

## AN EARLY PLEISTOCENE PLANT ASSEMBLAGE WITH EAST EUROPEAN AFFINITY IN THE VENETIAN-FRIULIAN BASIN (NE ITALY)

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**ABSTRACT:** A palaeobotanical study, including pollen and carpological analyses, has been carried out on the brown coal seam of San Pietro di Ragogna (Friulian foothills). The palynoflora and carpoflora have been analysed with the Plant Community Scenario approach for a better interpretation of their palaeovegetational signals. The coal-bearing layer, despite its limited chronological extension and exposure, is significant for the occurrence of several fossil fruits and seeds belonging to taxa with East European affinity, recorded for the first time in Italy, such as *Hypericum tertiaerum*, *Myriophyllum praespdatum*, *Najas major-pliocenica*, *Nymphaea borysthenica*, *Potamogeton cf. panormitanoides*, *Schoenoplectus cf. lacustroides*. Their concomitant occurrence with *Carex cf. elata*, *Menyanthes trifoliata* and *Nuphar aff. lutea*, which appear in Italian floras after the Piacenzian/Gelasian boundary, points to a Gelasian age of the studied coal deposit. Such hypothesis is also supported by the floristic/vegetational affinities with selected Gelasian floras from Central and Eastern Europe. The coal deposit directly overlays the regional unconformity, ascribed to the Messinian, which marks the base of the Quaternary succession in the Friulian piedmont plain. The geographical location of the site is also significant for the reconstruction of palaeovegetational changes at the Plio-Pleistocene transition. In fact, the occurrence of East European elements may indicate that the migration of plant taxa from Eastern Europe reached the easternmost part of Northern Italy, under the effects of climate worsening related to the inception of glacial periods in the Northern Hemisphere.

**Keywords:** Carpology, Pollen, Palaeovegetation, Early Pleistocene, PCS approach, SE Alps.

### 1. INTRODUCTION

The knowledge of the Early Pleistocene vegetation in the Alpine fringe of northern Italy is established thanks to palynological studies on some remarkable continental successions in the central Southalpine foothills (Ravazzi & Rossignol-Strick, 1995; Ravazzi et al., 2005; Muttoni et al., 2007; Ravazzi et al., 2009), as well on the marine succession of the Venice core, in the eastern portion, at the Adriatic shoreline (Massari et al., 2004). On the southern side of the Po Plain, in the outer fringe of the Northern Apennine, several palynological studies on marine successions cover the Pliocene and Pleistocene interval (e.g., Lona & Bertoldi, 1973; Rio et al., 1997; Bertini, 2001; Fusco, 2007). The pollen records of these successions are very rich, but are accompanied by a scarce macrofloral record (Gregor, 1990; Ravazzi & Rossignol-Strick, 1995; Ravazzi et al., 2005), which hampers the thorough documentation of the palaeofloral development during the Early Pleistocene. In this sense only the rich palaeocarpological record (Ghiotto, 1995; 2010) of the Steggio site (Sala & Tonon, 1992; Paronuzzi & Tonon, 1992), in the Venetian foothills, partially fills the macropalaeobotanical gap, but without providing pollen data. Also the geographical gap is partly filled, as the Steggio site is located (Fig. 1) between the Italian peninsular record (e.g., Gregor, 1990; Girotti et al., 2003; Magri et al., 2010) and the scattered record of Central and Eastern European localities (Fig. 1), summarized by Velichkevich & Zastawniak (2003).

The Venetian-Friulian plain was physically discon-

nected from the Po Plain till the second half of the Middle Pleistocene, when the progradation of the alluvial systems and the merging of the alluvial plains led to the filling of the northern Adriatic gulf (Massari et al., 2004; Muttoni et al., 2010; Garzanti et al., 2011). Moreover, the Venetian-Friulian plain was connected to the Danube basin through low relieves, in between the elevated barriers of the Eastern Alps and the Dinarides. Due to such palaeogeographic context, in the Early-Middle Pleistocene North-Eastern Italy was a corridor between Eastern Europe and the Italian Peninsula (Muttoni et al., 2010). Despite this key-location, North-Eastern Italy still has a relevant lack of palaeofloral information, so that every new palaeobotanical site represents an important improvement for the knowledge of the Early Pleistocene phytogeographic development in this area.

The present paper is aimed to investigate the palaeofloral characteristics of the first Early Pleistocene site in the Friulian foothills (San Pietro di Ragogna), in comparison to the palaeoenvironmental record of the south-alpine area and other palaeobotanical records from the rest of Italy and Eastern Europe.

### 2. GEOLOGICAL SETTING

The Ragogna hill represents the southernmost relief of the Carnian Prealps (Fig. 2) and is located in the correspondence of the frontal thrust of the Eastern Southalpine Chain (ESC), the Arba-Ragogna thrust (Galadini et al., 2005; Poli et al., 2009). The southern slope

