams. In Monte Cornacchia, *Cedrus deodara* and *C. atlantica* are present as a result of the reforestation between the 1950s and 1970s.

The forest ecosystem currently occupies a narrow area of the Apulian region as it has been gradually replaced by olive groves, vineyards, citrus groves (*Citrus sinensis* and *Citrus x clementina*) and other extensive/intensive cultivations. For this reason, towards the coast, the *Oleo-Ceratononion siliquae* Br.-Bl. ex Guinochet & Drouineau 1944, em. Rivas-Martinez 1975 presents increasingly degraded vegetation with dominant shrubby taxa such as *Phillyrea latifolia*, *Pistacia lentiscus*, *Myrtus communis*, *Quercus ilex* and the rare *Arbutus unedo* (Greco, 1991). Sometimes garrigue with *Cistus* spp., Poaceae, and bulbous plants (e.g., *Asphodelus fistulosus* subsp. *fistulosus*) are expanded. Monospecific reforestations with *Pinus halapensis* have been carried out alongside the degraded coastal Mediterranean scrub. The herbaceous and shrubby vegetation of the coast exhibits the prevalence of *Juniperus macrocarpa* in rocky coasts (Greco, 1991). *Hippocrepis emerus*, *Scilla*, *Cistus salvifolius*, *Thymus capitatus* are the most common plants on the sand dunes. The grassy plains are dominated by *Hordeum*, *Poa*, *Stipa*, *Bromus*, *Ononis*, *Medicago*. One of the main features of the flora of this area and for the biodiversity is the presence of several orchids (e.g., *Ophrys*, *Orchis*, *Serapias*, *Spiranthes spiralis*) (Greco, 1991).

Large and complex wetlands surrounding the MP include permanent aquatic, palustrine and terrestrial habitats hosting a high biodiversity and providing key ecosystem services. Before their draining, in particular during the 18th century (Greco, 1992), they represented a paralittoral strip of the MP. Both freshwater and salt marshes are well expanded. Freshwater marshes (e.g., Galeso, Fig. 2B) are developed in proximity of the karst springs and are dominated by *Phragmites australis*, (*Scirpo-Phragmitetum* Koch 1926 and *Polygono salicifolii-Phragmitetum* Barbagallo, Brullo, Furnari 1979).

The Palude la Vela (Fig. 2C) is a regional nature reserve. It incorporates the WWF Oasis in its southern portion and overlaps the Site of

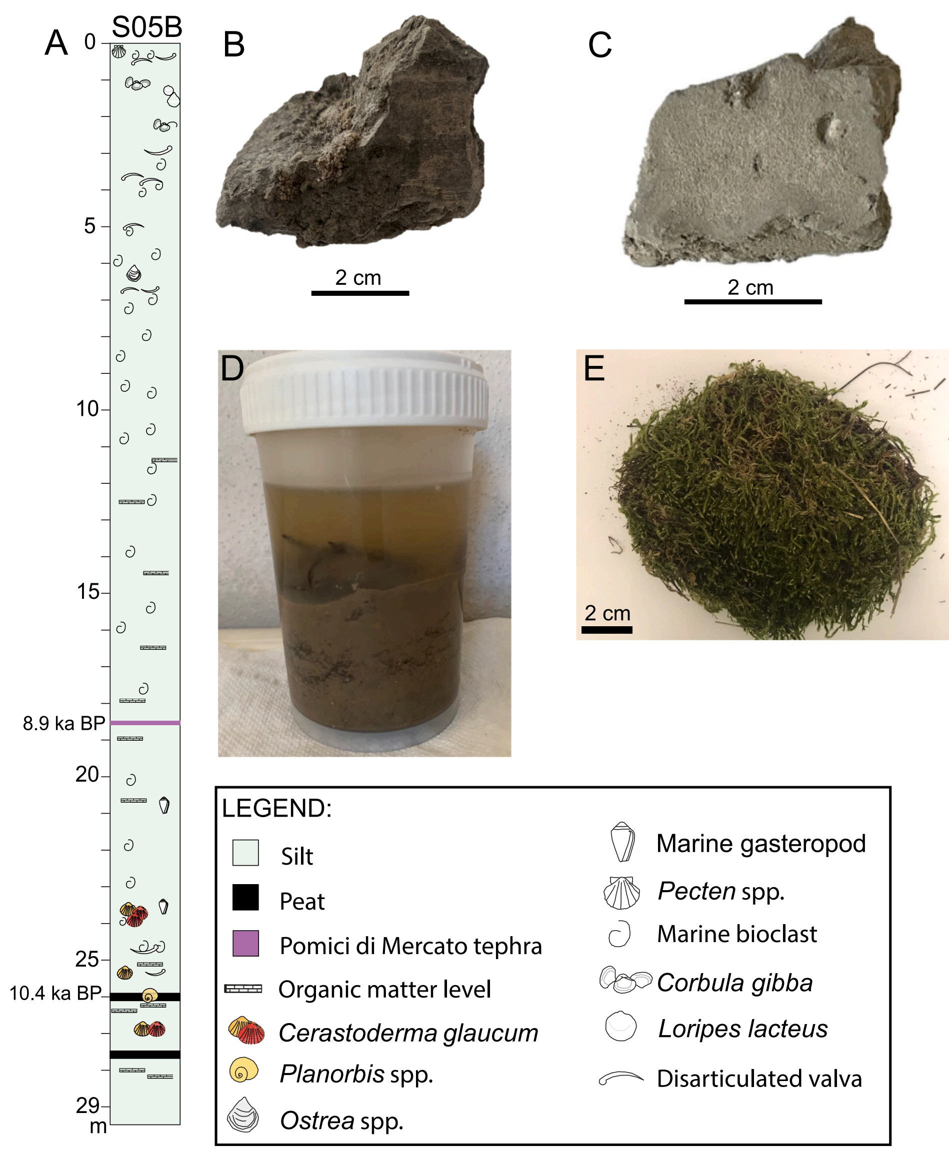

Fig. 4. Sedimentary log of the S05B core (A). Selected samples: silt organic-rich/peat-S05B (B); gray silt-S05B (C); surface sediment (D); moss (E).

Community Interest (SIC) IT9130004 “Mar Piccolo”. Its current vegetation is typical of saltmarshes characterized by the supremacy of *Salicornia fruticosa* with other halophytic taxa (e.g., *Atriplex portulacoides*, *Salicornia europea*, *Puccinellia festuciformis*, *Spirobassia hirsuta*, *Limbarda crithmoides*, *Matthiola sinuata*, *Sonchus maritimus*, *Suaeda maritima*, *Limonium virgatum*, *Arthrocnemum macrostachyum*) (for more details see in Lorenzoni and Lorenzoni, 1977).

Some alien taxa (e.g., *Eucalyptus*) was introduced in the MP for reforestation in 1950s–1960s (Greco, 1991) especially in Galeso. *Opuntia ficus-indica*, is quite common around the coast of MP. Other alien taxa, today common in gardens and along avenues, are Aracaceae, *Aloe*, *Agave* and ornamental Cactaceae.

3. Materials and methods

3.1. Sample collection

Pollen samples were collected from three different natural archives in the MP basin (i.e., sediment core S05B, surface sediments and mosses; Figs. 1 and 4).

3.1.1. Sedimentary core S05B

The S05B sediment core (29.49 m thick; Figs. 1 and 4A) includes organic-rich silts and peats from 29.49 to 25 m (Fig. 4B) overlain by 25 m of grayish silts to the top (Fig. 4C). At 25.95 m a peat level was dated at ca. 10.4 ka BP (Valenzano et al., 2018). A tephra, known as Pomici di Mercato, occurs at ca. 18.5 m (8.9 ka BP; e.g., Mele et al., 2011). The core was sampled every 3 cm, for a total of 971 samples.

3.1.2. Surfaces sediments

A total of 15 surface samples were collected (Figs. 1 and 4D), including 8 samples inside the MP (3 samples in the *Primo Seno* respectively near the Galeso mouth, near the natural channel between MP and *Mar Grande*, and close to the S05B core; 5 samples in the *Secondo Seno* along two perpendicular transepts), 1 sample in the Galeso stream (Figs. 1 and 2B), and 6 samples in Palude la Vela (Figs. 1 and 2C).

3.1.3. Mosses

A total of 8 moss samples were collected, in particular 1 moss sample from a pine forest near Taranto, 3 samples along the Galeso, and 4 samples in Palude la Vela from the hinterland towards the sea (Figs. 1 and 4E).

3.2. Pollen samples preparation

3.2.1. SB05 core and surface sediment samples

A total of 488 samples (473 samples of S05B core and 15 surface sediment samples) (Figs. 1 and 4A, B, C, D) were submitted to chemical–physical treatments including: (i) sediment powdering; (ii) weight of the sample (5 to 14 g depending on the lithology); (iii) adding of one *Lycopodium* tablet according to the marker-grains methods (Matthews, 1969); (iv) chemical processes with 20% HCl, 38% HF, 20% HCl, and $(NaPO_3)_6$; (v) sieving at 10 μm in an ultrasonic bath. The residues were diluted in glycerol with a ratio of 1:10 with respect to the dry residue. Mobile glass slides were mounted to facilitate the morphological observation of pollen grains.

3.2.2. Moss samples

A total of 8 moss samples (Figs. 1 and 4E) were submitted to chemical–physical treatments including: (i) weight of the sample (2 to 5 g); (ii) adding of one *Lycopodium* tablet (Matthews, 1969) with a few drops of 20% HCl to dissolve it; (iii) adding 100 ml of KOH 10%; (iv) sieved at 200 μm collecting the through-sieve material; (v) chemical processes with 20% HCl, 38% HF, and 20% HCl; (vi) sieving at 10 μm in an ultrasonic bath. The residues were diluted in glycerol with a ratio of 1:10 with respect to the dry residue. Mobile glass slides were mounted for light microscopy observation.

3.3. Microscopic analysis

A light microscopy (LM, Nikon 50i) at 400× and 1000× (oil immersion) magnification was used; 1000× magnification was applied to take pollen micrographs. Photographs were captured from S05B core samples as well as surface sediments and moss samples during the quantitative microscope analyses to reconstruct environmental and climate changes. Image acquisition was performed with a camera (Nikon Digital Sight) mounted on a trinocular tube. The image acquisition software (NIS elements F) was adjusted for automatic white balance. All scale bars represent 20 μm. Due to the limited depth of focus in light microscopy, LO-analysis has been applied (Erdtman, 1952, 1969). When LO-analysis was indispensable for taxonomic identification, multiple images of the same pollen grains are reported in the plates. Image processing was done with Adobe Illustrator 2023 version 27.5, on a white background. For some pollen grains (e.g., Campanulaceae indet., *Cornus*, *Sambucus, Sagittaria*) it was not possible to capture LM micrographs because of the high occurrence of organic matter and the absence of good stable views.

For pollen identification, we referred to several publications including pollen monographs, e.g., Pollen et Spores, *Review of Palaeobotany and Palynology*, Pollen et spores d'Europe et d'Afrique du Nord by Reille (1992, 1995, 1998), as well as the pollen reference collection at the Department of Earth Sciences at the University of Florence. Generally, it has been possible to define pollen taxa up to the rank of family or genus and more rarely of species.

3.4. Pollen terminology

The pollen morphological terminology follows that by Punt et al. (2007). The open nomenclature (cf.; sp.) is used according to Bengtson (1988), while the use of “indet.” is restrictively used for taxa above the rank of genus (e.g., Martinetto et al., 2022). The use of type is according to Sluys (2021).

4. Results

The palaeofloristic list consists of 130 taxa including 9 gymnosperms and 121 angiosperms (core S05B, Table 1 MP-S). The sub-recent floristic list consists of 100 taxa including 9 gymnosperms and 91 angiosperms (surface sediments and mosses, Table 1, MP-Ss; PLV-Ss, G-Ss; MP-M; PLV-M; G-M). The total floristic list (Table 1) resulting from the palynological analyses of the three different archives (S05B sediment core, surface sediment, and moss samples) consists of 143 taxa (10 gymnosperms and 133 angiosperms).

The LM micrographs of selected fossil and sub-recent pollen grains from three different natural archives of the MP were summarized into 15 high-resolution plates (595 × 841) (Plates I–XV).

The analyzed samples show an excellent preservation of pollen grains which favored their identification and the obtaining of good micrographs. The largest pollen grains dimensions were identified for *Picea* (Plate II, 1–5), *Abies* (Plate II, 6), and *Abies cephalonica* (Plate II, 7–8), while the smallest for *Castanea* (Plate X, 1–3). The most common pollen grains are those of *Pinus* (Plate I, 9–15), Amaranthaceae (Plate VI, 28–53), *Quercus pubescens*-type (Plate X, 8–19), *Olea* (Plate XI, 7–18), Wild Poaceae-group (Plate XIII, 19–27), and, exclusively for surface sediments and moss samples, *Eucalyptus* (Plate XIII, 1–14).

5. Systematics – pollen description

5.1. Gymnosperm pollen

The arrangement of conifer taxa follows alphabetic sequence of Order name. The classification proposed by Christenhusz et al. (2011)

Table 1

List of the Mar Piccolo pollen taxa arranged in alphabetic order. MP-S: S05B core (fossil data); MP-M: moss in MP; MP-Ss: surface sediments in MP; PLV-Ss: surface sediments in Palude la Vela; PLV-M: mosses in Palude la Vela; GAL-Ss: surface sediment in Galeso; GAL-M: mosses in Galeso.

Taxa				MP			PLV		GAL	
				S	Ss	M	Ss	M	Ss	M
GYMNOSPERM	Cupressales	Cupressaceae	Cupressoideae indet.	X		X		X		
			Juniperus	X	X		X	X		X
	Ephedrales	Ephedraceae	*Ephedra distachya* -type	X		X				X
			Ephedra fragilis -type	X	X		X			
			Ephedra cf. *torreyana*			X				
	Pinales	Pinaceae	*Abies*	X	X					
			Abies cephalonica	X						
			Cedrus	X	X		X	X		
			Picea	X	X		X			
			Pinus	X	X	X	X	X	X	X
ANGIOSPERM	Alismatales	Alismataceae	*Alisma plantago-aquatica*	X						
			Sagittaria	X						
		Araceae	*Lemna*	X						
		Potamogetonaceae	*Potamogeton*	X			X			
	Apiales	Apiaceae	Apiaceae indet.	X	X		X	X	X	X
			Bupleurum	X						
		Araliaceae	Araliaceae indet.	X						
			Hedera	X	X		X			
	Aquifoliales	Aquifoliaceae	*Ilex*	X						
	Arecales	Arecaceae	Arecaceae indet.		X		X			
	Asparagales	Asphodelaceae	*Aloe*		X	X				
			Asphodelus	X						
		Iridaceae	Iridaceae indet.	X						
			Scilla	X						
		Orchideaceae	*Spiranthes spiralis*					X		
	Asterales	Asteraceae-Asteroideae	*Ambrosia artemisiifolia* -type		X				X	X
			Artemisia	X	X	X	X	X	X	
			Carduus crispus -type	X			X			
			Carlina vulgaris -type	X						
			Centaurea nigra -type	X	X		X	X	X	X
			Inula britannica -type		X		X	X		
			Senecio vulgaris -type	X	X	X		X	X	X
		Asteraceae-Cichorioideae	Asteraceae-Cichorioideae indet.	X	X	X	X	X	X	X
		Campanulaceae	Campanulaceae indet.	X	X		X		X	
	Boraginales	Boraginaceae	Boraginaceae indet.	X	X			X		
	Brassicales	Brassicaceae	Brassicaceae indet.	X	X		X	X	X	X
			Draba	X						
			Erysimum	X	X					
			Matthiola	X						
		Salvadoraceae	cf. *Salvadora persica*		X					
	Buxales	Buxaceae	*Buxus*	X			X		X	
	Caryophyllales	Amaranthaceae	Amaranthaceae indet.	X	X	X	X	X	X	X
		Cactaceae	cf. Cactaceae indet.			X		X		
		Caryophyllaceae	Caryophyllaceae indet.	X		X	X	X		
		Polygonaceae	*Fagopyrum*	X						
			Polygonum	X	X		X			
			Rumex cf. *acetosella*	X	X		X	X		
ANGIOSPERM	Caryophyllales	Plumbaginaceae	*Armeria*	X			X			
			Limonium	X	X					
		Tamaricaceae	*Tamarix*	X			X			
	Cornales	Cornaceae	*Cornus*	X				X		
	Dipsacales	Caprifoliaceae	*Fedia cornucopiae*	X						
			Knautia	X						
			Scabiosa	X	X			X		
			Valeriana	X		X				
		Viburnaceae	*Sambucus*	X		X	X			X
			Viburnum lantana	X	X			X		
	Ericales	Ericaceae	Ericaceae indet.	X	X	X	X	X		X
		Primulaceae	Primulaceae indet.	X					X	
			Androsace	X						
	Fabaeles	Fabaceae	*Astragalus*				X			
			Ceratonia	X	X	X				X
			Hedysarum humile				X			
			Hippocrepis					X		
		Polygalaceae	Polygalaceae indet.	X						
	Fagales	Betulaceae	*Alnus*	X	X	X	X	X	X	X
			Betula	X	X	X	X	X		
			Carpinus betulus	X	X		X	X		
			Carpinus orientalis /Ostrya carpinifolia	X	X	X	X	X	X	X
			Corylus	X	X		X	X		
		Fagaceae	*Castanea*	X	X	X			X	
			Fagus	X	X		X	X	X	X
			Quercus cerris	X	X	X	X	X		
			Quercus ilex-coccifera -type	X	X	X	X	X	X	X
			Quercus pubescens -type	X	X	X	X	X	X	X
			Quercus suber	X	X					
		Juglandaceae	*Juglans*	X	X		X	X	X	
	Gentiales	Rubiaceae	*Galium*	X						
	Geraniales	Geranieaceae	*Erodium*	X		X	X	X		
			Geranium	X				X		
	Lamiales	Lamiaceae	Lamiaceae indet.	X	X		X	X		
			Phlomis	X						
			Sideritis	X	X					
		Oleaceae	*Fraxinus*	X	X	X	X	X		
			Ligustrum	X	X		X	X		
			Olea	X	X	X	X	X	X	X
			Phillyrea	X		X	X	X		
		Orobanchaceae	*Pedicularis*	X						
		Plantaginaceae	*Callitriche*	X			X			
			Plantago lanceolata	X	X	X	X	X	X	X
		Scrophulariaceae	*Verbascum*	X			X			X
	Liliales	Colchicaceae	*Colchicum*	X						
		Liliaceae	Liliaceae indet.	X						
	Malpighiales	Hypericaceae	*Hypericum*	X	X	X	X			X
ANGIOSPERM	Malpighiales	Linaceae	*Linum*	X						
		Salicaceae	*Populus*	X				X		
			Salix	X	X	X	X	X	X	
	Malvales	Cistaceae	*Cistus*	X			X			
			Helianthemum	X	X		X			
		Malvaceae - Malvoideae	Malveae	X						
		Malvaceae - Tilioideae	*Tilia*	X	X		X			
		Thymelaeaceae	*Thymelaea*	X						
	Myrtales	Lythraceae	Lythraceae indet.	X	X					
		Myrtaceae	*Eucalyptus*		X	X	X		X	X
			Myrtus	X						
		Onagraceae	*Epilobium*	X						
	Poales	Cyperaceae	Cyperaceae indet.	X	X		X	X		X
		Poaceae	Cerealia-group	X	X		X	X		X
			Lygeum	X						
			Wild Poaceae-group	X	X	X	X	X	X	X
		Typhaceae	*Sparganium*	X	X		X			
			Typha latifolia	X			X			
	Ranunculales	Papaveraceae	*Glaucium*	X						
			Fumaria	X	X					
		Ranunculaceae	Ranunculaceae indet.	X	X		X	X		
			Thalictrum	X			X	X		
	Rosales	Cannabaceae	*Cannabis*	X						
			Celtis	X						
			Humulus	X						
		Eleagnaceae	*Hip pophaë*	X						
		Euphorbiaceae	Euphorbiaceae indet.	X						
			Mercurialis	X		X	X			
			Ricinus	X						
		Rhamnaceae	*Rhamnus*	X		X				
			Ziziphus	X			X			
		Rosaceae	Rosaceae indet.	X				X	X	
			Sanguisorba minor -type	X			X	X		X
			Spiraea	X						
		Ulmaceae	*Ulmus*	X	X		X	X		
		Urticaceae	Urticaceae indet.	X						
	Sapindales	Anacardiaceae	*Pistacia*	X	X	X	X	X		X
			Rhus	X	X	X	X			
		Rutaceae	*Citrus* cf. *x aurantium*		X			X		
			Citrus medica	X						
		Sapindaceae	*Acer*	X	X	X		X		
	Santales	Loranthaceae	*Loranthus europaeus*	X						
	Saxifragales	Crassulaceae	*Sedum*	X	X	X	X	X	X	
		Grossulariaceae	*Ribes*	X						
		Saxifragaceae	Saxifragaceae indet.	X			X			
	Solanales	Convolvulaceae	Convolvulaceae indet.	X			X	X		X
	Vitales	Vitaceae	cf. *Cissus*	X						
			Vitis	X	X	X	X	X	X	X