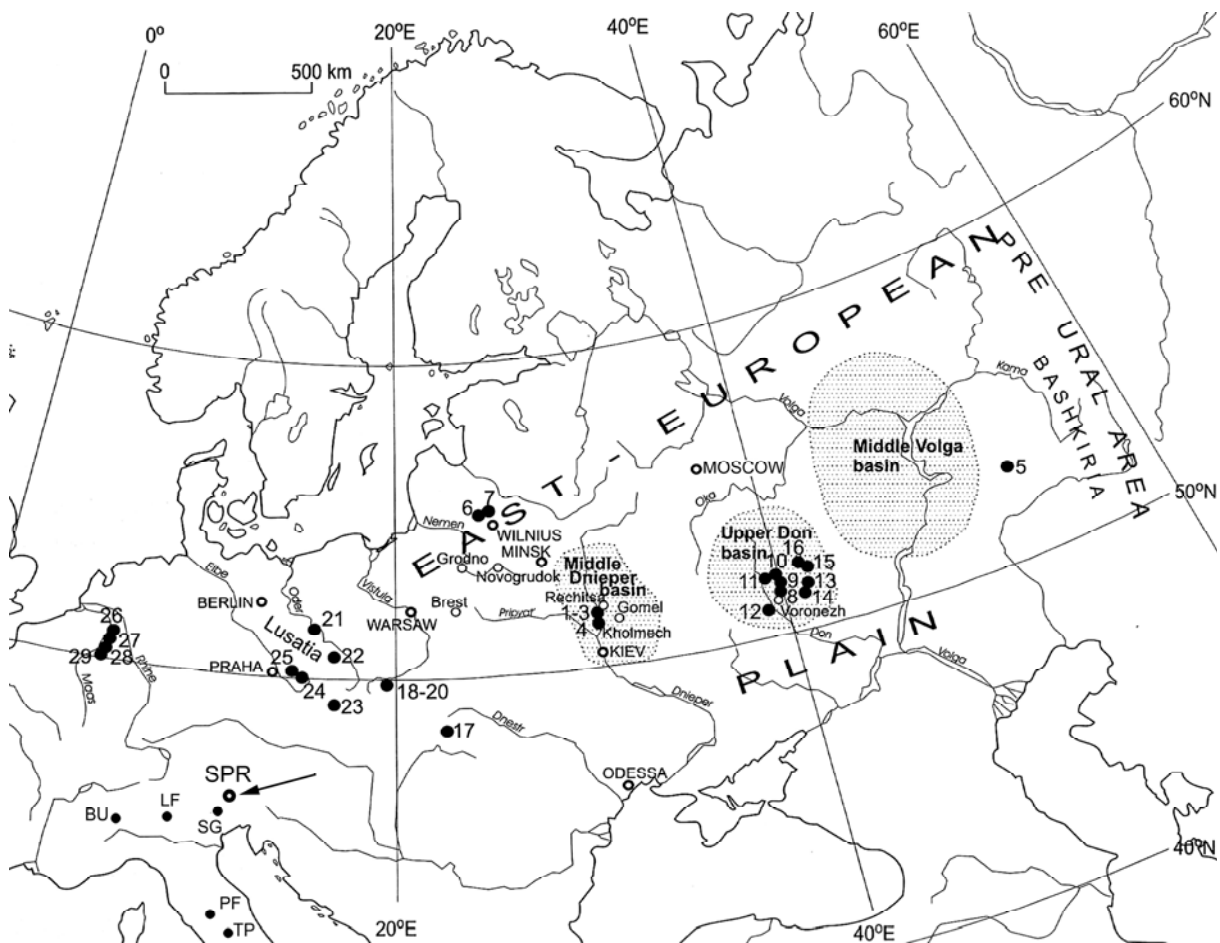


Fig. 1 - Map of the main European localities with fruit and seed assemblages assigned to the Pliocene and Gelasian; also a few Calabrian localities of Italy are reported (hereinafter "Calab.>"). Localities of Pliocene floras in Europe. 1 - Kholmech, 2 - Dvoretz, 3 - Kolochin, 4 - Stradubka, 5 - Simbugino, 6 - Šlavě, 7 - Daumantai, 8 - Cherovitskoye, 9 - Krivoborye, 10 - Ivnitsa, 11 - Dan'shino, 12 - Uryv, 13 - Moiseyev, 14 - Shekhman', 15 - Ranino, 16 - Manovitsy, 17 - Malaya Began', 18 - Mizerna, 19 - Krościenko, 20 - Grywałd, 21 - Ruszów, 22 - Kłodzko, 23 - Vildštejn Formation, 24 - Rippersroda, 25 - Nordhausen, 26 - Reuver, 27 - Brunssum, 28 - Swalmen, 29 - Tegelen. BU, Buronzo, Cervo River section; LF, Lefte (Calab.); PF, Pietrafitta (Calab.); SG, Steggio (Calab.); SPR, San Pietro di Ragogna; TP, Torre Picchio. Modified after Velichkevich & Zastawniak (2003).

of the Ragogna hill is characterised by deep incisions related to small tributaries of the Tagliamento River that followed the deepening of the fluvial network during the last deglaciation (Monegato et al., 2007). In the slope of the Tagliamento left bank, as well as within the incisions of the Ragogna hill, a succession of coarse continental deposits crops out, which has been the subject of studies since the end of 19th century. The early work by Tellini (1892) provides a first detailed description of the succession; he remarked a petrographic distinction between a lower ("Pontian") conglomerate, ascribed to a transitional-marine environment, and an upper continental conglomerate. The mollusc assemblage in the brown coal layer located at the base of the upper conglomerate unit was characterised by continental taxa such as *Helix*, *Limnea*, *Planorbis*, *Valvata*, *Bithynia*, *Unio* and *Pisidium* (Tellini, 1892). Whereas, no palaeobotanical analysis was carried out on the brown coal layer. The subsequent works (Stefanini, 1915; Feruglio, 1925, 1929) maintained Tellini's assumption considering the upper conglomerate as "Villafranchian", not because of the discovery of mammal assemblages, but for hypothetical

age-relationships with the type-succession of Villafranca d'Asti, rich in mammal remains (Carraro, 1996). Only recently, the surveys for the new Geological Map of Italy yielded an improvement to the knowledge of the stratigraphy of the Friulian foothills. These studies enlightened the tectonic structures of the front of the ESC (Galadini et al., 2005) and the presence of several angular unconformities characterising the stratigraphy of the succession (Paiero & Monegato, 2003; Zanferrari et al., 2008) related to the activity of the Arba-Ragogna thrust since the end of the Miocene (Poli et al., 2009). The lower conglomerate ("Pontian" *sensu* Tellini, 1892) was mapped as Montello Conglomerate and revised as a Messinian continental deposit (Zanferrari et al., 2008). The upper conglomerate ("Villafranchian" *sensu* Stefanini, 1915) was mapped as San Pietro di Ragogna Conglomerate (Zanferrari et al., 2008).

Both conglomerate units are well exposed in the southern slope of the Ragogna Hill along the Ponte and Mordaro creeks (Fig. 2). The succession has at the bottom the thick upper member of the Montello Conglomerate, which is about 600 m thick and tilted of 60° to 90°

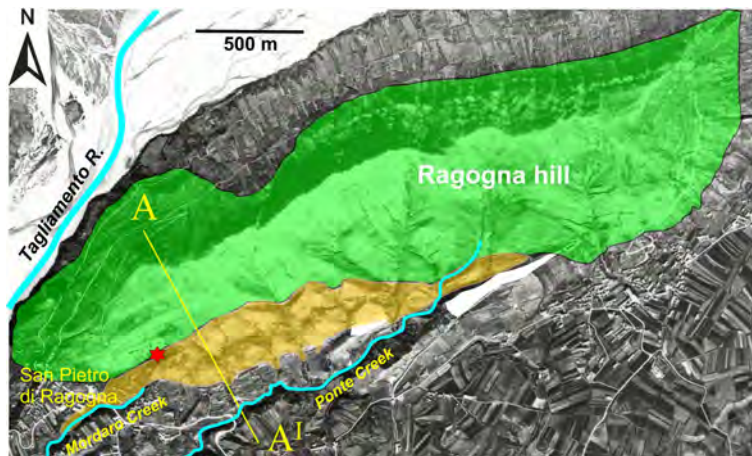


Fig. 2 - Aerial photo of Volo GAI (1951) of the Ragogna Hill with the sample location marked with the red star. Green area: Montello Conglomerate (Messinian); orange area San Pietro di Ragogna conglomerate. A-A': trace of the profile of Fig. 3.

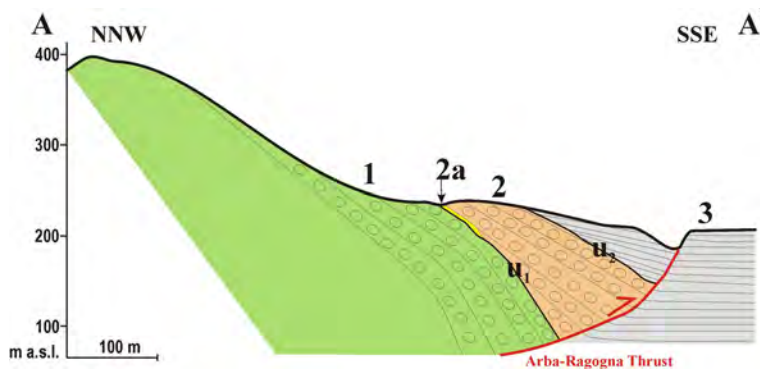


Fig. 3 - Geological section of the Ragogna Hill: 1. Montello Conglomerate (Messinian); 2. San Pietro di Ragogna conglomerate; 2a. coal seam location; 3. Middle-Upper Pleistocene units;  $u_1$ : angular unconformity of about 25°;  $u_2$ : angular unconformity of about 15°.

towards the south-east (Fig. 3). The pebbles of this conglomerate are exclusively made of Upper Triassic - Cretaceous carbonate rocks, with minor cherts and Eocene turbidites (Venturini & Tunis, 1992); sandstone layers and lenses are rare, while finer sediments are lacking. The Messinian age is constrained by radiometric datings at the marine/continental transition (Grandesso et al., 2000). No peat layers were recognised within this unit.

An angular unconformity marks the boundary of the Montello Conglomerate with the San Pietro di Ragogna Conglomerate (SPC). This is an erosion surface in which the difference in dip varies from 25° to 45° (Fig. 3), depending on where the erosional surface cuts the previously deformed Messinian unit. In correspondence of the boundary, the basal portion of the succession is made of a few-meters-thick consolidated silty clay with a brown coal seam. This coal, shows a millimetric lamination and lacks any sign of bioturbation; it contained well-recognizable plant remains, such as extremely compressed wood fragments, up to 10 cm in cross-section, and small fruits and seeds, mostly variously compressed and deformed, except for those included in clay-rich brown coal. Actually, this layer crops out in hardly-accessible spots because it had been intensively mined as fossil fuel during the late 19th centu-

ry (Feruglio, 1925), but abundant samples of this brown coal seam are available in dump deposits. Above these basal deposits, about five meters of coarse laminated sandstones occur and the upper transition to conglomerates is gradual. Conglomerates show crude to planar bedding; clasts are sub-rounded to rounded and maximum size span from 10 to 30 cm, with a coarse layer in which some clasts reach 50 cm in diameter (Fig. 4). Clast petrography is dominated by carbonates (dolostones and limestones), however it can be clearly distinguished from those of the Montello Conglomerate for the relative abundance in Palaeozoic and Lower Triassic sandstones, low-grade metamorphic phyllites and acidic volcanic fragments, pointing to a provenance from the post-Messinian Tagliamento catchment (Monegato & Stefani, 2010; Monegato & Vezzoli, 2011). The SPC has a preserved thickness of about 110 m and is bounded at the top by an erosion surface, over which a younger unit, of Middle Pleistocene age (Paiero & Monegato, 2003), lies with an angular unconformity ( $u_2$ ) of about 15° (Fig. 3).

### 3. MATERIAL AND METHODS

A pollen sample was collected in the brown coal seam, and treated following standard chemical methods (including acetolysis) in use at the Laboratory of Palynology and Paleoecology of Consiglio Nazionale delle Ricerche - Istituto per la Difesa e Protezione Ambientale (CNR-IDPA) of Milan. Pollen and charcoal concentrations have been calculated with the addition of *Lycopodium* tablets following procedures outlined by Stockmarr (1971); fucsina-red was added for a better distinction of palynomorphs. The identification of pollen grains and spores was based on the atlas and identification keys of European Pollen Floras (Moore et al., 1991; Reille, 1992-1995; Punt & Blackmore, 1976-2004; Beug, 2004) and on the reference collection of the CNR-IDPA. Pollen nomenclature follows the ALPADABA (Alpine Palynological Database) list of pollen types housed at the Institute of Plant Sciences, University of Bern.

Plant macrofossils have been obtained by preparation of two bulk sediment samples (SPR1B9A, 3 dm<sup>3</sup> and SPR1COF, 4 dm<sup>3</sup>). However, it has been very difficult to disaggregate the sediment, since the standard procedure (Basilici et al., 1997) did not work very well with the extremely compact and carbonate-rich brown coal of SPR. Several cycles of drying, treatment with 5% H<sub>2</sub>O<sub>2</sub> and freezing were necessary to obtain the fluidification of only 2/3 of the sediment volume, so 1/3 could not be analysed. After the last immersion in 5% H<sub>2</sub>O<sub>2</sub>, the floating fraction, rich in fruits and seeds, has been filtered with a mesh size of 0.3 mm. The plant remains within the fluidified sediment, deposited at the bottom of the bucket, have been collected with a mesh size of 0.8 mm and washed with a powerful water jet.