was used. Below we specify the main morphological features for pollen grains identification and their relative abundance.

Order: Cupressales Link (1829)

Family: Cupressaceae Gray, 1822 *nom. cons.*, sensu Fajaron 2005

Subfamily: Cupressoideae Sweet, 1829

Pollen grains of Cupressoideae do not show morphological features that allow the identification at genus or species level (e.g., Van Campo-Duplan, 1953; Bortenschlager, 1990; Kurmann, 1994; Ruggiero and Bedini, 2017) except for *Juniperus* (e.g., Demske et al., 2013).

Cupressoideae indet. (Plate I, 1)

Description: Monad (ca. 40 μm), inaperturate, subspherical shape, commonly split, sculpturing scabrate.

Remarks: Cupressoideae indet. pollen grains were commonly observed in the fossil record (S05B), while in mosses (MP, Palude la Vela) they were rarely recorded.

Genus: **Juniperus** L., 1753 (Plate I, 2)

Description: Monad (ca. 30 μm), inaperturate, subspherical shape, commonly split, sculpturing scabrate. Thinner exine with sharper aperture compared to Cupressoideae indet. pollen grains (e.g., Demske et al., 2013).

Remarks: *Juniperus* was commonly observed in the fossil record (S05B). It was rarely detected in both surface sediments (MP, Palude la Vela) and mosses (Palude la Vela, Galeso).

Order: Ephedrales Dumort (1829)

Family: Ephedraceae Dumort (1829)

Genus: **Ephedra** L., 1753

According to Beug (1956) two pollen types of *Ephedra* have been recognized: *E. distachya*-type and *E. fragilis*-type. Furthermore, *E.* cf. *torreyana* has been recognized according to Ickert-Bond et al. (2003).

Ephedra distachya-type (Plate I, 3–6)

Description: Monad (ca. 40 μm), elliptical shape, inaperturate, polyplicate with branched pseudosulci.

Remarks: *Ephedra distachya*-type was scantly observed in the fossil record (S05B). It was rarely detected in mosses (MP, Galeso).

Ephedra fragilis-type (Plate I, 7)

Description: Monad (ca. 40 μm), elliptical shape, inaperturate, polyplicate with unbranched pseudosulci.

Remarks: *Ephedra fragilis*-type was scantly observed in the fossil record (S05B). It was rarely detected in surface sediments (MP, Palude la Vela).

Species: *Ephedra* cf. *torreyana* S.Wats. (Plate I, 8)

Description: Monad (ca. 40 μm), elliptical shape, inaperturate, polyplicate with zigzag folding pattern, polar apices protrude.

Remarks: A single pollen grain of *Ephedra* cf. *torreyana* was observed in the moss of MP.

Order: Pinales Gorozh. (1904)

Family: Pinaceae Spreng. ex F.Rudolphi, (1830) *nom. cons.*

According to Van Campo and Sivak (1972) and Sivak (1975) the main morphological features to distinguished Pinaceae pollen grains are size, number of sacci, shape of sacci, shape of corpus, connection between sacci and corpus, and structure of both alveolate infratectum and germinal area.

By LO-analysis it is possible to detect the infratectum alveolate structure, constituted by a maximum of three layers characterized by a different size of alveoli (small/narrow, intermediate, and large/wide).

Genus: **Abies** Mill., 1754 (Plate II, 6)

Description: Monad (ca. 160 μm), bisaccate, oblate shape, elliptical corpus, sacci close to spherical narrowly attached to the corpus, thick cappa. Alveolate infratectum composed of three layers of alveoli, polygonal shaped. Psilate in the area of leptoma.

Remarks: *Abies* was commonly observed in the fossil record (S05B), while in surface sediments (MP) it was rarely detected.

Species: *Abies cephalonica* Lound, 1838 (Plate II, 7–8)

Description: Monad (ca. 120 μm), bisaccate, oblate shape, elliptical corpus, sacci close to spherical shape narrowly attached to the corpus and arranged according to a trigonal symmetry to the latter, thicker and more fringed cappa than other *Abies* species (Leopold and Zaborac-Reed, 2014).

Remarks: *Abies cephalonica* was rarely observed in the fossil record (S05B).

Genus: **Cedrus** Trew, 1757 (Plate I, 16–23)

Description: Monad (ca. 60 μm), bisaccate, oblate shape, elliptic corpus, sacci truncated cone shaped attached to the corpus, thick cappa. Incomplete alveolate infratectum, radially arranged to the corpus (Erdtman, 1965).

Remarks: *Cedrus* was scantly observed in the fossil record (S05B). It was rarely detected in both surface sediments (MP, Palude la Vela) and mosses (Palude la Vela).

Genus: **Picea** A.Dietr., 1824 (Plate II, 1–5)

Description: Monad (ca. 120 μm), bisaccate, oblate shape, elliptical corpus, sacci half spherical and above the equator, sacci attached to the corpus. Incomplete alveolate infratectum composed by only two layers (medium and small/narrow) of alveoli polygonal shaped. In the germinal area granulations are present.

Remarks: *Picea* was scantly observed in the fossil record (S05B). It was sporadically detected in surface sediments (MP, Palude la Vela).

Genus: **Pinus** L., 1753 (Plate I, 9–15)

Description: Monad (ca. 60 μm), bisaccate, oblate shape, elliptical corpus, sacci spherical and narrow attached to the corpus, sacci smaller than corpus, small cappa. Alveolate infratectum composed by three layers of alveoli polygonal shaped. Variations in alveolar structure are often considerable between species.

Remarks: *Pinus* was abundantly observed in the fossil record (S05B), and in both surface sediments and mosses (MP, Palude la Vela, Galeso).

5.2. Angiosperm pollen

The arrangement of angiosperms follows alphabetic sequence of Order name. The systematic terminology follows Angiosperm Phylogeny Group IV (APG IV, 2016). Below we specify the main morphological features for pollen grains identification and their relative abundance.

Order: Alismatales R.Br. ex Brecht. & J.Presl

Family: Alismataceae Vent., *nom. cons.*

Genus: **Alisma** L., 1753

Species: *Alisma plantago-aquatica* L., 1753 (Plate III, 1–2)

Description: Monad (ca. 20 μm), spherical-polygonal shape, pantaporate with circular and well-defined pores, scabrate/granulate exine with granulation tending to radiate towards the pores.

Remarks: *Alisma plantago-aquatica* was rarely observed in the fossil record (S05B).

Genus: **Sagittaria** Ruppius ex L., 1753

Description: Monad (ca. 20 μm), spherical shape, inaperturate, smooth or finely granular exine with numerous small spines generally various in size.

Remarks: *Sagittaria* was rarely observed in the fossil record (S05B).

Family: Araceae Juss., *nom. cons.*

Genus: **Lemna** L., 1753 (Plate III, 3–6)

Description: Monad (<20 μm), subspherical shape, monoporoidate, smooth exine with numerous thin and small spines.

Remarks: *Lemna* was rarely observed in the fossil record (S05B).

Family: Potamogetonaceae Vent., *nom. cons.*

Genus: **Potamogeton** L., 1753 (Plate III, 7–9)

Description: Monad (ca. 30 μm), subspherical shape, inaperturate, reticulate exine with very small lumina.

Remarks: *Potamogeton* was rarely observed in the fossil record (S05B). A single pollen grain was observed in the surface sediment of Palude la Vela.

Order: Apiales Nakai

Family: Apiaceae Lindl., *nom. cons.*

According to Baczyński et al. (2019), genera of Apiaceae have a similar morphology making a unique determination difficult. Here, two morphotypes of Apiaceae have been recognized Apiaceae indet.–

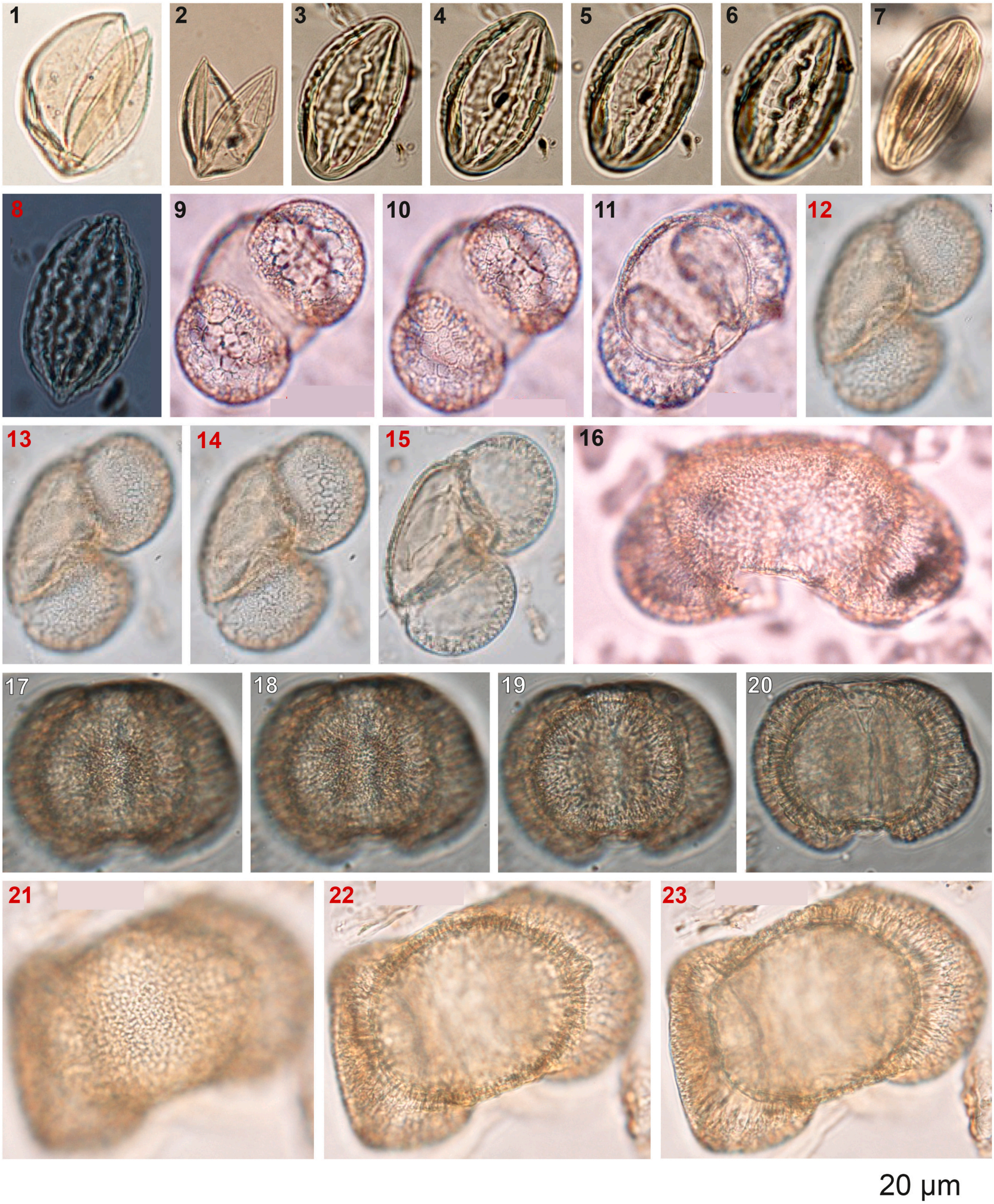

Plate I. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number) and mosses (red number). **1.** Cupressoideae indet.; **2.** *Juniperus*; **3–6**. *Ephedra distachya*-type; **7.** *Ephedra fragilis*-type; **8.** *Ephedra* cf. *torreyana*; **9–15.** *Pinus*; **16–23.** *Cedrus*.

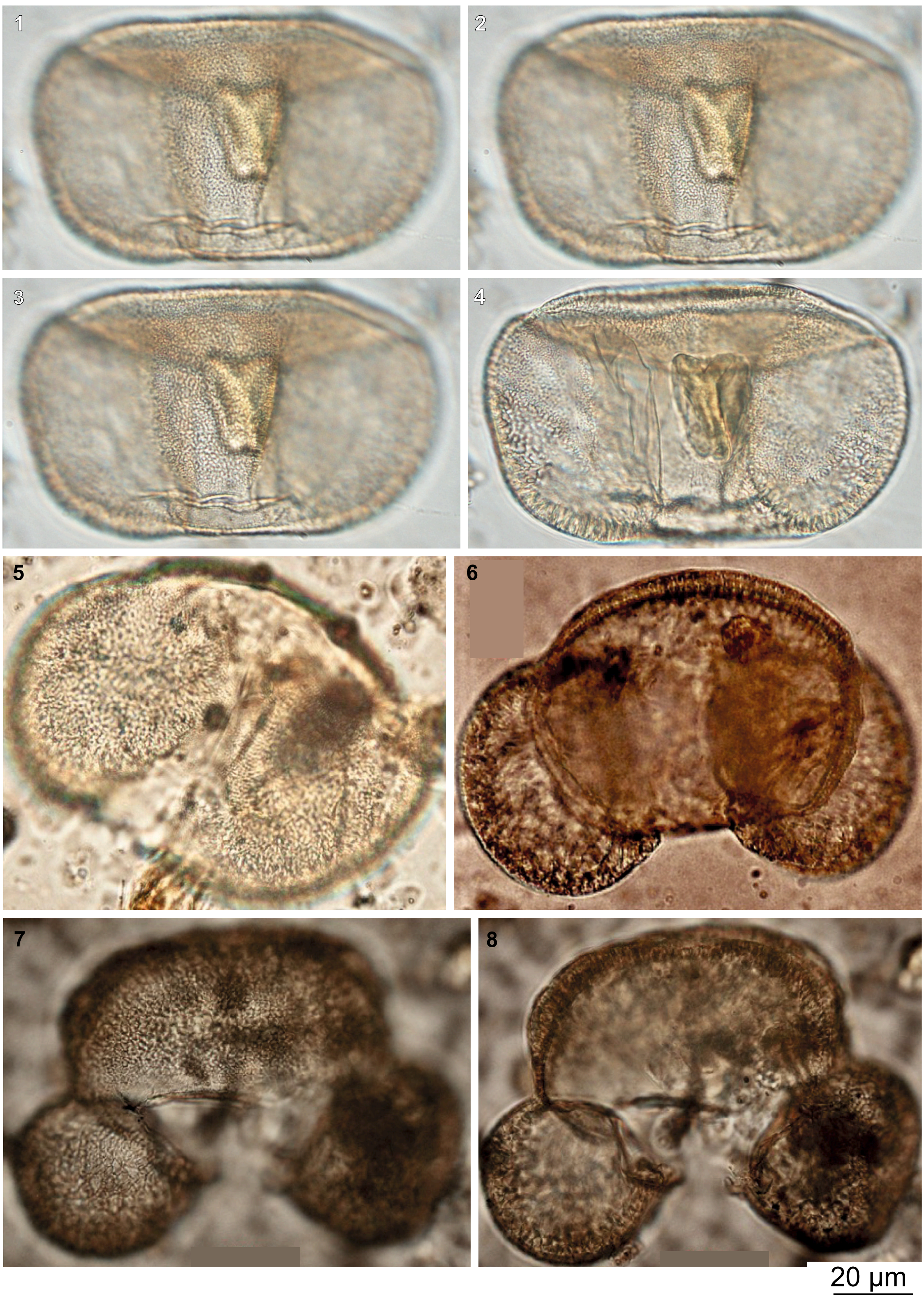

Plate II. LM micrographs of pollen grains from the S05B core (black number) and surface sediments (white number). **1–5.** *Picea*; **6.** *Abies*; **7–8.** *Abies cephalonica.*