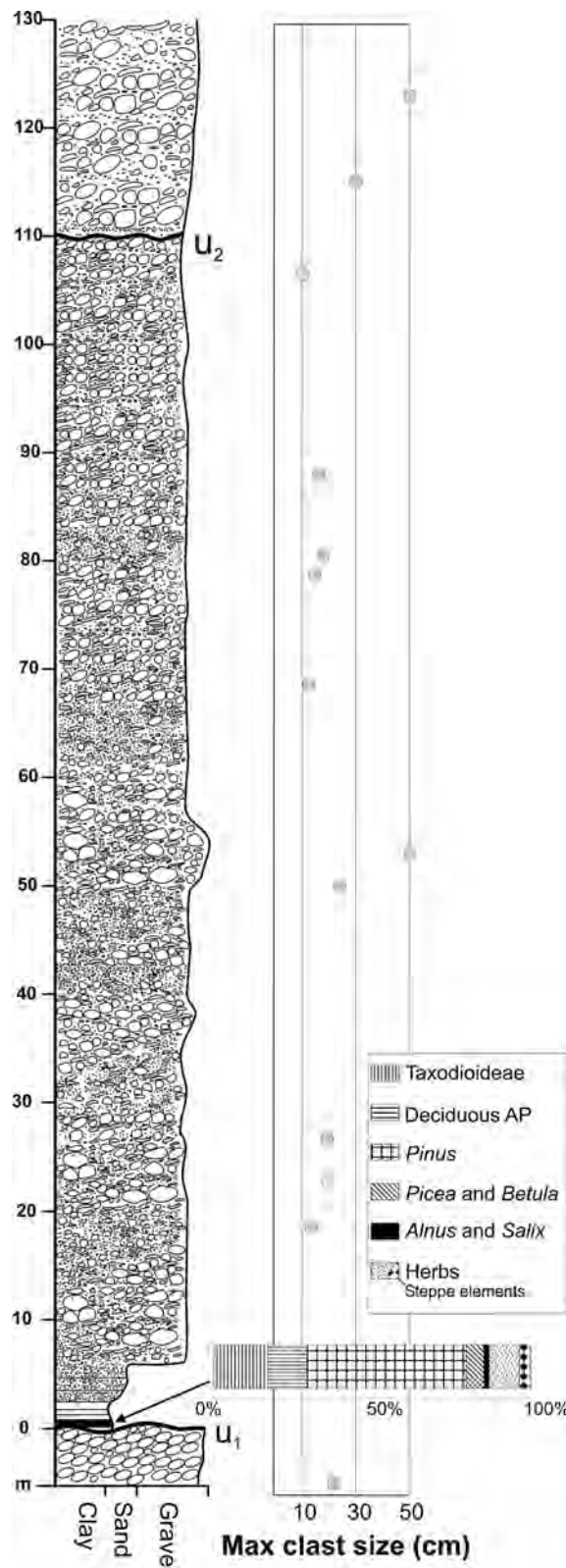


Fig. 4 - LOG of the Rio Ponte section of the San Pietro di Ragogna conglomerate;  $u_1$  and  $u_2$  are the angular unconformities of Fig. 3. Arrow indicates the sampled layer for which a synthetic pollen spectrum is reported. Aquatic and wetland herbs (Tab. 1) have been excluded from the pollen sum.

The residues obtained after washing have been slowly dried and observed under a stereomicroscope in order to pick up fruits and seeds and to identify them on the basis of their characteristic morphological traits.

For identification, we combined the information provided by specialised literature (mainly: Geissert et al., 1990; Mai & Walther, 1988; Nikitin, 2006; Reid & Reid, 1915; Velichkevich & Zastawniak, 2003, 2006, 2009) with the direct observation of fresh fruit and seed material of the Modern Carpological Collection (MCC) stored at the Department of Earth Sciences of the Torino University. Finally, these identifications were compiled into floristic lists, and abundance data were generated based on counts of the fruit and seed taxa identified.

For the interpretation of palaeovegetation, the micro- and macropalaeobotanical quantitative and qualitative data have been analysed and graphically synthesized by means of the Plant Community Scenario (PCS) approach (Martinetto & Vassio, 2010): both data sets are fundamental for palaeoenvironmental and palaeobiogeographic interpretations (Birks & Birks, 2000), because they usually provide complementary and integrating information (Bůžek et al., 1985; Bertini & Martinetto, 2011). Among the several aims of the PCS approach, in the present paper we focused on the homogenous rendering and subsequent comparison of the information provided by different fossil plant records, in order to propose a more reliable reconstruction of the palaeovegetation. At the state of the art, and despite the attempt in this sense (Martinetto & Vassio, 2010; Vassio, 2012), there is still no precise method to correct the well-known bias between qualitative composition of carpological assemblages and their potential source plant communities. Therefore it is not possible to transform the PCS diagram into a quantitative reconstruction of palaeovegetation. However, the PCSs obtained from ancient deposits can be successfully compared to the ones obtained from modern sedimentary contexts (Vassio, 2012), where the vegetation has been directly surveyed.

The relationship PCS of modern vegetation- PCS of modern sediment-borne carpological assemblages is the key for the interpretation of the unknown palaeovegetational context which is implicit into a PCS diagram obtained from a fossil assemblage.

## 4. RESULTS

### 4.1 Palaeofloral analysis

The pollen analysis on the brown coal yielded an assemblage dominated by conifers (Tab. 1 and Fig. 4): *Pinus*, which exceeds 50 %, and *Picea* (2.3%). The remaining arboreal plants are Taxodioidae and broad-leaved trees, such as *Quercus*, *Ulmus*, *Carya*, *Tilia* and *Betula*. Trees represent 87% of pollen; non-arboreal taxa are dominated by Poaceae (8%). The abundance of herbaceous aquatic and wetland taxa (such taxa were not included in the total pollen sum in Tab. 1) indicates a wet environment (i.e., a mire) close to the sedimentation site.

The carpological analysis of two samples (SPR1B9A, SPR1C0F) permitted the identification of 33 taxa (Tab. 2), most of them at species level, thus allowing to obtain

	pollen sum	pollen percentage	pollen concentration
<b>Trees and shrubs</b>			
<i>Pinus</i>	291	50,4	33502
<i>Picea</i>	13	2,3	1497
Taxodiaceae	98	17,0	11283
<i>Ephedra distachya</i> type	1	0,2	115
<i>Alnus glutinosa</i> type	5	0,9	576
<i>Betula</i>	19	3,3	2187
<i>Carya</i>	8	1,4	921
<i>Corylus</i>	10	1,7	1151
<i>Fraxinus</i> type	2	0,3	230
deciduous <i>Quercus</i>	25	4,3	2878
<i>Salix</i>	4	0,7	461
<i>Tilia</i>	9	1,6	1036
<i>Ulmus</i>	17	2,9	1957
Juglandaceae	1	0,2	115
<b>Total</b>	503	87,2	57910
<b>Herbs</b>			
Poaceae	45	7,8	5181
<i>Artemisia</i>	19	3,3	2187
Asteraceae	3	0,5	345
Chenopodiaceae	5	0,9	576
<i>Lilium</i>	1	0,2	115
Celastraceae	1	0,2	115
<b>Total</b>	74	12,8	8519
<b>Aquatic and wetland herbs</b>			
Cyperaceae	117		
<i>Typha</i> sp.	1		
<i>Nymphaea</i>	5		
<b>Total</b>	123		
<b>Freshwater algae</b>			
<i>Botryococcus</i>	1		
Zygnemataceae	1		
<b>Pteridophytes</b>			
Monoletae spores	31		
Small round spores	170		
Big round spores	50		
<i>Equisetum</i>	12		
Moss spores	32		
Pollen sum	577		
Pollen concentration (gran./g)	66429		

Tab. 1 - Pollen analysis of the San Pietro di Ragogna brown coa.

a quite detailed description of the vegetational composition, at least of a limited area close to the depositional site (as reported in chapter 4.3).

Because the pollen assemblage does not show distinctive taxa for a trustworthy biostratigraphy, the systematic discussion is provided only for fruit and seed taxa, which yield new interesting scenarios for the Italian palaeovegetation.

#### 4.2 Relevant fruit and seed taxa - systematic part

The systematics of families follows Farjon (1998), Gadek et al. (2000) and APG III (2009).

##### Family Cyperaceae - Genus *Carex* L.

*Carex* cf. *elata* All. - Plate I-2-9

The interesting 2-sided *Carex* achenes from SPR have been examined in the frame of an ongoing comprehensive work, focussed on sect. *Phacocystis* in Europe (Jimenez-Mejias, 2011). Several 2-sided achenes could be assigned to sect. *Phacocystis*, because of the diagnostic persistence of utricle remains attached at the achene's base (Plate I-8), the non-jointed style (unfortunately always incomplete) and the frequent occurrence of a thin basal callus (Plate I-9). The extensive examination of modern material of all the European species permitted to restrict the field of affinity to a single species: *Carex elata* All. (Plate I-1). However, the determi-

TAXON NAME	sample B9A	sample C0F
<i>Acer</i> sect. <i>Platanioidea</i>		9
<i>Acer</i> cf. <i>campestre</i> L.		3
<i>Acer</i> gr. <i>opalus</i> L.	1	
<i>Alnus</i> cf. <i>glutinosa</i> Mill.		1
<i>Betula</i> sp.	1	
Brassicaceae indet.		1
<i>Carex</i> cf. <i>elata</i> All.	21	25
<i>Carex</i> cf. <i>rostrata-pliocenica</i> P. Nikitin		1
<i>Carex</i> sp.	1	2
<i>Carpinus betulus</i> L.		19
Characeae		10 ca
cf. <i>Crataegus</i>	3	1
<i>Eleocharis microstylosa</i> Mai et Walther	2	4
<i>Hypericum teriaerum</i> P. Nikitin		11
cf. <i>Linum</i>		1
<i>Menyanthes trifoliata</i> L.		115
Musci		10 ca
<i>Myriophyllum praespicatum</i> P. Nikitin	8	4
<i>Najas major-pliocenica</i> Dorofeev ex Velichkevich	29	70
<i>Niphar</i> aff. <i>lutea</i> (L.) Sibth. et Sm.	7	162
<i>Nymphaea borysihemica</i> Dorofeev	7	29
<i>Phragmites</i> -type stems	1	2
Pinaceae	2	5
<i>Pinus peuce</i> Griseb.		1
<i>Potamogeton natans</i> L.		8
<i>Potamogeton</i> cf. <i>panormitanoides</i> Dorofeev	1	
<i>Potamogeton</i> (indeterminable)		13
<i>Schoenoplectus</i> cf. <i>lacustris</i> Velichkevich et Zastawniak		1
<i>Scirpus sylvaticus</i> L.	1	4
<i>Tilia tuberculata</i> Szafer		1
<i>Trapa</i> sp.		1
<i>Typha</i> sp.	3	5
<i>Vitis</i> sp.	1	

Tab. 2 - Abundance of the fruit and seed taxa identified in the two sediment samples from San Pietro di Ragogna.

nation is left in open nomenclature because it is not yet clear if, before the Pleistocene, the modern *Carex elata* All. did already exist. In fact such species has proved to be of recent hybridogenous origin, and its ancestors are still not well known (Jimenez-Mejias, 2011). So, it is still to be better investigated if fruits of this type, in the Gelasian-Calabrian fossil record, testify for the occurrence of *C. elata* or an unknown ancestor.

**Distribution:** The European fossil record of *C. elata* has to be revised on the basis of the new assessment of diagnostic fruit characters (Jimenez-Mejias, 2011). However, the revision of the abundant Italian material of the CENOFITA collection (Martinetto & Vassio, 2010) suggests that *C. elata* or *Carex* cf. *elata* are not documented in the Piacenzian or earlier. The first occurrence of fruits of *Carex* cf. *elata*, with abundant and well preserved material, is recorded in a succession which is tentatively assigned to the Gelasian (Castelletto Cervo II-Buronzo: Martinetto, 2001; Zanni & Ravazzi, 2007). Fossil fruits of *C. elata* are also reliably documented within Middle Pleistocene interglacials (Mai, 2010).