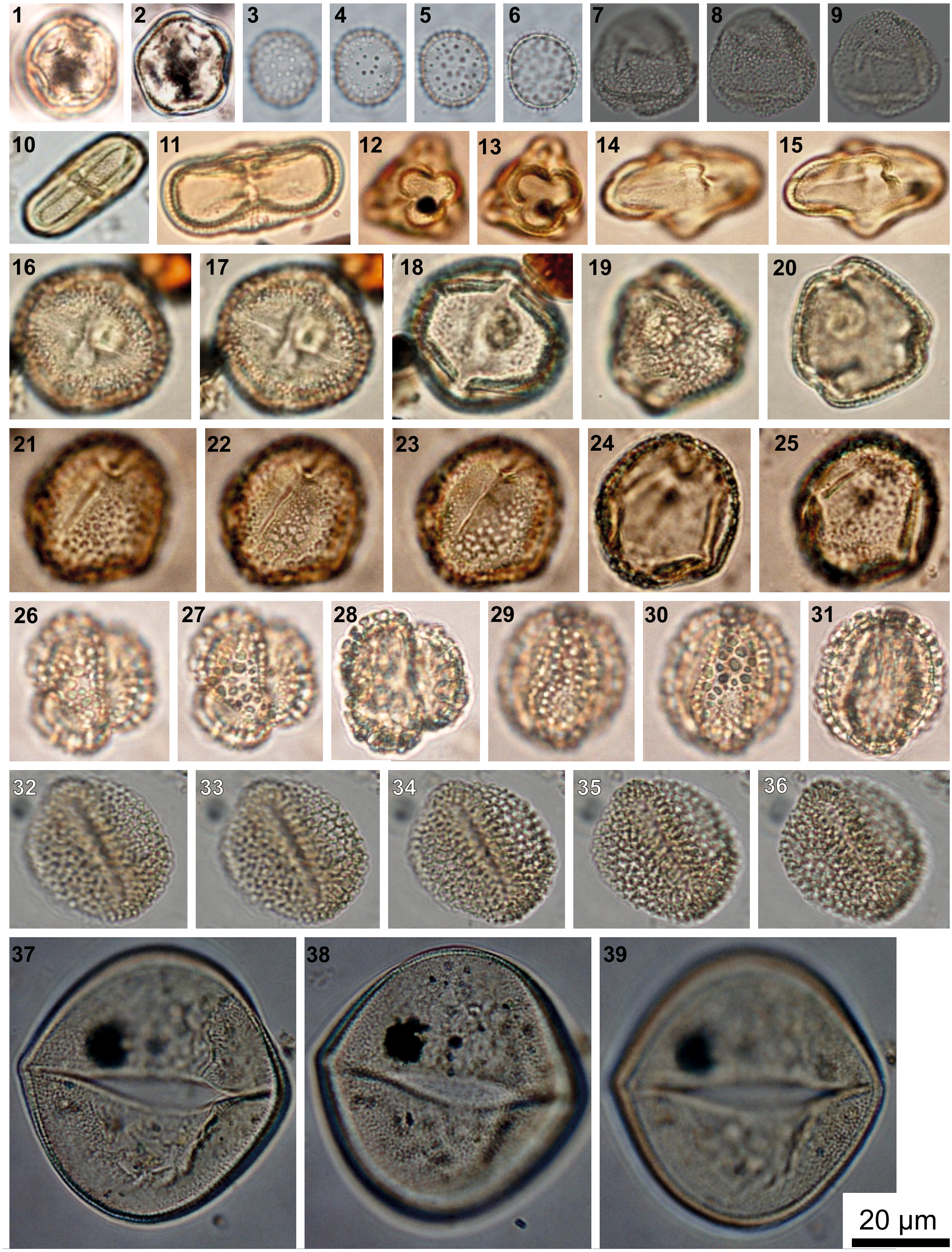

Plate III. LM micrographs of pollen grains from the S05B core (black number) and surface sediments (white number). **1–2.** *Alisma plantago-aquatica*; **3–6.** *Lemna*; **7–9.** *Potamogeton*; **10.** Apiaceae indet.– morphotype 1; **11.** Apiaceae indet.– morphotype 2; **12–15.** *Bupleurum*; **16–20.** Araliaceae indet.; **21–25.** *Hedera*; **26–31.** *Ilex*; **32–36.** Aracaceae indet.; **37–39.** *Asphodelus*.

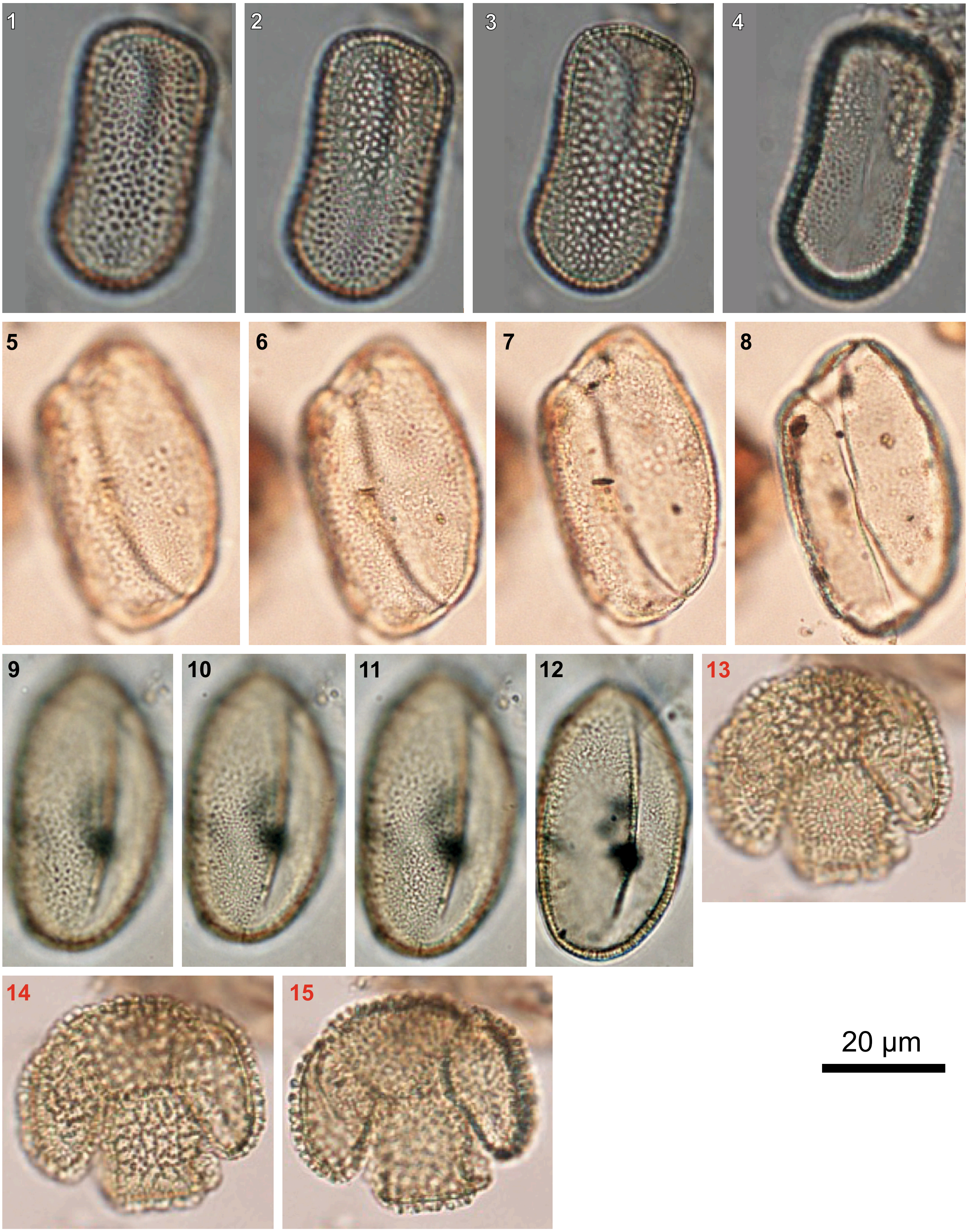

Plate IV. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number) and mosses (red number). **1–4.** *Aloe*; **5–8.** Iridaceae indet.; **9–12.** *Scilla*; **13–15.** *Spiranthes spiralis*.

morphotype 1 and Apiaceae indet.– morphotype 2. Only genus *Buplerum* has been recognized according to De Leonardis et al. (2009).

Apiaceae indet.– morphotype 1 (Plate III, 10)

Description: Monad (ca. 20 μm), elliptical shape, polar caps obtuse and straight exine outline, apiculation only in the sexine which appears to be smooth and with undulation at the mesocolpium, fastigium absent, ectocolpi above equator in continuity with the margins of endoaperture straight, diffuse and horned.

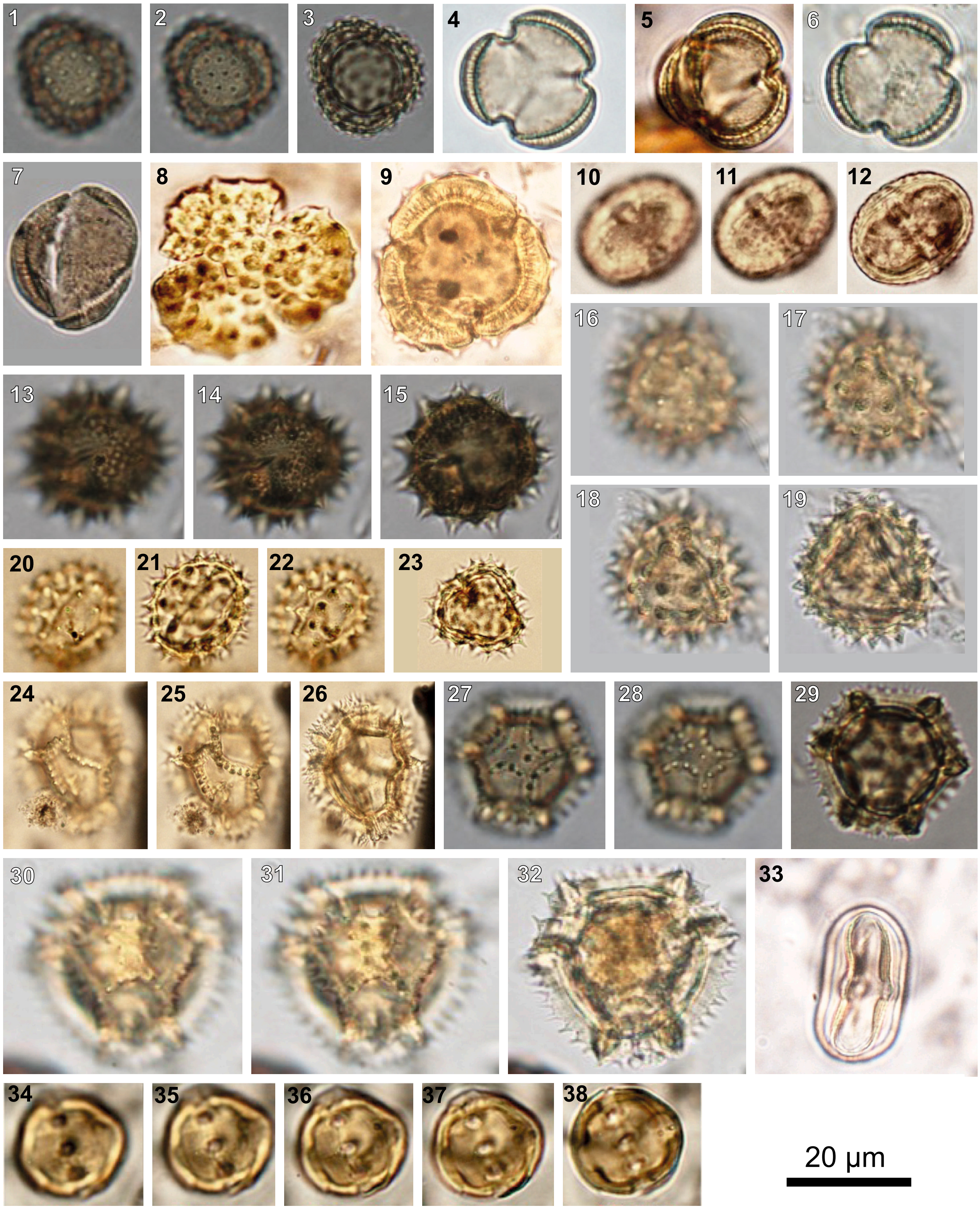

Plate V. LM micrographs of pollen grains from the S05B core (black number) and surface sediments (white number). **1–3.** *Ambrosia artemisiifolia*-type; **4–7.** *Artemisia*; **8.** *Carduus crispus*-type; **9.** *Carlina vulgaris*-type; **10–12.** *Centaurea nigra*-type; **13–15.** *Inula britannica*-type; **16–23.** *Senecio vulgaris*-type; **24–32.** Asteraceae-Cichorioideae indet.; **33.** Boraginaceae indet.– morphotype 1; **34–38.** Boraginaceae indet.– morphotype 2.

Remarks: Apiaceae indet.– morphotype 1 pollen grains were commonly observed in the fossil record (S05B). They were rarely detected in both surface sediments and mosses (MP, Palude la Vela, Galeso).

Apiaceae indet.– morphotype 2 (Plate III, 11)

Description: Monad (ca. 30 μm), bone-shaped, concave, polar caps obtuse, exine apiculation present only in sexine, fastigium present, sexine undulated at mesocolpium, ectocolpi above the equator is

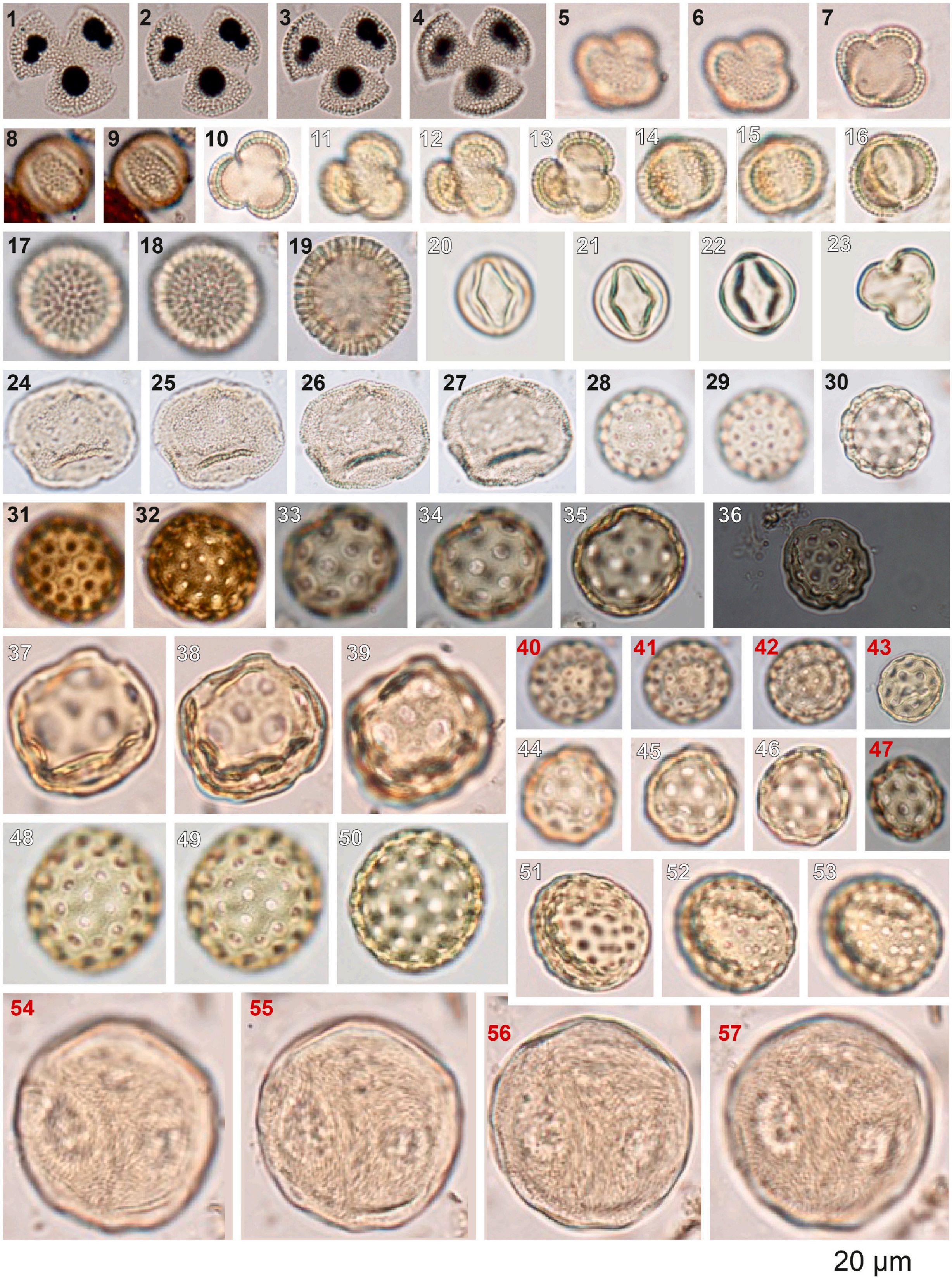

Plate VI. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number) and mosses (red number). **1–4.** Brassicaceae indet.; **5–7.** *Draba*; **8–16.** *Erysimum*; **17–19.** *Matthiola*; **20–23.** cf. *Salvadora persica*; **24–27.** *Buxus*; **28–53.** Amaranthaceae indet.; **54–57.** cf. Cactaceae indet.

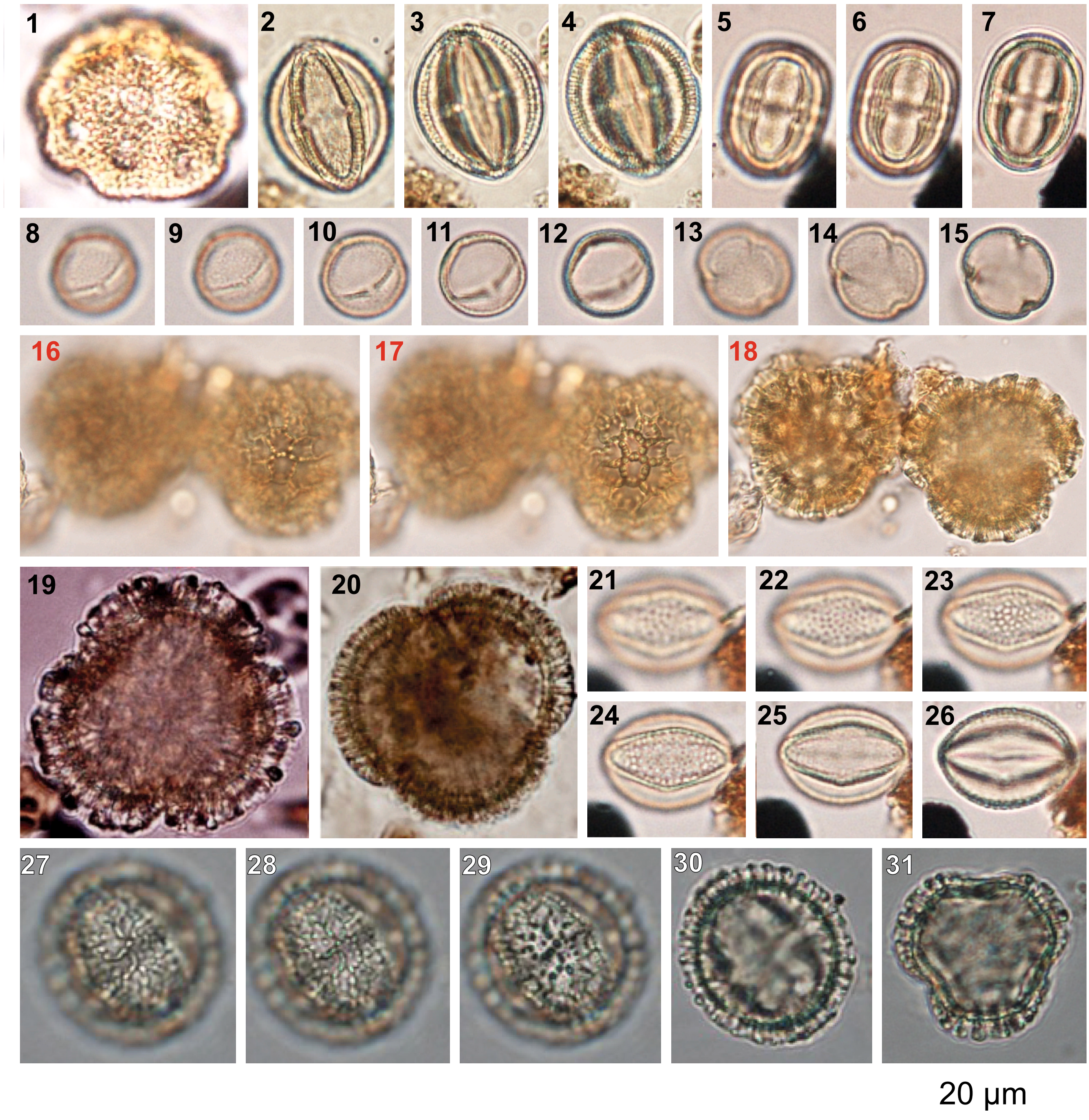

Plate VII. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number) and mosses (red number). **1.** Caryophyllaceae indet.; **2–4.** *Fagopyrum*; **5–7.** *Polygonum*; **8–15.** *Rumex* cf. *acetosella*; **16–19.** *Armeria*; **20.** *Limonium*; **21–26.** *Tamarix*; **27–31.** *Viburnum lantana*.

discontinuous and the margin of endoaperture convex and horned.

Remarks: Apiaceae indet.– morphotype 2 pollen grains were commonly observed in the fossil record (S05B). They were rarely detected in both surface sediments and mosses (MP, Palude la Vela, Galeso).

Genus: **Bupleurum** L., 1753 (Plate III, 12–15)

Description: Monad (ca. 20 μm), prolate and sub-rhomboidal shape, tricolporates with three longitudinal equatorial colpi acute at the equatorial axis, sub-tectate regulate exine (De Leonardis et al., 2009).

Remarks: Bupleurum was observed in the fossil record (S05B).

Family: Araliaceae Juss. *nom. cons.*

Araliaceae indet. (Plate III, 16–20)

Description: Monad (ca. 30 μm), isopolar, prolate shape, tricolporate with colpi acute in correspondence of the pores, margo present, reticulate exine with small and irregular lumina.

Remarks: A single pollen grain of Araliacae indet. was observed in the fossil record (S05B).

Genus: **Hedera** L., 1753 (Plate III, 21–25)

Description: Monad (ca. 20 μm), isopolar, subspherical shape, prolate, tricolporate with colpi acute in correspondence of the pores, margo present, reticulate exine with wide lumina.

Remarks: Hedera was scantly observed in the fossil record (S05B). It

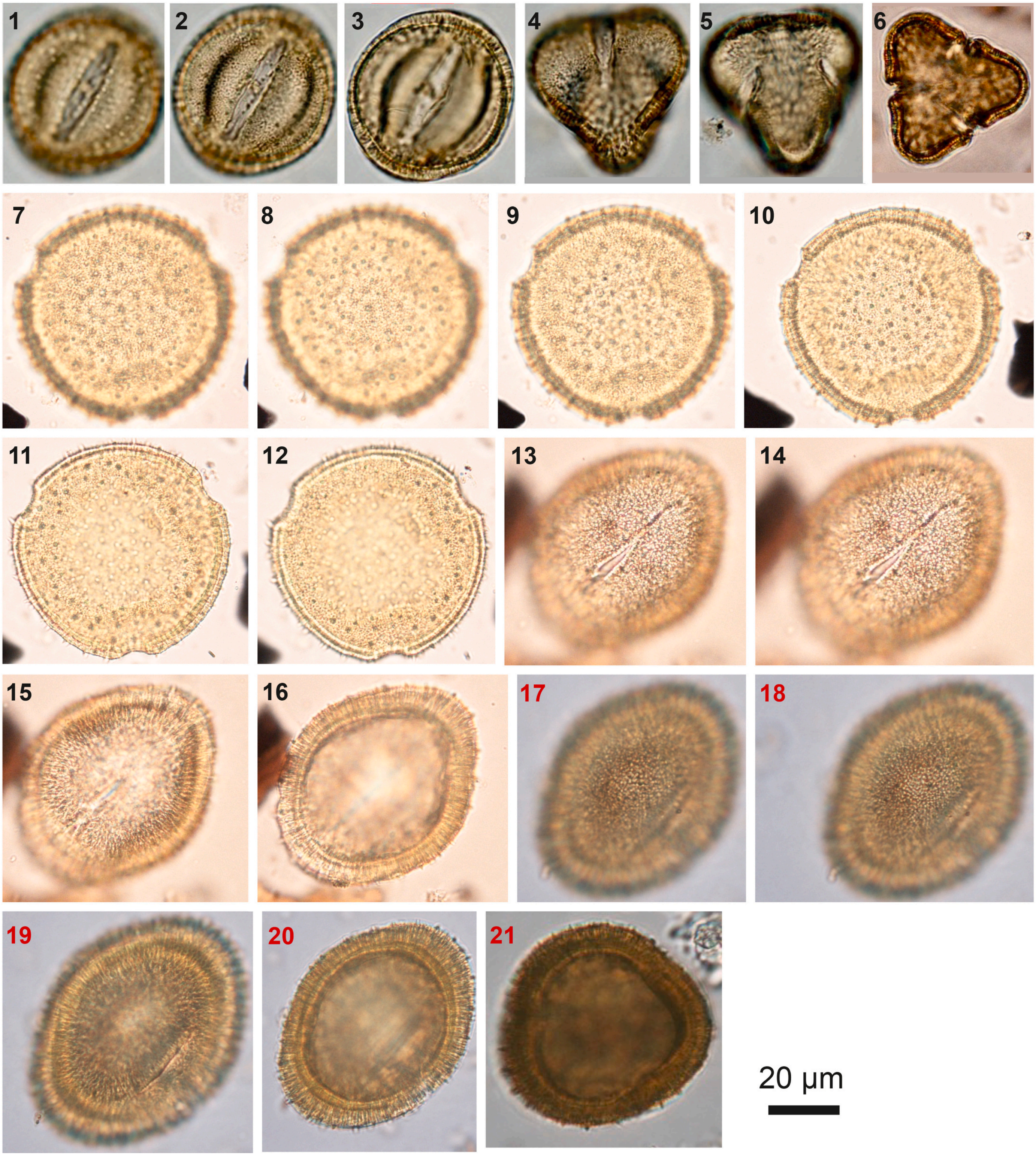

Plate VIII. LM micrographs of pollen grains from the S05B core (black number) and mosses (red number). **1–6.** *Fedia cornucopiae*; **7–12.** *Knautia*; **13–21.** *Scabiosa.*

was rarely detected in surface sediments (MP, Palude la Vela).

Order: Aquifoliales Senft

Family: Aquifoliaceae Brecht. & J.Presl, *nom. cons.*

Genus: **Ilex** L., 1753 (Plate III, 26–31)

Description: Monad (ca. 20 μm), isopolar, prolate shape, tricolp (oriod)ate, baculate exine.

Remarks: Ilex was rarely observed in the fossil record (S05B).

Order: Arecales Bromhead

Family: Arecaceae Brecht. & J.Presl., *nom. cons.*

Arecaceae indet. (Plate III, 32–36)

Description: Monad (ca. 40 μm), prolate shape, rounded polar edges, monocolpate with narrow colpus round ended, microreticulate exine with small and irregular lumina.

Remarks: Arecaceae indet. pollen grains were rarely observed in

Plate IX. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number) and mosses (red number). **1–3.** Ericaceae indet.; **4–6.** *Androsacea*; **7–9.** *Ceratonia*; **10–13.** *Hedysarum humile*; **14–18.** *Hippocrepis*; **19–24.** Polygalaceae indet.; **25–28.** *Alnus*; **29–30.** *Betula*; **31.** *Carpinus betulus*; **32–36.** *Carpinus orientalis/Ostrya carpinifolia*; **37–39.** *Corylus*.

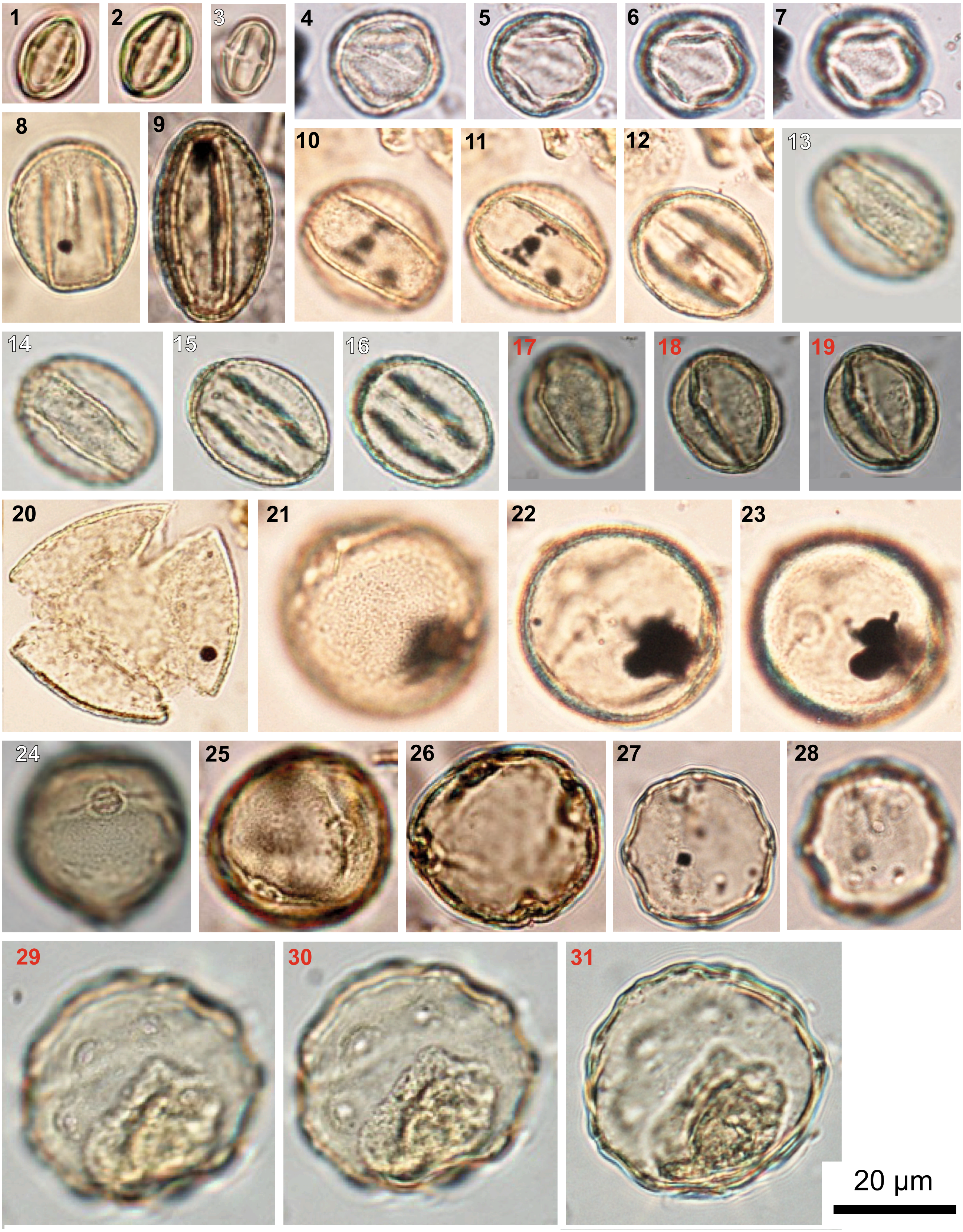

Plate X. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number) and mosses (red number). **1–3.** *Castanea*; **4–7.** *Quercus ilex-coccifera*-type; **8–19.** *Quercus pubescens*-type; **20.** *Quercus cerris*; **21–24.** *Fagus*; **25–26.** *Fagus* tetracolporate; **27–31.** *Juglans*.

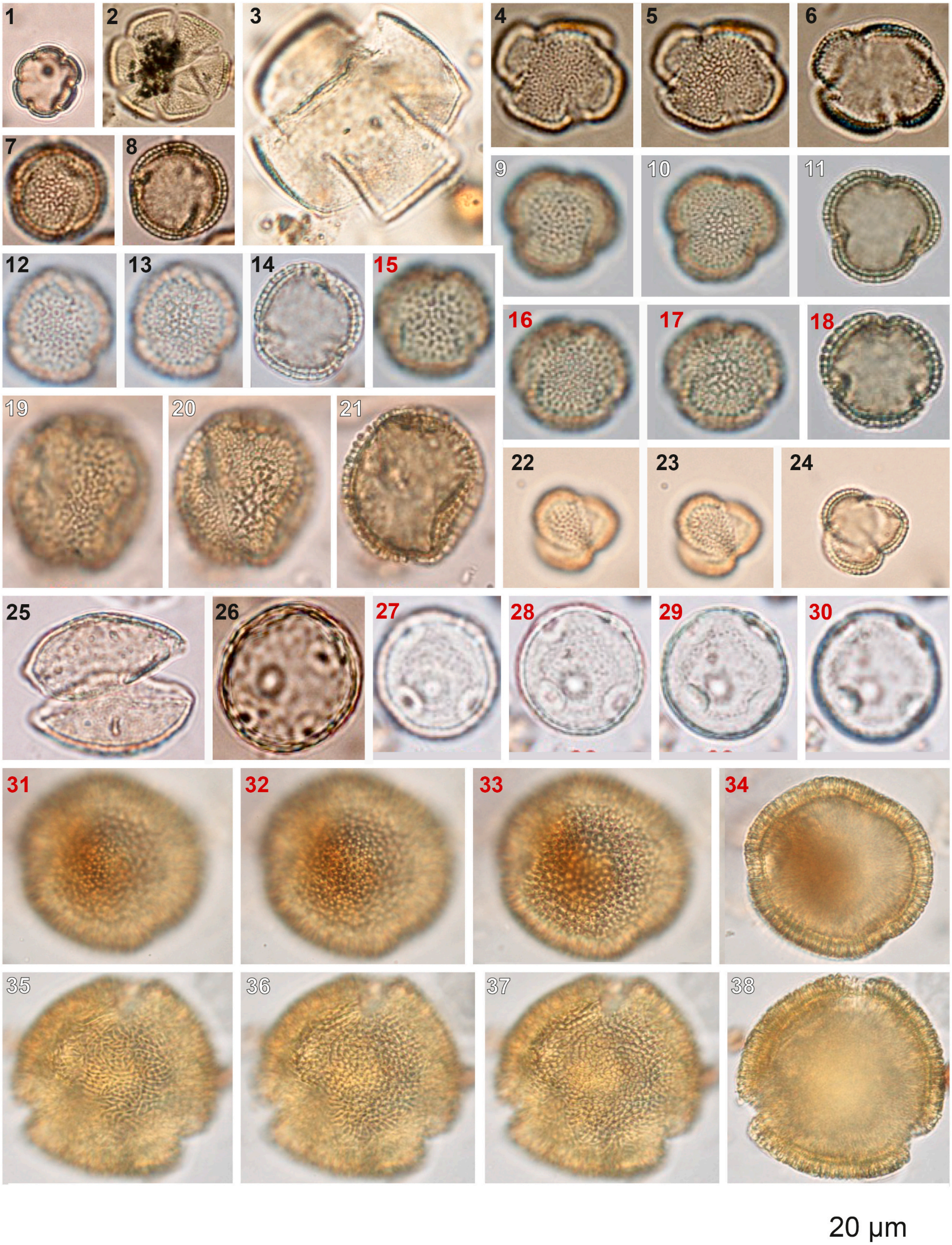

Plate XI. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number) and mosses (red number). **1.** *Galium*; **2.** Lamiaceae indet.; **3.** *Sideritis*; **4–6.** *Fraxinus*; **7–8.** *Olea*– morphotype 1; **9–18.** *Olea*– morphotype 2; **19–21.** *Ligustrum*; **22–24.** *Phillyrea*; **25.** *Pedicularis*; **26–30.** *Plantago lanceolata*; **31–34.** *Geranium*; **35–38.** *Erodium*.