*Eleocharis microstylosa* Mai - Plate I-10-13

The very small, slender fruits with small tubercle and longitudinally elongated cells correspond in shape, dimensions and structure of the tubercle to the specimens of *E. microstylosa* Mai described by Mai & Walther (1988). The very similar fruits of *E. praemaximoviczii* Dorofeev are distinguished by larger mean dimensions, broader fruits, and more apparent tubercle (Velichkevich & Zastawniak, 2003). Among the species living today in

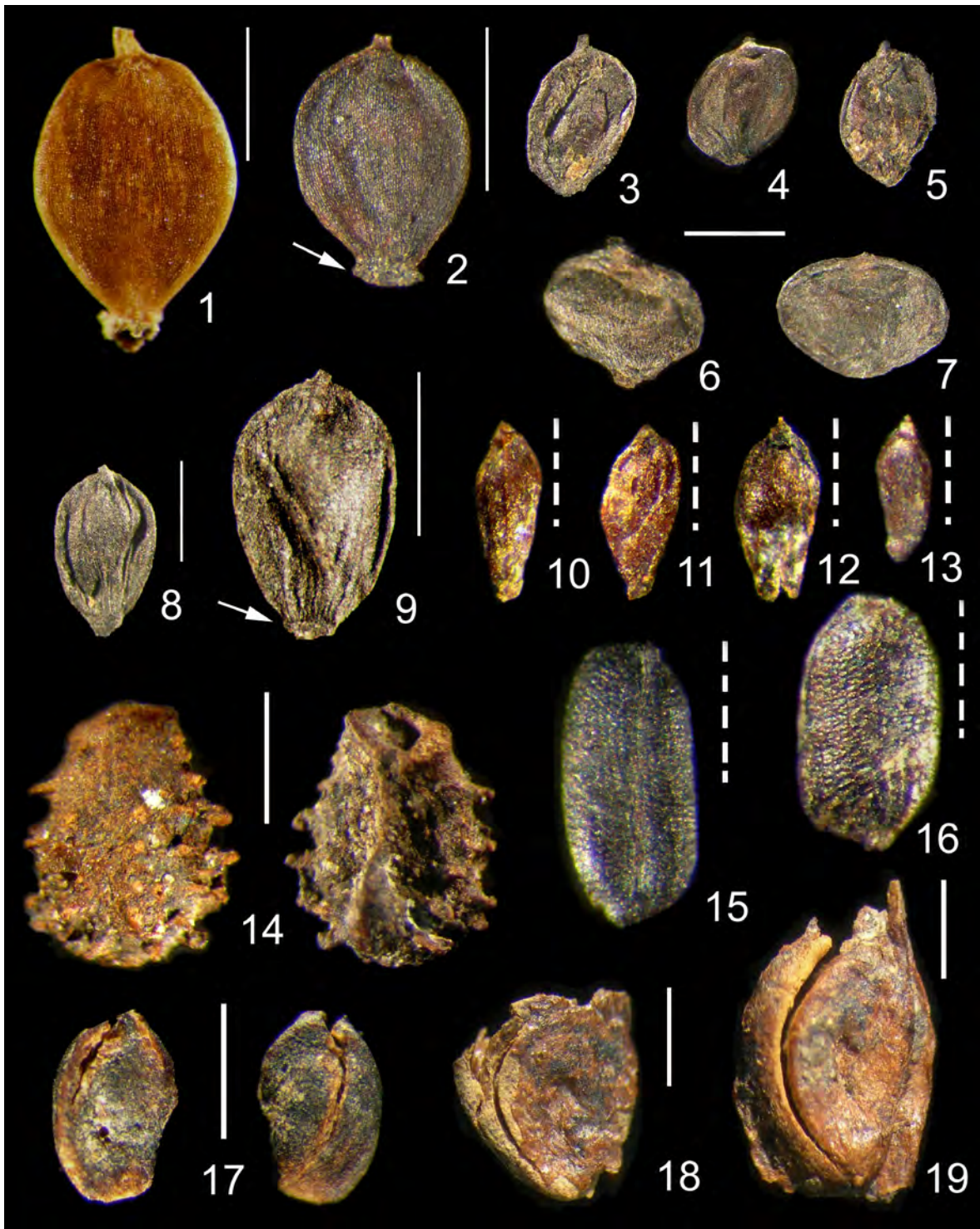


Plate I - Stereomicroscope micrographs of selected fossil fruits and seeds from San Pietro di Ragogna (continuous magnification bar = 1 mm; dashed bar = 0.5 mm): 1 - *Carex* cf. *elata* All.; modern achene from San Carlo Canavese, for comparison with the fossil specimens; 2-9 - *Carex* cf. *elata* All.; 2 - undeformed achene with apparent longitudinal rows of small cells and distinct remains of utricule tissues at the base (arrow); 3-8 - achenes, variously deformed by diagenetic compression; 7 - achene diagenetically shortened against the long axis; 8, 9 - laterally compressed achene with small, but distinct, callus (arrow); 10-13 - *Eleocharis microstylosa* Mai; 10 - achene with a distinct longitudinal ridge, clue to a 3-sided section; 11 - achene with rows of longitudinally elongated cells; 12 - the largest recovered achene; 13 - small achene with clear tubercle; 14 - *Myriophyllum praespicatum* P. Nikitin, endocarp in dorsal and ventral view; 15, 16 - *Hypericum tertiaeerum* P. Nikitin; 15, seed showing the raised raphe running from base to apex; 16, seed with apparent rows of transversally elongated, and slightly oblique, cells; 17 - *Potamogeton* cf. *panormitanoides* Dorofeev, endocarp from both sides; 18, 19 - *Potamogeton natans* L., fruits in lateral view, with apparent remains of the lustrous exocarp covering the endocarp.