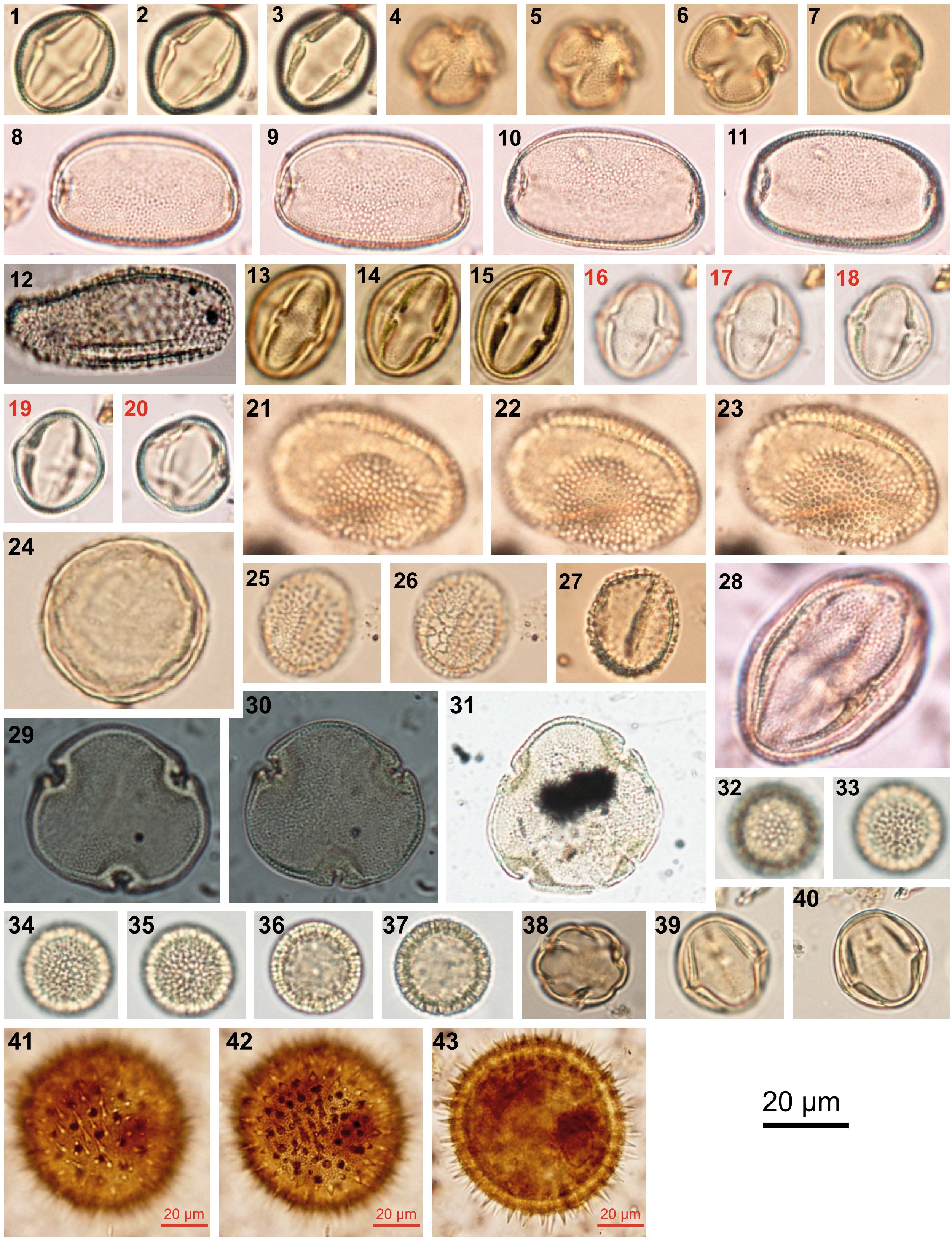

Plate XII. LM micrographs of pollen grains from the S05B core (black number) and mosses (red number). **1–7.** *Verbascum*; **8–11.** *Colchicum*; **12.** Liliaceae indet.; **13–20.** *Hypericum*; **21–23.** *Linum*; **24.** *Populus*; **25–27.** *Salix*; **28.** *Heliathemum*; **29–30.** *Tilia*; **31.** *Tilia* tetracolporate; **32–37.** *Thymelaea*; **38–40.** Lythraceae indet.; **41–43.** Malveae.

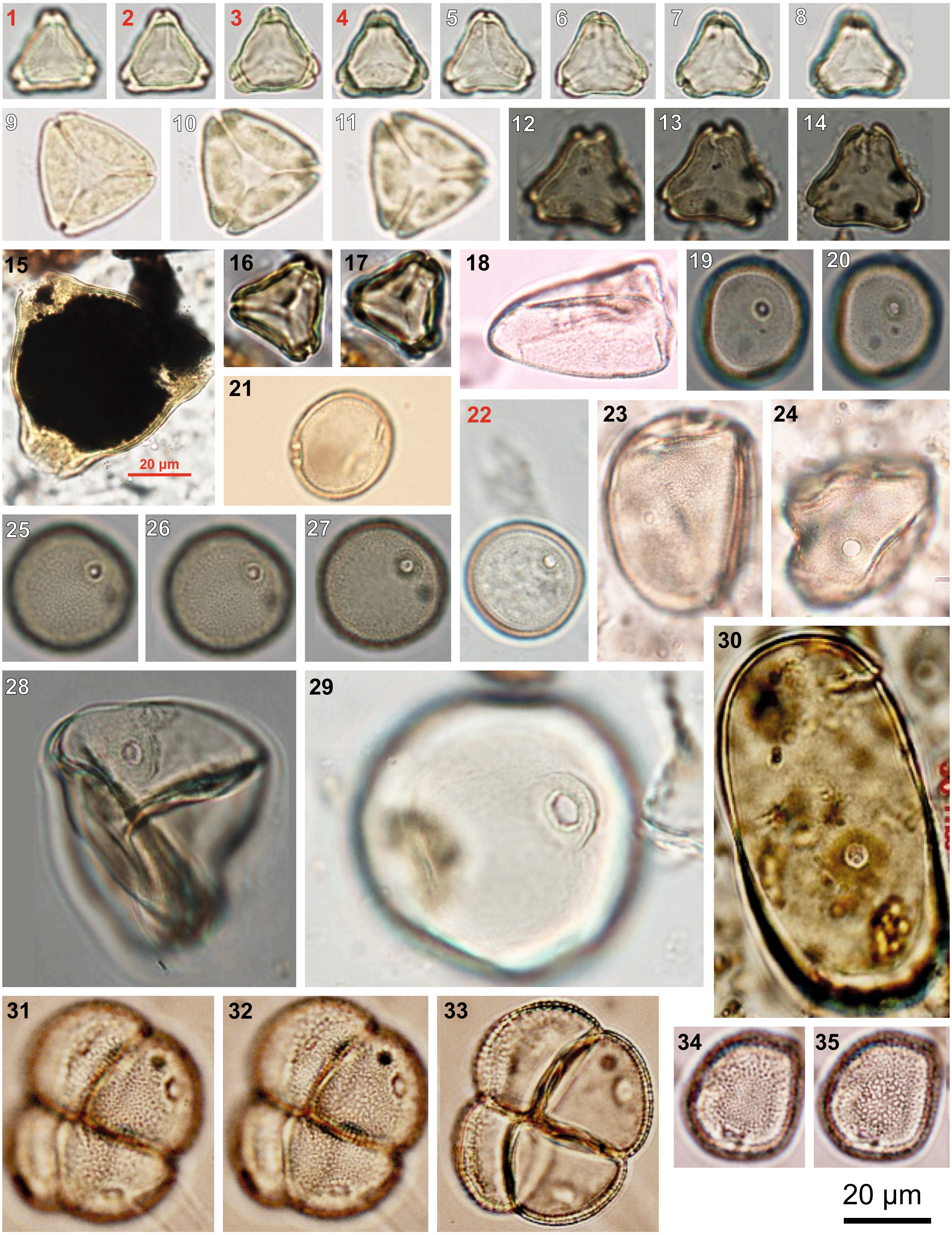

Plate XIII. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number) and mosses (red number). **1–14.** *Eucalyptus*; **15.** *Epilobium*; **16–17.** *Myrtus*; **18.** Cyperaceae indet.; **19–27.** Wild Poaceae-group; **28–29.** Cerealia-group**; 30.** *Lygeum*; **31–33.** *Typha latifolia*; **34–35.** *Sparganium.*

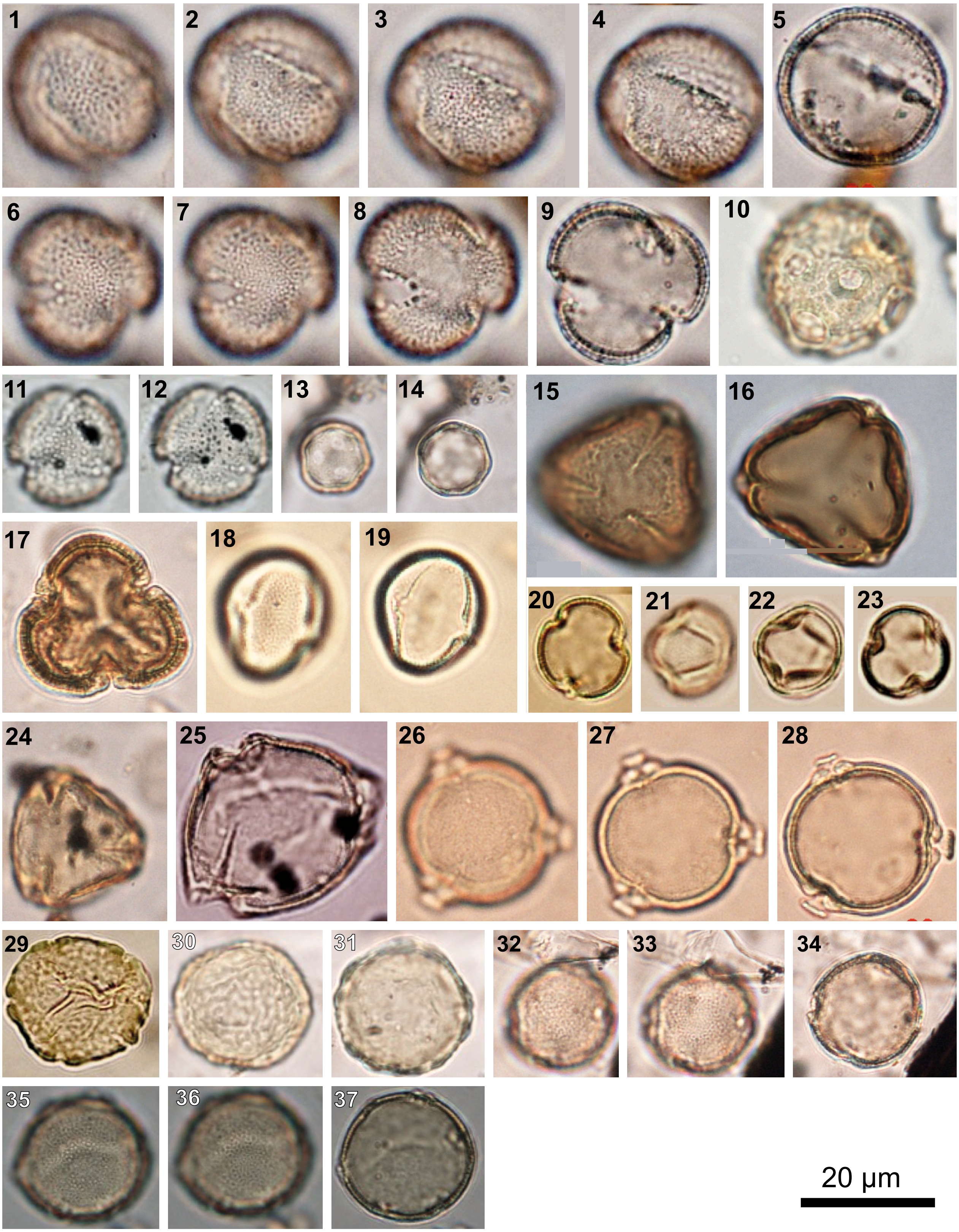

Plate XIV. LM micrographs of pollen grains from the S05B core (black number); surface sediments (white number). **1–9.** *Glaucium*; **10.** *Fumaria*; **11–12.** Ranunculaceae indet.; **13–14.** *Thalictrum*; **15–16.** *Hippophaë*; **17.** Euphorbiaceae indet.; **18–20.** *Mercurialis*; **21–23.** *Spiraea***;** **24.** *Rhamnus*; **25.** Rosaceae indet.; **26–28.** *Sanguisorba minor*-type; **29–31.** *Ulmus*; **32–37.** *Pistacia.*

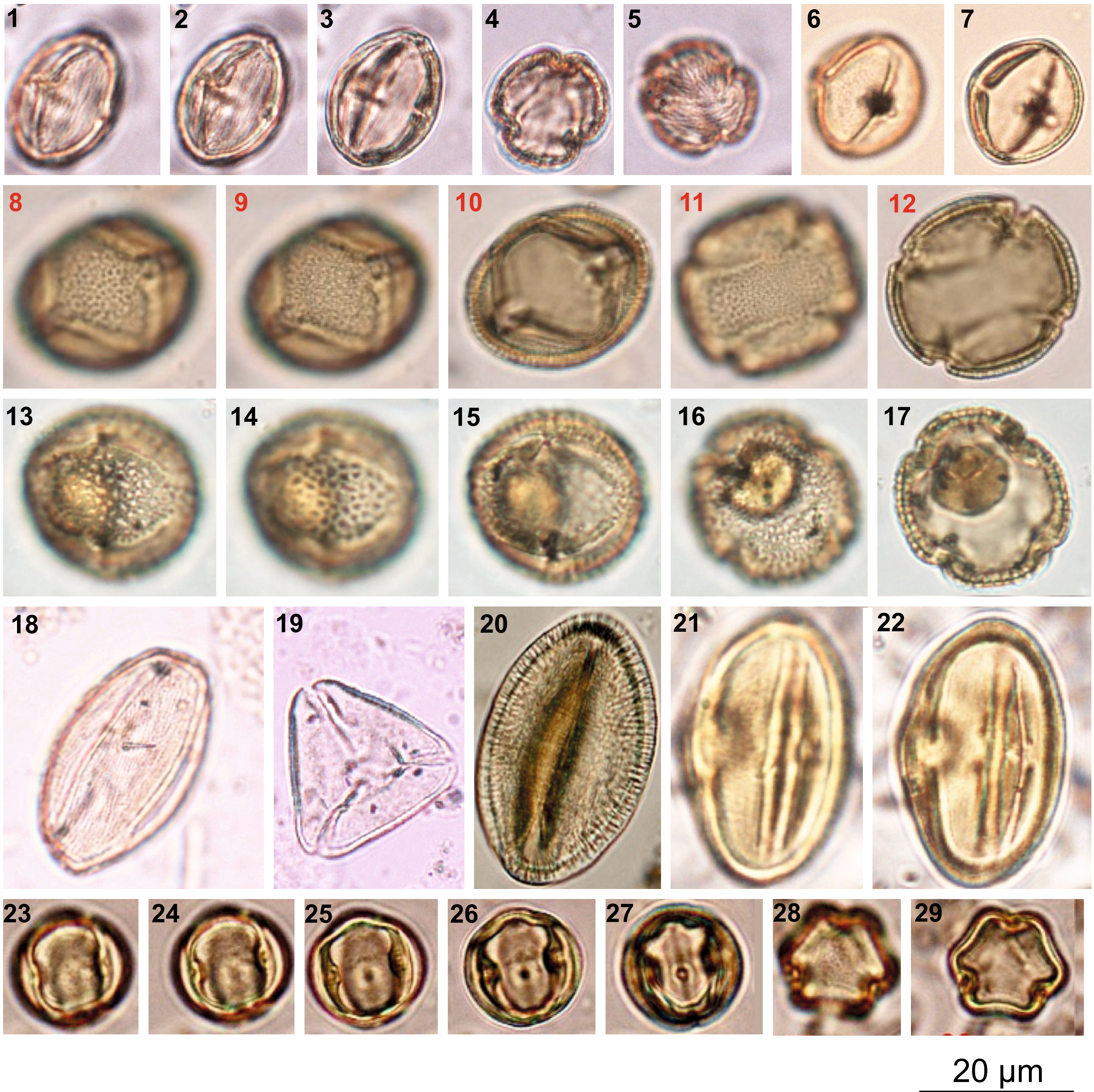

Plate XV. LM micrographs of pollen grains from the S05B core (black number); mosses (red number). **1–5.** *Rhus*; **6–7.** *Sedum*; **8–12.** *Citrus* cf. x *auranthium*; **13–17.** *Citrus medica*; **18.** *Acer*; **19.** *Loranthus europaeus*; **20.** Convolvulaceae indet.; **21–22.** cf. *Cissus*; **23–29.** *Vitis*.

surface sediments (MP, Palude la Vela).

Order: Asparagales Link

Family: Asphodelaceae Juss., *nom. cons. prop.*

Genus: **Aloe** L., 1753 (Plate IV, 1–4)

Description: Monad (ca. 40 μm), prolate shape, rounded polar edges, monocolpate with a narrow colpus, microreticulate exine with small and regular lumina. Generally, found in massulae (Elsie et al., 1998).

Remarks: Aloe was rarely observed in both surface sediments and the moss of MP.

Genus: **Asphodelus** L., 1753 (Plate III, 37–39)

Description: Monad (ca. 50 μm), subspherical shape, monocolpate with colpus progressively wider in the central portion, microreticulate exine that appears faded in correspondence of the colpus.

Remarks: Asphodelus was commonly observed in the fossil record (S05B).

Family: Iridaceae Juss., *nom. cons.*

Iridaceae indet. (Plate IV, 5–8)

Description: Monad (ca. 50 μm), isopolar, oblate shape, smooth polar edges, monocolpate with long and wide colpus, reticulate exine with small lumina.

Remarks: Iridaceae indet. pollen grains were commonly observed in the fossil record (S05B).

Genus: **Scilla** L., 1753 (Plate IV, 9–12)

Description: Monad (ca. 50 μm), isopolar, oblate shape, acute polar edges, monocolpate with long and narrow colpus, reticulate exine with small lumina.

Remarks: Scilla was rarely observed in the fossil record (S05B).

Family: Orchidaceae Juss., *nom. cons.*

Genus: **Spiranthes** Rich, 1817

Species: *Spiranthes spiralis* L., Chevall, 1827 (Plate IV, 13–15)

Description: Rhomboidal tetrad (ca. 40 μm), reticuloidate. Columellae are free forming a reticulum-like with lumina of different dimensions.

Remarks: A single pollen grain of *Spiranthes spiralis* was observed in a moss of Palude la Vela.

Order: Asterales Link

Family: Asteraceae Brecht. & J.Presl *nom. cons.*

Subfamily: Asteroideae

Five pollen types have been distinguished according to Punt and Hoen (2009). Furthermore, one genus (*Artemisia*) has been distinguished too.

Ambrosia artemisiifolia-type (Plate V, 1–3)

Description: Monad (ca. 20 μm), subspherical shape, tricolporate with short and narrow colpi, microechinate exine (Punt and Hoen, 2009). Both *A. artemisiifolia*-type and *Xanthium strumarium*-type pollen grains have short colpi, large number of echinae in polar view, small apertures and broad cavea. However, *A. artemisiifolia*-type is distinguishable from the other pollen type, being echinate or distinctly microechinate. Moreover, the echinae show a distinct broad base (Punt and Hoen, 2009).

Remarks: *Ambrosia artemisiifolia*-type was rarely observed in both surface sediments (MP, Galeso) and mosses (Galeso).

Genus: **Artemisia** L., 1753 (Plate V, 4–7)

Description: Monad (ca. 20 μm), subspherical shape, tricolporate, microechinate exine with high and tectate columellae.

Remarks: Artemisia was commonly observed in the fossil record (S05B). It was rarely detected in both surface sediments (MP, Palude la Vela, Galeso) and mosses (MP, Palude la Vela).

Carduus crispus-type (Plate V, 8)

Description: Monad (ca. 40 μm), prolate shape, tricolporate with colpi not very sunken, margo absent, echinate exine (Punt and Hoen, 2009).

Remarks: Carduus crispus-type was scantly observed in both the fossil record (S05B) and surface sediments (Palude la Vela).

Carlina vulgaris-type (Plate V, 9)

Description: Monad (ca. 30 μm), isopolar, oblate shape, tricolporate with long and narrow colpi, margo present, echinate exine with high columellae (Punt and Hoen, 2009).

Remarks: *Carlina vulgaris*-type was scantly observed in the fossil record (S05B).

Centaurea nigra-type (Plate V, 10–12)

Description: Monad (ca. 20 μm), isopolar, prolate shape, tricolporate with long and narrow colpi, margo absent, scabrate-echinate exine with small and circular columellae (Punt and Hoen, 2009).

Remarks: Centaurea nigra-type was scantly observed in the fossil record (S05B). It was rarely detected in both surface sediments (MP, Palude la Vela, Galeso) and mosses (Palude la Vela, Galeso).

Inula britannica-type (Plate V, 13–15)

Description: Monad (ca. 20 μm), isopolar, subspherical shape, tricolporate with long and narrow colpi, echinae bordering the colpi, margo absent, echinate exine with narrow cavea (Punt and Hoen, 2009).

Remarks: Inula britannica-type was rarely observed in surface sediments of MP while in both surface sediments and mosses of Palude la Vela it was abundantly recorded.

Senecio vulgaris-type (Plate V, 16–23)

Description: Monad (ca. 20 μm), isopolar, subspherical shape, tricolporate with long and narrow colpi, margo absent, cavae is sometime indistinct, echinate exine with small, circular and crowded columellae (Punt and Hoen, 2009).

Remarks: Senecio vulgaris-type was commonly observed in both the fossil record (S05B) and surface sediments of MP. At Galeso, it was rarely detected in the surface sediment while in mosses it was commonly recorded. In mosses of Palude la Vela and MP it was rarely recorded.

Subfamily: Cichorioideae

Asteraceae-Cichorioideae indet. (Plate V, 24–32)

Description: Monad (20–40 μm), isopolar, subspherical shape, tricolporate, lophate, echinolophate exine.

Remarks: Asteraceae-Cichorioideae indet. pollen grains were commonly observed in the fossil record (S05B) and in both surface sediments and mosses (MP, Palude la Vela, Galeso).

Family: Campanulaceae Juss. *nom. cons.*

Campanulaceae indet.

Description: Monad (ca. 20 μm) apolar, subspherical shape, triporate, microechinate exine.

Remarks: Campanulaceae indet. pollen grains were rarely observed in both fossil record (S05B) and surface sediments (MP, Palude la Vela, Galeso).

Order: Boraginales Juss. ex Bercht & J.Presl.

Family: Boraginaceae Juss. *nom. cons*.

Boraginaceae indet. (Plate V, 33–38)

Description: Monad (ca. 20 μm), isopolar, prolate shape, zonocolporate microreticulate-psilate exine. Two morphotypes have been recognized, Boraginaceae indet.– morphotype 1 (Plate V, 33) and Boraginaceae indet.– morphotype 2 (Plate V, 34–38**)**. Boraginaceae indet.– morphotype 1 present a microreticulate-reticulate exine while Boraginaceae indet.– morphotype 2 present psilate-granulate exine.

Remarks: Boraginaceae indet. pollen grains were rarely observed in the fossil record (S05B), surface sediments (MP) and mosses (Palude la Vela).

Order: Brassicales Bromhead

Family: Brassicaceae Brunett, *nom. cons*.

Brassicaceae indet. (Plate VI, 1–4)

Description: Monad (20–30 μm), prolate shape, tricolpate, microreticulate/reticulate exine with open lumina in correspondence of the colpi.

Remarks: Brassicaceae indet. pollen grains were commonly observed in the fossil record (S05B). They were rarely detected in both surface sediments (MP, Palude la Vela, Galeso) and mosses (Palude la Vela, Galeso).

Genus: **Draba** Dill. ex L., 1753 (Plate VI, 5–7)

Description: Monad (ca. 15 μm), isopolar, prolate shape, tetracolpate with long colpi, reticulate exine with lumina of different dimensions.

Remarks: *Draba* was rarely observed in the fossil record (S05B).

Genus: **Erysimum** L., 1753 (Plate VI, 8–16)

Description: Monad (ca. 15 μm), isopolar, prolate shape, tricolpate with narrow and sunken colpi acute ended, reticulate exine with lumina of different dimensions, muri simplicolumellate, perforate tectum.

Remarks: *Erysimum* was rarely observed in both the fossil record (S05B) and surface sediments (MP).

Genus: **Matthiola** W. T. Aiton (Plate VI, 17–19)

Description: Monad (ca. 20 μm), apolar, spherical shape, inaperturate, reticulate exine with lumina of different dimensions, columellae are high and free.

Remarks: Matthiola was rarely observed in the fossil record (S05B).

Family: Salvadoraceae Lindl., *nom. cons.*

Genus: **Salvadora** L., 1753

Species: cf. *Salvadora persica* Wall. (Plate VI, 20–23)

Description: Monad (ca. 10 μm), prolate shape, tricolporate with narrow colpi acute in correspondence of the pores, smooth exine.

Remarks: A single pollen grain of cf. *Salvadora persica* was observed in the surface sediment of MP.

Order: Buxales Takht. Ex Reveal

Family: Buxaceae Dumort., *nom. cons.*

Genus: **Buxus** L., 1753 (Plate VI, 24–27)

Description: Monad (ca. 30 μm), subspherical shape, pantaporate with small and not well-defined pores, microreticulate exine.

Remarks: Buxus was rarely observed in both the fossil record (S05B) and surface sediments (Palude la Vela, Galeso).

Order: Caryophyllales Juss. ex Brecht. & J.Presl.

Family: Amaranthaceae Juss. *nom. cons*.

Amaranthaceae indet. (Plate VI, 28–53)

Description: Monad (15–30 μm), apolar, subspherical shape, pantaporate, pores are small without an annulus, scabrate exine.

Remarks: Amaranthaceae indet. pollen grains were abundantly observed in the fossil record (S05B), surface sediments and mosses (Palude la Vela). They were commonly detected in surface sediments (MP) and mosses (Galeso). In the surface sediments of Galeso they were rarely detected.

A huge variability of morphological characteristic (size, number of pores, dimensions of pore) was observed. However, the possibility to define a genus or species is rather difficult as the pollen grains of Amaranthaceae are very similar to each other.

Family: Cactaceae Juss. *nom. cons.*

cf. Cactaceae indet. (Plate VI, 54–57)

Description: Monad (ca. 30 μm), apolar, subspherical shape, pantaporate with wide pores, annulus absent, striate exine.

Remarks: cf. Cactaceae indet. pollen grains were rarely observed in mosses (Palude la Vela, MP).

Family: Caryophyllaceae Juss. *nom. cons.*

Caryophyllaceae indet. (Plate VII, 1)

Description: Monad (ca. 30 μm), apolar, subspherical shape, irregular margin, pantaporate with wide pores, annulus is not present, reticulate-scabrate exine.

Remarks: Caryophyllaceae indet. pollen grains were rarely observed in the fossil record (S05B). They were scantly observed in both surface sediments (Palude la Vela) and mosses (MP, Palude la Vela).

Family: Polygonaceae Juss. *nom. cons.*

Genus: **Fagopyrum** Mill., 1754 (Plate VII, 2–4)

Description: Monad (ca. 20 μm), isopolar, prolate-subprolate shape, tricolporate with wide colpi interrupted by a circular and small pore, reticulate exine, columellae high and tectate.

Remarks: Fagopyrum was rarely observed in the fossil record (S05B).

Genus: **Polygonum** L., 1753 (Plate VII, 5–7)

Description: Monad (ca. 15 μm), isopolar, subprolate shape, tricolporate with wide colpi acute in correspondence of the small circular pores, microreticulate exine, columellae not high and tectate.

Remarks: Polygonum was rarely observed in both the fossil record (S05B) and surface sediments (MP, Palude la Vela).

Genus: **Rumex** L., 1753

Species: *Rumex* cf. *acetosella* L., 1753 (Plate VII, 8–15)

Description: Monad (ca. 15 μm), isopolar, subspherical shape, tricolporate with narrow colpi quite acute in correspondence of the small circular pores, microreticulate exine.

Remarks: Rumex cf. *acetosella* was rarely observed in both the fossil record (S05B) and surface sediments (MP, Palude la Vela).

Family: Plumbaginaceae Juss. *nom. cons.*

Genus: **Armeria** Willd, 1890 (Plate VII, 16–19)

Description: Monad (ca. 40 μm), isopolar, prolate-subprolate shape, tricolpate with long and wide colpi, reticulate exine with wide lumina, columellae are high and alternated with clavae.

Remarks: Armeria was rarely observed in both the fossil record (S05B) and surface sediments (Palude la Vela).

Genus: **Limonium** Mill., 1754 (Plate VII, 20)

Description: Monad (ca. 40 μm), isopolar, prolate-subprolate shape, tricolpate, reticulate exine, columellae high and no alternated with clavae.

Remarks: Limonium was rarely observed in both the fossil record (S05B) and surface sediments (MP).

Family: Tamaricaceae Link. *nom. cons.*

Genus: **Tamarix** L., 1753 (Plate VII, 21–26)

Description: Monad (ca. 20 μm), isopolar, prolate-subprolate shape, tricolpate with short and narrow colpi, reticulate exine with circular lumina.

Remarks: Tamarix was rarely observed in both the fossil record (S05B) and surface sediments (Palude la Vela).

Order: Cornales Link

Family: Cornaceae Brecht. & J.Presl., *nom. cons.*

Genus: **Cornus** L., 1753

Description: Monad (ca. 30 μm), prolate shape, tricolporate, colpi present costae, H-endoaperture, scabrate exine, tectum is pitted with short verrucae.

Remarks: Cornus was rarely observed in both the fossil record (S05B) and mosses (Palude la Vela).

Order: Dipsacales Juss

Family: Caprifoliaceae Juss., *nom. cons.*

Genus: **Fedia** Gaertn.

Species: *Fedia cornucopiae* L., 1753 (Plate VIII, 1–6)

Description: Monad (ca. 40 μm), triangular shape in polar view and elliptic shape in equatorial view, tricolpate with long and wide colpi acute ended, echinate exine with spines arranged along the colpi, columellae are simple (Clarke, 1978).

Remarks: A single pollen grain of *Fedia cornucopiae* was observed in the fossil record (S05B).

Genus: **Knautia** L., 1753 (Plate VIII, 7–12)

Description: Monad (ca. 60 μm) subspherical shape, triporate, echinate exine, sexine thicker than nexine.

Remarks: Knautia was rarely observed in the fossil record (S05B).

Genus: **Scabiosa** L., 1753 (Plate VIII, 13–21)

Description: Monad (ca. 60 μm), prolate shape, tricolpate with long and wide colpi, echinate exine with high columellae, echinae are present above the tectum.

Remarks: Scabiosa was rarely observed in both the fossil record (S05B) and surface sediments (MP). It was commonly detected in mosses (Palude la Vela).

Genus: **Valeriana** L., 1753

Description: Monad (ca. 40 μm), subspherical, oblate shape, tricolpate with colpi moderate long and acute ended, echinate exine, columellae simple.

Remarks: Valeriana was rarely observed in both the fossil record (S05B) and the moss of MP.

Family: Viburnaceae Raf., *nom. cons.*

Genus: **Sambucus** L., 1753

Description: Monad (ca. 30 μm), isopolar, oblate shape, tricolporate microreticulate exine.

Remarks: Sambucus was rarely observed in the fossil record (S05B) and in both surface sediments (Palude la Vela) and mosses (MP, Galeso).

Genus: **Viburnum** L., 1753

Species: *Viburnum lantana* L., 1753 (Plate VII, 27–31)

Description: Monad (ca. 30 μm), isopolar, oblate-subspherical shape, tricolporate, reticulate exine with clavae.

Remarks: Viburnum lantana was rarely observed in the fossil record (S05B), and in both surface sediments (MP) and mosses (Palude la Vela).

Order: Ericales Brech. & J.Presl

Family: Ericaceae Juss. *nom. cons.*

Ericaceae indet. (Plate IX, 1–3)

Description: Tetragonal tetrad, (20–50 μm), tricolp(oroid)ate, psilate exine.

Remarks: Ericaceae indet. pollen grains were commonly observed in the fossil record (S05B), while in both surface sediments (MP, Palude la Vela) and mosses (MP, Palude la Vela, Galeso) they were rarely detected.

Family: Primulaceae Batsch ex Borkh., *nom. cons.*

Primulaceae indet.

Description: Monad (ca. 20 μm), prolate shape, tricolporate, scabrate-reticulate exine.

Remarks: Primulaceae indet. pollen grains were rarely observed in both the fossil record (S05B) and the surface sediments of Galeso.

Genus: **Androsace** L., 1753 (Plate IX, 4–6)

Description: Monad (ca. 20 μm), prolate, tricolporate with apertures not fused in the polar edges, microreticulate exine.

Remarks: Androsace was rarely observed in the fossil record (S05B).

Order: Fabales Bromhead

Family: Fabaceae Lidl., *nom. cons.*

Genus: **Astragalus** L., 1753

Description: Monad (ca. 20 μm), oblate shape, tricolporate, microreticulate exine.

Remarks: A single pollen grain of *Astragalus* was observed in the surface sediment of Palude la Vela.

Genus: **Ceratonia** L., 1753 (Plate IX, 7–9)

Description: Monad (ca. 20 μm), subspherical shape, tetracolporoidate, microreticulate exine with quite high columellae.

Remarks: Ceratonia was rarely observed in the fossil record (S05B) as well as in both surface sediments (MP) and mosses (MP, Galeso).

Genus: **Hedysarum** L., 1753

Species: *Hedysarum humile* L., 1753 (Plate IX, 10–13)

Description: Monad (ca. 40 μm), sub-rectangular shape, tricolpate with long colpi, microreticulate exine.

Remarks: Hedysarum humile was rarely observed in surface sediments (Palude la Vela).

Genus: **Hippocrepis** L., 1753 (Plate IX, 14–18)

Description: Monad (ca. 20 μm), oblate shape, tricolporate with small and circular pores, microreticulate exine.

Remarks: Hippocrepis was commonly observed in mosses (Palude la Vela).

Family: POLYGALACEAE Hoffmanns. & Link, *nom. cons.*

Polygalaceae indet. (Plate IX, 19–24)

Description: Monad (ca. 25 μm), subprolate shape, polycolporate, microreticulate exine.

Remarks: Polygalaceae indet. pollen grains were rarely observed in the fossil record (S05B).

Order: Fagales Engl.

Family: Betulaceae Gray., *nom. cons*.

Genus: **Alnus** Mill, 1754 (Plate IX, 25–28)

Description: Monad (ca. 20 μm), isopolar, subspherical shape, 4–6 porate, aspidate, arcuate, smooth exine, sexine is thicker than nexine.

Remarks: Alnus was commonly observed in the fossil record (S05B), surface sediments and mosses (MP, Palude la Vela). It was rarely detected in both surface sediments and mosses (Galeso).

Genus: **Betula** L., 1753 (Plate IX, 29–30)

Description: Monad (ca. 20 μm), isopolar, subspherical shape, triporate, aspidate, vestibulate, exine is smooth, sexine is thicker than nexine.

Remarks: Betula was rarely observed in the fossil record (S05B) and in both surface sediments and mosses (MP, Palude la Vela).

Genus: **Carpinus** L., 1753

Species: *Carpinus betulus* L., 1753 (Plate IX, 31)

Description: Monad (ca. 20 μm), isopolar, subspherical shape, tetraporate, aspidate, exine is smooth.

Remarks: Carpinus betulus was rarely observed in both the fossil record (S05B) and surface sediments (MP, Palude la Vela). A single pollen grain was observed in a moss of Palude la Vela.

Species: *Carpinus orientalis/Ostrya carpinifolia* (Plate IX, 32–36)

Description: Monad (ca. 30 μm), isopolar, subspherical shape, triporate, aspidate. Smooth exine, sexine is thicker than nexine. The distinction between *Carpinus orientalis* and *Ostrya carpinifolia* is quite difficult as the only morphological feature that differentiate their pollen grains is the more rounded shape and the more protruded outwards pores of *Ostrya carpinifolia.*

Remarks: Carpinus orientalis/Ostrya carpinifolia was commonly observed in the fossil record (S05B) and in both surface sediments (MP, Palude la Vela) and mosses (MP; Palude la Vela, Galeso). A single pollen grain was observed in the surface sediment of Galeso.

Genus: **Corylus** L., 1753 (Plate IX, 37–39)

Description: Monad (ca. 20 μm) isopolar, subspherical/sub-triangular shape, triporate, aspidate smooth exine, sexine is thicker than nexine.

Remarks: Corylus was commonly observed in both the fossil record (S05B) and surface sediments (MP, Palude la Vela). In mosses of Palude la Vela it was rarely detected.