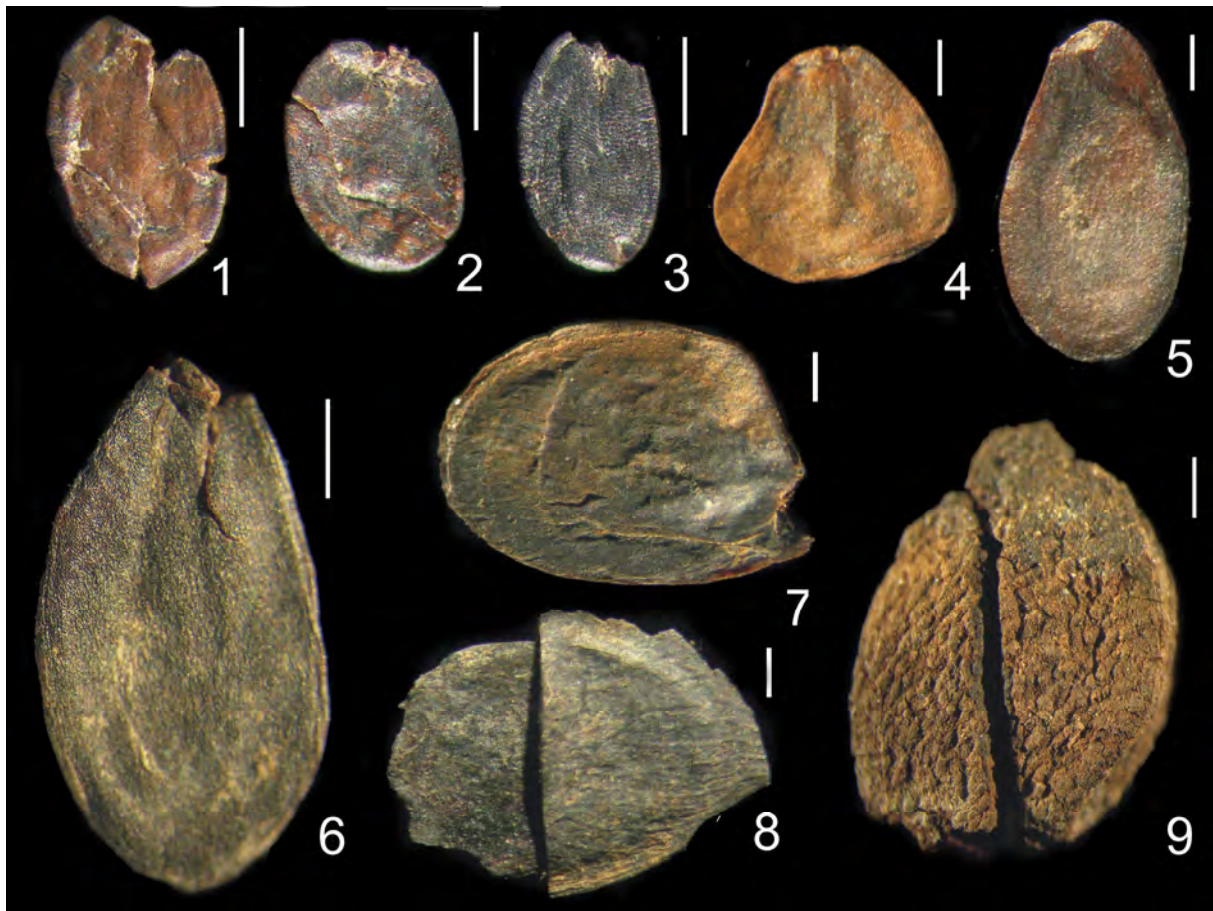


Plate II - Stereomicroscope micrographs of selected fossil fruits and seeds from San Pietro di Ragogna (magnification bar = 1 mm): 1-3 - *Nymphaea borysthenica* Dorofeev; compressed seeds with variable sculpture; 4-6 - *Nuphar* aff. *lutea* (L.) Sibth. et Sm.; 4 - longitudinally compressed seeds; 5 - laterally compressed seed, probably preserving the original longitudinal outline; 6 - another laterally compressed seed showing the typical finely foveolate ornamentation; 7, 8 - *Acer* sect. *Platanoidea*: 7 - endocarp in lateral view; 12 - fruit with wing remains to the right and the left half removed to show the seed inside; 9 - *Tilia tuberculata* Szafer, compressed and incomplete fruit showing the typical tuberculate sculpture.

Italy (Ercole et al. in press), they are partly similar to those of *E. carniolica* and even more to *E. pellucida* (Verloove, 2010), an East Asian species recently introduced in Italy, from which the fossils can be distinguished for the narrower fruit and the smaller tubercle. One of the fossils has a 3-sided section, as frequently occurring in *E. pellucida* (never in *E. carniolica*).

**Distribution:** Mai & Walther (1988) reported this species from the localities Kroszcienko (Zanclean, Poland) and Öbel (Piacenzian, NW Germany), Mizerna II/III (Gelasian, Poland) and Tegelen (Gelasian, The Netherlands); first occurrence in Italy.

#### Family Haloragaceae

*Myriophyllum praesplicatum* P. Nikitin - Plate I-14

The fruits are rather similar to those of the modern *M. spicatum*, but they are particularly short and broad, and have several large tubercles on the dorsal face, a feature that is indicated by Velichkevich & Zastawniak (2003) as characteristic of the type specimens of *M. praesplicatum* from the locality Krivobor'e, together with the chalaza situated above the base. Endocarps of modern *M. spicatum* are always more slender and have

fewer and less distinct tubercles. *M. praesplicatum* also has definitely more distinct surface cells. The endocarps of another morphospecies, *M. pseudospicatum* Dorofeev are smaller, with smaller and blunt tubercles (Velichkevich & Zastawniak, 2003).

**Distribution:** Mai & Walther (1988) reported this species from the Miocene of western Siberia and the Neogene of Europe, where possibly the youngest occurrence is the Gelasian of Kholmech (Velichkevich & Zastawniak, 2007). First occurrence in Italy.

#### Family Hypericaceae

*Hypericum tertiarum* P. Nikitin - Plate I-15, 16; Fig. 5a

The several seeds of *Hypericum* recovered at SPR show a relatively high variability (Fig. 5a,b), but most of them (Fig. 5a) agree in all characters with those of *H. tertiarum*, described with good detail by Velichkevich & Zastawniak (2003), who stated they their specimens correspond to those of the type locality Krivobor'e as for dimensions (0.7-1.0 x 0.45-0.6 mm), shape and testa sculpture. Nikitin (2006) clearly showed the differences between *H. tertiarum* P. Nikitin and *H. septestum* P. Nikitin ex V. P. Nikitin.