Family: Fagaceae Dumort., *nom. cons.*

Genus: **Castanea** (Plate X, 1–3)

Description: Monad (ca. 10 μm), prolate shape, tricolporate, straight colpi, psilate exine.

Remarks: Castanea was scantly observed in the fossil record (S05B). It was rarely detected in both the moss of MP and surface sediments (MP, Galeso).

Genus: **Fagus** L., 1753 (Plate X, 21–26)

Description: Monad (ca. 35 μm), subspherical, breviaxial, tricolporate (rarely tetracolporate Plate X, 25–26) with circular pores in the middle portion of the colpi, granulate exine.

Remarks: Fagus was commonly observed in the fossil record (S05B), while in surface sediments (MP, Palude la Vela, Galeso) was scantly observed. In mosses (Palude la Vela, Galeso) it was rarely detected.

Genus: **Quercus** L., 1753

Two pollen types of *Quercus* have been observed: *Quercus pubescens*-type (deciduous oaks) and *Quercus ilex-coccifera*-type (evergreen oaks). Furthermore, two species have been recognized: *Quercus cerris* and *Quercus suber* (both semi-deciduous oaks). They have been identified according to Colombo et al. (1983), Smith (1973) and Panahi et al. (2012).

Species: *Quercus cerris* L., 1753 (Plate X, 20)

Description: Monad (ca. 40 μm), prolate shape, tricolpate, exine granulate.

Remarks: Quercus cerris was commonly observed in the fossil record (S05B), while in both surface sediments and mosses (MP, Palude la Vela) it was rarely detected.

Quercus ilex-coccifera-type (Plate X, 4–7)

Description: Monad (max. 20 μm), prolate shape, tricolporoidate, angular colpi and very small poroids, granulate exine.

Remarks: Quercus ilex-coccifera-type was commonly/abundantly observed in the fossil record (S05B) and surface sediments (MP). It was rarely detected in both surface sediments (Palude la Vela, Galeso) and mosses (MP, Palude la Vela, Galeso).

Quercus pubescens-type (Plate X, 8–19)

Description: Monad (ca. 30 μm), prolate shape, tricolpate, straight colpi, granulate exine. Variation in shape (more or less prolate) and in length of colpi are common.

Remarks: Quercus pubescens-type was abundantly observed in the fossil record (S05B) and in surface sediments (MP, Palude la Vela). In Galeso surface sediments it was rarely detected, while in mosses (MP, Palude la Vela, Galeso) it was commonly recorded.

Species: *Quercus suber* L., 1753

Description: Monad (ca. 40 μm), prolate shape, tricolporoidate, angular colpi, very small poroids, exine granulate.

Remarks: Quercus suber was rarely observed in the fossil record (S05B).

Family: Juglandaceae DC. ex Perleb., *nom. cons*.

Genus: **Juglans** L., 1753 (Plate X, 27–31)

Description: Monad (ca. 40 μm), isopolar, 6–16 zonaporate, aspidate, microechinate exine (at optical microscope generally appears smooth).

Remarks: Juglans was commonly observed in the fossil record (S05B), while in both surface sediments (MP, Palude la Vela, Galeso) and mosses (Palude la Vela) it was scantly detected.

Order: Gentianales Juss. ex Bercht. & J.Presl

Family: Rubiaceae Juss., *nom. cons*.

Genus: **Galium** L., 1753 (Plate XI, 1)

Description: Monad (ca. 15 μm), isopolar, oblate shape, 6–8 colpate, verrucate-scabrate exine.

Remarks: Galium was rarely observed in the fossil record (S05B).

Order: Geraniales Juss. ex Brecht. & J.Presl.

Family: Geraniaceae Juss., *nom. cons*.

Genus: **Erodium** L'Hér ex Alton, 1976 (Plate XI, 35–38)

Description: Monad (ca. 50 μm), subspherical shape in equatorial view and subtriangular shape in polar view, tricolporate and brevicolpate. Multi-layered striate-reticulate exine. The uppermost layer consists in long and short striae while in the lowermost layer the circular sections of columellae are visible (Stafford and Blackmore, 1991).

Remarks: Erodium was scantly observed in the fossil record (S05B). It was rarely observed in both surface sediments (Palude la Vela) and mosses (Palude la Vela, MP).

Genus: **Geranium** L., 1753 (Plate XI, 31–34)

Description: Monad (ca. 40 μm), spheroidal shape in equatorial view and subtriangular shape in polar view, tricolporate and brevicolpate. Multi-layered exine consisting in free baculae and/or clavae and gemmae with different high in alternation with columellae beneath which form the muri of reticulum. No striate layers are present (Stafford and Blackmore, 1991).

Remarks: Geranium was rarely observed in both the fossil record (S05B) and mosses (Palude la Vela).

Order: Lamiales Bromhead

Family: Lamiaceae Martinov, *nom. cons.*

Lamiaceae indet. (Plate XI, 2)

Description: Monad (ca. 20 μm), isopolar, subspherical shape, polycolpate, microreticulate exine.

Remarks: Lamiaceae indet. pollen grains were rarely observed in the fossil record (S05B), surface sediments (MP, Palude la Vela) and mosses (Palude la Vela).

Genus: **Phlomis** L., 1753

Description: Monad (ca. 30 μm), isopolar, subspherical shape, tricolpate, microreticulate exine.

Remarks: Phlomis was rarely observed in the fossil record (S05B).

Genus: **Sideritis** L., 1753 (Plate XI, 3)

Description: Monad (ca. 40 μm), isopolar, polygonal shape, tetracolpate, smooth exine.

Remarks: Sideritis was rarely observed in both the fossil record (S05B) and surface sediments (MP).

Family: Oleaceae Hoffmanns. & Link *nom. cons.*

Genus: **Fraxinus** L., 1753 (Plate XI, 4–6)

Description: Monad (ca. 20 μm), isopolar, prolate shape and 3–4 colpate, microreticulate exine with thin muri simplicolumellate, columellae small and circular.

Remarks: Fraxinus was scantly observed in the fossil record (S05B). It was rarely detected in both surface sediments and mosses (MP, Palude la Vela).

Genus: **Ligustrum** L., 1753 (Plate XI, 19–21)

Description: Monad (ca. 30 μm), isopolar, prolate shape, tri-zonocolp (oroid)ate, reticulate exine with thick muri simplicolumellate. The reticulum is coarse in mesocolpium. Lumina are variable in size and shape towards polar edges and colpi, columellae high and free.

Remarks: Ligustrum was scantly observed in the fossil record (S05B). It was rarely detected in both surface sediments (MP, Palude la Vela) and mosses (MP, Palude la Vela).

Genus: **Olea** L., 1753 (Plate XI, 7–18)

Description: Monad (ca. 20 μm), isopolar, oblate shape, tri-zonocolp (oroid)ate, reticulate exine, columellae free and variable in size, reticulum varying from fine to coarse, muri are thick and simplicolumellate, lumina not markedly decrease in size and shape towards the apertures.

Two morphotypes of *Olea* have been observed. *Olea*– morphotype 1 (Plate XI, 7–8) has smaller reticulum and shorter columellae, while *Olea*– morphotype 2 (Plate XI, 9–18) has a wider reticulum and higher columellae.

Remarks: Olea was commonly observed in the fossil record (S05B). It was abundantly observed in both surface sediments and mosses (MP, Palude la Vela, Galeso).

Genus: **Phillyrea** L., 1753 (Plate XI, 22–24)

Description: Monad (ca. 20 μm), isopolar, oblate shape, 3–4 zonocolp (oroid)ate, finely reticulate exine, muri thin and simplicolumellate, lumina not decreasing towards the colpi.

Remarks: Phillyrea was rarely observed in the fossil record (S05B), surface sediments (Palude la Vela) and the moss of MP.

Family: Orobanchaceae Vent., *nom. cons*

Genus: **Pedicularis** L., 1753 (Plate XI, 25)

Description: Monad (ca. 30 μm), isopolar, oblate shape, monocolpoidate, the aperture is split-like, psilate exine.

Remarks: Pedicularis was rarely observed in the fossil record (S05B).

Family: Plantaginaceae Juss. *nom. cons.*

Genus: **Callitriche** L., 1753

Description: Monad (ca. 20 μm), apolar, subspherical shape, inaperturate, microgemmate exine.

Remarks: Callitriche was rarely observed in both the fossil record (S05B) and surface sediments (Palude la Vela).

Genus: **Plantago** L., 1753

Species: *Plantago lanceolata* L., 1753 (Plate XI, 26–30)

Description: Monad (ca. 20 μm), apolar, spherical shape, pantoporate with circular pores, annulus is thick, verrucate exine.

Remarks: Plantago lanceolata was commonly observed in both the fossil record (S05B) and surface sediments (Palude la Vela). It was abundantly detected in mosses (Palude la Vela) while in surface sediments and mosses (MP and Galeso) it was rarely observed.

Family: Scrophulariaceae Juss. *nom. cons.*

Genus: **Verbascum** L., 1753 (Plate XII, 1–7)

Description: Monad (ca. 20 μm), isopolar, prolate shape, tricolporate with long colpi acute ended, microreticulate exine with lumina of different shape.

Remarks: Verbascum was rarely observed in the fossil record (S05B) and in both surface sediments (Palude la Vela) and mosses (Galeso).

Order: Liliales Preleb

Family: Colchicaceae DC., *nom. cons.*

Genus: **Colchicum** L., 1753 (Plate XII, 8–11)

Description: Monad (ca. 40 μm), bilateral symmetrical, prolate shape, diporate with circular pores, reticulate exine with small lumina.

Remarks: Colchicum was observed commonly in the fossil record (S05B).

Family: Liliaceae Juss., *nom. cons.*

Liliaceae indet. (Plate XII, 12)

Description: Monad (ca. 40 μm), isopolar, prolate shape, monocolpate, reticulate exine with large and regular lumina, columellae are free and not high.

Remarks: Liliaceae indet. pollen grains were rarely observed in the fossil record (S05B).

Order: Malpighiales Juss. ex Brecht. & J.Presl.

Family: Hypericaceae Juss., *nom. cons.*

Genus: **Hypericum** L., 1753 (Plate XII, 13–20)

Description: Monad (ca. 20 μm), subprolate, tricolporate, perforate-microreticulate exine. The endoaperture are cruciform with short lateral extensions according to Ocak et al. (2013).

Remarks: Hypericum was commonly observed in both the fossil record (S05B) and mosses of MP. In surface sediments (MP, Palude la Vela) was rarely detected. A single pollen grain was observed in a moss sample of Galeso.

Family: Linaceae DC. ex. Perleb, *nom. cons.*

Genus: **Linum** L., 1753 (Plate XII, 21–23)

Description: Monad (ca. 40 μm), shape suboblate-prolate, tricolpate, polyforate exine with a characteristic dimorphic ornamentation with large gemmoid and small baculoid.

Remarks: Linum was rarely observed in the fossil record (S05B).

Family: Salicaceae Mirb., *nom. cons.*

Genus: **Populus** L., 1753 (Plate XII, 24)

Description: Monad (ca. 30 μm) spherical shape, inaperturate, verrucate, scabrate and gemmate exine.

Remarks: Populus was rarely observed in both the fossil record (S05B) and mosses (Palude la Vela).

Genus: **Salix** L., 1753 (Plate XII, 25–27)

Description: Monad (ca. 20 μm), prolate shape, tricolp(oroid)ate, reticulate exine, columellae are free, lumina decrease in size towards the colpi.

Remarks: Salix was scantly observed in both the fossil record (S05B) and surface sediments (MP, Galeso). It was commonly observed in surface sediments (Palude la Vela) while, in mosses (MP, Palude la Vela) it was rarely recorded.

Order: Malvales Juss. Ex Brecht. & J.Presl

Family: Cistaceae Juss., *nom. cons*.

Genus: **Cistus** L., 1753

Description: Monad (ca. 30 μm), prolate shape, tricolporate with long colpi quite angular in correspondence of the pores, reticulate exine.

Remarks: Cistus was rarely observed in both the fossil record (S05B) and surface sediments (Palude la Vela).

Genus: **Helianthemum** Mill., 1974 (Plate XII, 28)

Description: Monad (ca. 40 μm), prolate shape, tricolporate with straight and long colpi, circular pores, reticulate exine.

Remarks: Helianthemum was rarely observed in both the fossil record (S05B) and surface sediments (MP, Palude la Vela).

Family: Malvaceae Juss., *nom. cons.*

Subfamily: Malvoideae Burnett, 1835

Tribe: Malveae J.Presl, 1826 (Plate XII, 41–43)

Description: Monad (ca. 60 μm), apolar, spheroidal shape, pantaporate. Spines extremely high and dimorphic. The dimorphism of spines, the nexine thicker than sexine and the high number of pores (more 45) permit to distinguish Malveae from Hibiscieae (El Naggar and Sawady, 2008).

Remarks: Malveae was rarely observed in the fossil record (S05B).

Subfamily: Tilioideae

Genus: **Tilia** L., 1753 (Plate XII, 29–31)

Description: Monad (ca. 35 μm), isopolar, spheroidal shape, tricolporate (rarely tetracolporate, Plate XII, 31), brevicolpate. Peculiar exine with *Tilia* structure characterized by a sexine structure with a pertectate tectum (Punt et al., 2007).

Remarks: Tilia was commonly observed in the fossil record (S05B), while in surface sediments (MP, Palude la Vela) was rarely detected.

Family: Thymelaeaceae Juss., *nom. cons*.

Genus: **Thymelaea** Tourn. ex L., 1753 (Plate XII, 32–37)

Description: Monad (ca. 20 μm), spherical shape, pantaporate with indistinct pores, reticulate exine, columellae fused.

Remarks: A single pollen grain of *Thymelaea* was observed in the fossil record (S05B).

Order: Myrtales Juss. ex Brecht. & J.Presl.

Family: Lythraceae J.St.-Hil. *nom. cons.*

Lythraceae indet. (Plate XII, 38–40)

Description: Monad (ca. 20 μm), isopolar, prolate shape, radially symmetrical, heterocolporate with an alternation of pores and colpi, smooth exine.

Remarks: Lythraceae indet. pollen grains were rarely observed in both the fossil record (S05B) and surface sediments (MP).

Family: Myrtaceae Juss. *nom. cons*.

Genus: **Eucalyptus** L'Hér, 1789 (Plate XIII, 1–14)

Description: Monad (12–30 μm), subtriangular shape, tricolpate, parasyncolpate (Adeleye et al., 2020), psilate, verrucate or scabrate exine. The intraspecific variation of morphological character (e.g., wall thickness, colpi length, apocolpial island, dimension) is high (Adeleye et al., 2020) causing an exceedingly difficult recognition of the species.

Remarks: Eucalyptus was observed only in surface sediments and moss samples.

It was abundantly observed in both the surface sediment and mosses (Galeso), while in surface sediments (Palude la Vela) it was rarely detected. A single pollen grain was observed in the moss of MP. It was commonly recorded in surface sediment (MP) and quite abundant in the samples located in *Primo Seno* (Fig. 1).

Genus: **Myrtus** Tourn., ex L., 1753 (Plate XIII, 16–17)

Description: Monad (ca. 15 μm), subtriangular shape, tricolpate, syncolpate, absence of apocolpial island, scabrate-psilate exine.

Remarks: Myrtus was rarely observed in the fossil record (S05B).

Family: Onagraceae Juss. *nom. cons*.

Genus: **Epilobium** Dill, ex L. 1753 (Plate XIII, 15)

Description: Monad (ca. 60 μm), isopolar, spheroidal shape, triporate. The pores are wide and present an annulus, psilate exine.

Remarks: Epilobium was rarely observed in the fossil record (S05B).

Order: Poales Small

Family: Cyperaceae Juss, *nom. cons*.

Cyperaceae indet. (Plate XIII, 18)

Description: Cryptotetrads (ca. 35 μm) (Erdtman, 1952), subtriangular shape, 1–4 colpoidate, colpoids consist of linearly arranged granulations, tectata-perforate exine with semitectate surface in correspondence of the colpoids.

Remarks: Cyperaceae indet. pollen grains were commonly observed in fossil record (S05B), while in surface sediments (MP, Palude la Vela) and in mosses (Palude la Vela) they were scantly detected. A single pollen grain was observed in a moss of Galeso.

Family: Poaceae Barnhart, *nom. cons*.

Since morphological characteristics (size, pore/annulus diameter) are often similar (also between taxa with different ecological significance) it is difficult to distinguish the single taxa among the numerous Poaceae. However, different morphological keys have been proposed (e. g., Anderson, 1979; Beug, 1961, 2004; Perveen and Qaiser, 2012). Here we have adopted, but only partially, that of Küster (1988) that allows the distinction of Small Poaceae-group, *Arrhenatherum*-type and Cerealia-group. In fact, the distinction between Small Poaceae-group and *Arrhenatherum*-type was very difficult during our counting, and it was more convenient for us to combine the two previous groups in a larger one informally called Wild Poaceae-group. Consequently, our record includes within Poaceae: Wild Poaceae-group, Cerealia-group and *Lygeum.*

Cerealia-group (Plate XIII, 28–29)

Description: Monad (> 40 μm), subspherical shape, monoporate with annulus diameter greater than twice the pore diameter which is > 4 μm, generally smooth exine.

Remarks: Cerealia-group pollen grains were commonly observed in the higher portion of S05B core, while in both surface sediments (MP, Palude la Vela) and mosses (Palude la Vela, Galeso) it was scantly recorded.

Genus: **Lygeum** L., 1754 (Plate XIII, 30)

Description: Monad (ca. 60 μm), elliptic shape, monoporate with pore in the inner portion, thick annulus.

Remarks: Lygeum was rarely observed in the fossil record (S05B).

Wild Poaceae-group (Plate XIII, 19–27)

Description: Monad (max. 40 μm), subspherical shape, monoporate with annulus diameter smaller than the pore diameter which is < 4 μm, smooth or quite microreticulate exine.

Remarks: Wild Poaceae-group pollen grains were abundantly observed in the fossil record (S05B); in surface sediments and mosses they were commonly detected (MP, Palude la Vela, Galeso).

Family: Typhaceae Juss, *nom. cons*.

Genus: **Sparganium** L., 1753 (Plate XIII, 34–35)

Description: Monad (ca. 20 μm), subspherical shape, ulculate, ulcus is slightly sunken, reticulate exine.

Remarks: Sparganium was commonly observed in the fossil record (S05B), while in surface sediments (MP, Palude la Vela) it was rarely detected.

Genus: **Typha** L., 1753

Species: *Typha latifolia* L., 1753 (Plate XIII, 31–33)

Description: Tetragonal tetrad (ca. 40 μm), each monad is ulculate, ulcus is slightly sunken, reticulate exine.

Remarks: Typha latifolia was commonly observed in the fossil record. A single pollen grain was observed in a surface sediment of Palude la Vela.

Order: Ranunculales Juss., ex Bercht. & J.Presl

Family: Papaveraceae Juss., *nom. cons*.

Genus: **Glaucium** Crantz, 1763 (Plate XIV, 1–9)

Description: Monad (ca. 25 μm), isopolar, shape subprolate, tricolpate with granulations along the colpi, finely microreticulate exine.

Remarks: Glaucium was rarely observed in the fossil record (S05B).

Genus: **Fumaria** Tourn. ex L., 1753 (Plate XIV, 10)

Description: Monad (ca. 35 μm), apolar, subspherical shape, pantaporate, pores present a thick annulus, verrucate exine.

Remarks: Fumaria was observed rarely in the fossil record (S05B). A single pollen grain was observed in the surface sediment of MP.

Family: Ranunculaceae Juss., *nom. cons*.

Ranunculaceae indet. (Plate XIV, 11–12)

Description: Monad (ca. 20 μm), subspherical shape, tricolpate with narrow colpi, scabrate-microechinate exine.

Remarks: Ranunculaceae indet. pollen grains were rarely observed in both the fossil record (S05B) and surface sediments (MP, Palude la Vela). A single pollen grain was observed in a moss of Palude la Vela.

Genus: **Thalictrum** L., 1753 (Plate XIV, 13–14)

Description: Monad (ca. 15 μm), subspherical shape, 6–12 pantaporate, pores not well defined, microechinate with some granulation in correspondence of pores.

Remarks: Thalictrum was rarely observed in the fossil record (S05B), and in both surface sediments and mosses (Palude la Vela).

Order: Rosales Brecht. & J.Presl

Family: Cannabaceae Martinov., *nom. cons*.

Genus: **Cannabis** L., 1753

Description: Monad (ca. 30 μm), prolate spheroidal shape, triporate with a thickening of sexine in correspondence of the pores. The outline is quite thin, smooth exine.

Remarks: Cannabis was rarely observed in the fossil record (S05B).

Genus: **Celtis** L., 1753

Description: Monad (ca. 30 μm), prolate shape, 3–4 zonaporate with a well-defined annulus. Exine is quite smooth.

Remarks: Celtis was rarely observed in the fossil record (S05B).

Genus: **Humulus** L., 1753

Description: Monad ($<$20 μm), shape sub-oblate, triporate with a thickening of sexine in correspondence of the pores. The parameter to distinguish *Humulus* from *Cannabis* are the size (*Humulus* is smaller) and the presence of a weak pore protrusion.

Remarks: Humulus was rarely observed in the fossil record (S05B).

Family: Eleagnaceae Juss., *nom. cons*.

Genus: **Hippophaë** L., 1753 (Plate XIV, 15–16)

Description: Monad (ca. 30 μm), isopolar, prolate shape, tricolporate, scabrate exine.

Remarks: Hippophaë was rarely observed in the fossil record (S05B).

Family: Euphorbiaceae Juss., *nom. cons*.

Euphorbiaceae indet. (Plate XIV, 17)

Description: Monad (ca. 30 μm), prolate shape in equatorial view and subtriangular shape in polar view, tricolporate, microreticulate exine with high and semitectate columellae. In polar view in correspondence of the opening a clear thickening of the exine is visible (similar to a bird beak).

Remarks: Euphorbiaceae indet. pollen grains were rarely observed in the fossil record (S05B).

Genus: **Mercurialis** L., 1753 (Plate XIV, 18–20)

Description: Monad (ca. 20 μm), prolate shape, tricolporate, microreticulate exine with very small lumina.

Remarks: Mercurialis was rarely observed in the fossil record (S05B), surface sediments (Palude la Vela) and the moss of MP.

Genus: **Ricinus** L., 1753

Description: Monad (ca. 20 μm), prolate shape, tricolporate with narrow colpi and pores elongated equatorially, microreticulate exine with tectate columellae.

Remarks: Ricinus was rarely observed in the fossil record (S05B).

Family: Rhamnaceae Juss., *nom. cons*.

Genus: **Rhamnus** L., 1753 (Plate XIV, 24)

Description: Monad (ca. 25 μm), shape subprolate, triangular shape in polar view, tricolporate. In equatorial view the apertures assume a particolar H-shape, striato-rugulate exine.

Remarks: Rhamnus was rarely observed in both the fossil record (S05B) and the moss of MP.

Genus: **Ziziphus** Mill, 1754

Description: Monad (ca. 30 μm), subprolate, triangular shape in polar view, tricolporate. *Ziziphus* is distinguishable by *Rhamnus* as it presents four granulations in correspondence of the apertures. Striato-rugulate exine with a thin infratectal layer that appears granular.

Remarks: Ziziphus was rarely observed in both the fossil record (S05B) and surface sediments (Palude la Vela).

Family: Rosaceae Juss., *nom. cons*.

Rosaceae indet. (Plate XIV, 25)

Description: Monad (ca. 40 μm), oblate shape, tricolporate, colpi are short, pores protruding outward in polar view, striate exine.

Remarks: Rosaceae indet. pollen grains were rarely observed in the fossil record (S05B). They were rarely detected in both mosses (Palude la Vela) and surface sediments (Galeso).

Genus: **Sanguisorba** L., 1753

According to Lee et al. (2011) *Sanguisorba minor*-type has been recognized.

Species: *Sanguisorba minor*-type (Plate XIV, 26–28)

Description: Monad, (ca. 30 μm), spherical, tricolporate, microreticulate. In polar view in correspondence of the apertures an operculum is present.

Remarks: Sanguisorba minor-type was commonly observed in the fossil record (S05B). It was rarely detected in both surface sediments (Palude la Vela) and mosses (Palude la Vela, Galeso).

Genus: **Spiraea** L., 1753 (Plate XIV, 21–23)

Description: Monad (ca. 15 μm), isopolar, sub-spherical shape with rounded lobe in polar view, tricolporate with shorth and narrow colpi and small pores, microstriate/microgranulate exine.

Remarks: Spiraea was rarely observed in the fossil record (S05B).

Family: Ulmaceae Mirb., *nom. cons*.

Genus: **Ulmus** L., 1753 (Plate XIV, 29–31)

Description: Monad (ca. 30 μm), subspherical shape, 3–6 zonaporate, rugulate exine.

Remarks: Ulmus was commonly observed in the fossil record (S05B). It was rarely observed in both surface sediments (MP, Palude la Vela) and mosses (Palude la Vela).

Family: Urticaceae Juss., *nom. cons*.

Urticaceae indet.

Description: Monad (ca. 20 μm), subspherical, 2–6 zonaporate with a smooth exine.

Remarks: Urticaceae indet. pollen grains were rarely observed in the fossil record (S05B).

Order: Sapindales Juss. ex Brecht. & J.Presl

Family: Anacardiaceae R.Br., *nom. cons*.

Genus: **Pistacia** L., 1753 (Plate XIV, 32–37)

Description: Monad (ca. 30 μm), apolar, sub-spherical shape, pantaporate, microreticulate exine.

Remarks: Pistacia was commonly observed in both the fossil record (S05B) and surface sediments (MP). It was rarely recorded in both surface sediments (Palude la Vela) and mosses (MP, Palude la Vela, Galeso).

Genus: **Rhus** L., 1753 (Plate XV, 1–5)

Description: Monad (ca. 20 μm), prolate shape, tricolporate with long and sunken colpi with acute ends, striate exine.

Remarks: Rhus was rarely observed in both the fossil record (S05B) and sub-recent sample (MP and Palude la Vela, moss sample of MP).

Family: Rutaceae Juss., nom. cons.

Genus: **Citrus** L., 1753

Species: *Citrus* cf. *x aurantium* (Plate XV, 8–12)

Description: Monad (ca. 30 μm), isopolar, oblate shape, rectangular in polar view, tetracolporate with wide pores, microreticulate exine with small lumina.

Remarks: Citrus cf. *x aurantium* was rarely observed in both surface sediments (MP) and mosses (Palude la Vela).

Species: *Citrus medica* L., 1753 (Plate XV, 13–17)

Description: Monad (ca. 30 μm), spheroidal shape, tetracolporate, microreticulate exine with small lumina. The identification is according to Russo Ermolli et al. (2017) and Barone Lumaga et al. (2020).

Remarks: A single pollen grain of *Citrus medica* was observed in the fossil record (S05B).

Family: Sapindaceae Juss., *nom. cons.*

Genus: **Acer** L., 1753 (Plate XV, 18)

Description: Monad (ca. 40 μm), isopolar, prolate shape, tricolpate, striate exine.

Remarks: Acer was scantly observed in the fossil record (S05B). It was rarely detected in both surface sediments (MP) and mosses (MP, Palude la Vela).

Order: Santalales Berchtold & J.Presl.

Family: Loranthaceae Juss., *nom. cons.*

Genus: **Loranthus** Jacq., 1762

Species: *Loranthus europaeus* Jacq., 1762 (Plate XV, 19)

Description: Monad (ca. 30 μm), oblate, subtriangular shape, trisyncolpate with long colpi. psilate exine

Remarks: Loranthus europaeus was rarely observed in the fossil record (S05B).

Order: Saxifragales Brecht. & J.Presl

Family: Crassulaceae J.St.-Hil. *nom. cons.*

Genus: **Sedum** L., 1753 (Plate XV, 6–7)

Description: Monad (ca. 20 μm), prolate shape, tricolporate, long and narrow colpi tenuimarginate, pores elliptical shape, microrugulate exine, tectum slightly irregular.

Remarks: Sedum was scantly observed in the fossil record (S05B). It was rarely detected in both surface sediments (MP, Palude la Vela, Galeso) and the moss of MP.

Family: Grossulariaceae DC. *nom. cons.*

Genus: **Ribes** L., 1753

Description: Monad (ca. 30 μm), spherical shape, 8–9 pantaporate, with pores located in rugoid/granulate areas, sexine thinner than nexine.

Remarks: Ribes was rarely observed in the fossil record (S05B).

Family: Saxifragaceae Juss, *nom. cons.*

Saxifragaceae indet.

Description: Monad (ca. 30 μm), sub-prolate shape, tricolpate with narrow colpi, striate exine.

Remarks: Saxifragaceae indet. pollen grains were rarely observed in both the fossil record (S05B) and surface sediments (Palude la Vela, Galeso).

Order: Solanales Juss. ex Bercht. & J.Presl.

Family: Convolvulaceae Juss. *nom. cons.*

Convolvulaceae indet. (Plate XV, 20)

Description: Monad (ca. 40 μm), isopolar, prolate shape, tricolpate microreticulate exine, columellae high and sometimes bifid.

Remarks: Convolvulaceae indet. pollen grains were rarely observed in fossil record (S05B). They were scantly observed in both surface sediments (Palude la Vela and Galeso) and mosses (Galeso).

Order: Vitales Juss. Ex Brecht. & J.Presl

Family: Vitaceae Juss, *nom. cons.*

Genus: cf. **Cissus** L., 1753 (Plate XV, 21–22)

Description: Monad (ca. 40 μm), prolate shape, tricolporate with circular and big pores, rugulate-reticulate exine.

Remarks: A single pollen grain of cf. *Cissus* was observed in the fossil record (S05B).

Genus: **Vitis** L., 1753 (Plate XV, 23–29)

Description: Monad (ca. 20 μm), sub-spherical shape, tricolporate with short colpi interrupted by a circular pore, scabrate exine.

Remarks: Vitis was rarely observed in fossil record (S05B). It was commonly detected in both surface sediments and mosses (MP, Palude la Vela, Galeso).

6. Discussion and conclusion

Pollen analyses of the sub-recent (surface sediment and moss) and fossil (S05B) pollen records allowed the detection of the main components of the flora around the MP. The latter includes edaphic/local, regional, and extra regional taxa plus some alien taxa. Our pollen dataset provides a descriptive and illustrated atlas of selected taxa facilitating the pollen identification and consequently the reconstructions of vegetation and climate changes in the MP basin (southern Italy), during the Holocene. It also represents a useful guide for pollen analyses in southern Europe and Mediterranean area.

In the fossil record non-arboreal plants (NAP, 90 taxa) are mainly characterized by taxa typical of edaphic/local conditions associated with both freshwater marshes (e.g., dominated by Cyperaceae) and saltmarshes (especially Amaranthaceae), extending close to MP. Submerged aquatic plants (e.g., *Potamogeton*) are scanty. Other NAP predominantly include cosmopolitan (e.g., *Knautia*, *Scabiosa*, and *Plantago*) and some steppe (e.g., *Artemisia*, *Ephedra* s.l., and *Lygeum*) taxa. Arboreal plants (AP, 40 taxa) are especially represented by Mediterranean (e.g., *Pistacia* and *Quercus ilex-coccifera*-type) and Sub-Mediterranean (e.g., *Quercus pubescens*-type and *Carpinus orientalis*) taxa. Riparian taxa are also present (e.g., *Alnus* and *Salix*).

In the sub-recent samples (surface sediments and mosses), NAP and AP include 63 and 37 taxa, respectively. The different number of taxa with respect to the fossil record is quite evident especially for the NAP (63 versus 90 taxa). This probably relies on different concomitant factors such as a higher number of fossil samples and the effects of both freshwater marsh drainage and high urbanization in sub-recent samples. At Galeso, the high pollution could be responsible for the scanty occurrence of freshwater marsh taxa (e.g., Cyperaceae). Here ruderal taxa (e.g., *Plantago lanceolata* and *Sedum*) together with pollen causing allergic diseases (e.g., *Ambrosia artemisiifolia*-type, a highly invasive taxon), suggest a heavily anthropized environment. AP are poorly represented, except *Eucalyptus*. The latter witnesses the deforestation and subsequent reforestation with alien taxa during 1950s–1960s, in both surface and moss samples. At MP and Palude la Vela regional nature reserve the local/edaphic saltmarsh taxa (e.g., Amaranthaceae and *Armeria*) are well represented in surface sediment and moss samples.

Aerodynamics of Pinaceae pollen grains facilitates their long-distance dispersal by wind or runoff. Among Pinaceae, *Cedrus*, *Abies*, *A. cephalonica* and *Picea* represent an extra regional component of the pollen rain as they grow at high altitude, far away the MP. Instead, *Pinus* could be present both near-by the depositional basin and in more high altitudinal belts. *Pinus* is usually well represented and preserved in both fossil and sub-recent samples. Especially in sub-recent sediments *Pinus* is sometimes over-represented because of monospecific reforestations carried out along the MP coast. The scanty presence of *Cedrus*, *Abies*, *A. cephalonica* and *Picea* pollen grains attests here an extra-local component of the MP pollen rain. *Abies* is present both in the fossil and sub-recent records and could come from southern and central Apennines and/or the Balkans mountains. The occurrence of *Abies cephalonica*, an endemic species of the Balkan peninsula (central and southern Greece, islands of Eubea and Cephalonia), in a specific interval of the fossil record, concomitant with the absence of *Picea* and *Abies* suggests its arrival by East-Southeast wind. *Picea* is present in both fossil record and in sub-recent sediment. Its occurrence in southern Italy is reported for the MIS 2 of the Lago Grande di Monticchio (Allen et al., 2002). Nowadays *Picea* is restricted in the Alps, northern-central Apennines, and Balkans. Its presence in MP fossil and sub-recent records suggests a long transport from the east Balkans, as proposed by Di Rita and Magri (2009) and/or from northern Italy. *Cedrus* is currently restricted in Algeria and Morocco (*Cedrus atlantica*; Slimani et al., 2014) and in Lebanon (*Cedrus libani*; Fady et al., 2008). Hajar et al. (2008) suggest a local presence of *Cedrus* with at least 5% occurrence; thus, its sporadic occurrence in MP fossil record supports rather a long-distance transport from North Africa and/or Middle East (e.g., Reille, 1990; Magri and Parra, 2002; Di Rita et al., 2018). Its latest occurrence in southern Italy is attested in MIS 12 (Vallo di Diano, Russo Ermolli, 1994; Russo Ermolli et al., 2015). The presence of *Cedrus* in sub-recent samples could be also due to long-distance transport from North Africa and/or Middle East. However, in Monte Cornacchia *C. deodara* (native from Asia) and *C. atlantica* are present because of the reforestation during the 1950s–1970s. Therefore, it is not possible to exclude the Duano

Apennines as a source of *Cedrus* s.l. pollen grains, in sub-recent samples.

Olea, *Vitis,* Cerealia-group, and *Juglans* are important markers of increasing anthropization; they are very well documented in both the most recent sediments of the fossil record and in all sub-recent samples. The presence of alien taxa in the fossil record suggests their transport in the Mediterranean area by merchants. *Citrus medica* was found in sample S05B-32 (at 1.82 m below seabed, b.s.b.). *Citrus medica*, one of the ancestral species of the genus, is Northeast India or north Southeast Asia native (Nicolosi et al., 2005; Fuller et al., 2011) and it was one of the first to spread eastward (e.g., Persia, Zohary et al., 2012). Langgut (2017) traced the displacement of *Citrus medica* up to its first unequivocal evidence in the Mediterranean dating back to the V–IV century BC (Langgut et al., 2015). In Italy, *Citrus medica* has been found in Campania and Roman archeological sites (Mariotti Lippi, 2000; Russo Ermolli et al., 2017; Barone Lumaga et al., 2020). The discovery of *Citrus medica* in the MP is highly significant to trace its route of diffusion in the Mediterranean but also to have chronological evidence for the MP record. According to the dates of its introduction (Langgut et al., 2015), its occurrence in MP cannot be older than the V–IV century BC. Alien taxa were observed also in the sub-recent record. *Eucalyptus* is the most abundant alien taxa in sub-recent pollen record. It is highly abundant in Galeso pollen record as it is a component of the local vegetation. The presence of *Citrus* cf. *aurantium* is coherent with intensive cultivation of *Citrus x clementina* around the MP; the latter originates by a grafting of tangerines (*C. reticulata*) and bitter orange (*C. x aurantium*). Other alien taxa are Arecaeae indet., *Aloe* and cf. Cactaceae indet. commonly used as ornamental plants in private and public garden in Taranto.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Data availability

Data will be made available on request.

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