**Distribution:** Velichkevich & Zastawniak (2003) reported Miocene records from Germany to Siberia, and more frequent Pliocene ones from central Russia to Germany. Our overview of the CENOFITA collection (Martinetto & Vassio, 2010) permitted to summarize the occurrences in Italy: typical seeds of *H. tertiaerum* occur rarely in Zanclean assemblages, and frequently in Piacenzian ones; they still occur also in the uppermost part of the Cervo River section in Piedmont, interpreted as Gelasian (Martinetto, 2001). As for the occurrences in

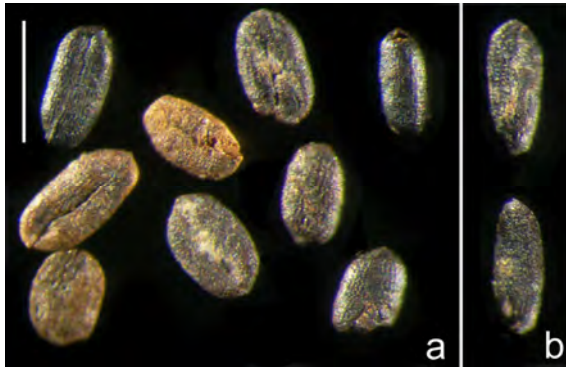


Fig. 5 - Population of fossil seeds of *Hypericum* from San Pietro di Ragogna; a) specimens with the characters typical for *Hypericum tertiaerum* P. Nikitin; b) two narrower seeds (Magnification bar = 1 mm).

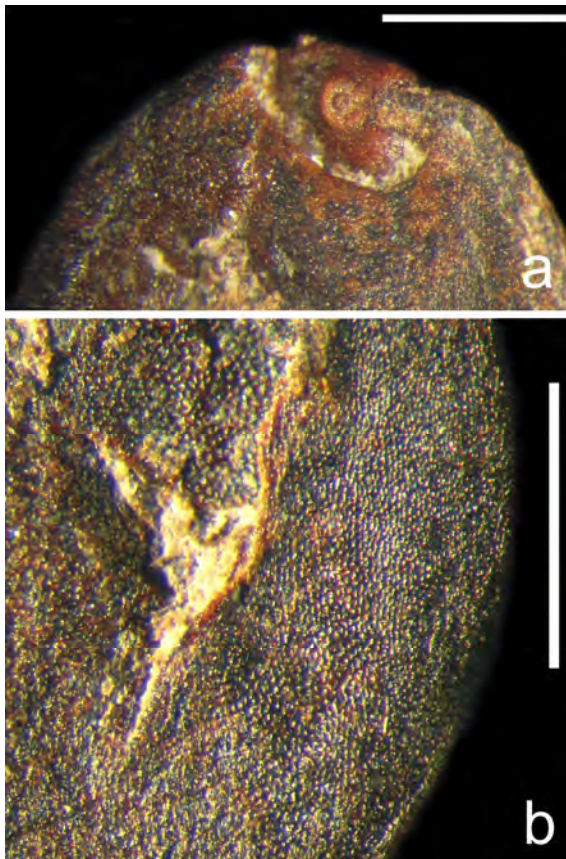


Fig. 6 - *Nuphar* aff. *lutea* (L.) Sibth. et Sm., fossil seeds from San Pietro di Ragogna; a) detail of the operculum of a seed; b) detail of the cell structure of another seed (Magnification bar = 1 mm).

the Calabrian, there is no unequivocal record, a similar form of *Hypericum* seeds was only found by R. Pini & R. Ravazzi in a locality of the Lefte Basin (Ravazzi & Rosignol-Strick, 1995); this material should be better investigated because its characters also agree with those of the younger species *H. pleistocenicum*, whose seed coat is as thick as that of *H. tertiaerum*, but with distinctly narrower cells (Velichkevich & Zastawniak, 2009). Definitely different *Hypericum* forms occur in the neighbouring Lower Pleistocene site of Steggio (Ghiotto, 2010) and in the Middle Pleistocene sites (Vassio, 2012).

#### Family Malvaceae

##### *Tilia tuberculata* Szafer- Plate II-9

A single, fragmentary and much compressed fruit is assigned to this species on the ground of the typical ornamentation, compared to that of specimens from the relatively neighbouring locality of Steggio (Ghiotto, 2010). Other characters which are still visible are 3 of the 5 original ridges (the others cancelled by compression), the attenuate apical part and the unevenness of the internal structure, also including a spongy tissue as typical for fossil fruits of *Tilia*.

**Distribution:** Mai & Walther (1988) and Ghiotto (2010) reported this species from the "Upper" Pliocene of Germany and Russia, and in the Lower Pleistocene localities Schweinheim (Germany) and Steggio (Italy: here interpreted as Calabrian, less probably Gelasian: Ciangherotti et al., 2007).

#### Family Nymphaeaceae

##### *Nuphar* aff. *lutea* (L.) Sibthorp et Smith - Plate II-4-6; Fig. 6

The very abundant seeds of *Nuphar* found in both samples agree very well in shape, dimensions, operculum structure (Fig. 6a) and ornamentation (finely foveolate: Fig. 6b) with those of the living *Nuphar lutea* (L.) Sibth. et Sm. However, the comparison with fossil seeds from Middle-Late Pleistocene localities (Bucine, Valeriano Creek: Vassio, 2012), reliably referable to *N. lutea*, showed that they have the same shape and operculum structure, but differ for the larger cells, thus raising doubts on the precise specific identification. In addition, Dorofeev (1974) described, on the basis of fossil seeds from Russia and Siberia, several species (e.g., *N. tanaitica* Dorofeev) particularly difficult to differentiate from *N. lutea*.

Our revision of the CENOFITA collection (Martinetto & Vassio, 2010) permitted to conclude that a distinct species, with more rounded shape, different operculum, and smaller cells with thicker walls (*N. canaliculata* C et E.M. Reid) occurs in several Pliocene localities of Italy.

**Distribution:** Mai & Walther (1988) and Velichkevich & Zastawniak (2003) reported an Upper Miocene record of *N. lutea* from Poland. This same species is also reported for the Mio-Pliocene of Alsace (Geissert et al., 1990), and more frequently in Pliocene floras from central Russia to Germany. In Italy *N. canaliculata* occurs widely in the Zanclean and Piacenzian, whereas *Nuphar* aff. *lutea* seem to appear at first at SPR, and the fossil record is still too fragmentary to assess the relationship between this form and the typical *N. lutea* found in Middle-Late Pleistocene localities. A further detailed





Fig. 7 - *Nymphaea borysthenica* Dorofeev - fossil seed from San Pietro di Ragona, with apparent rows of transversally elongated cells (Magnification bar = 1 mm).

investigation of *Nuphar* fossil seeds is desirable, and comparison with analogous material throughout Europe may yield interesting biochronological results.

*Nymphaea borysthenica* Dorofeev - Plate II-1-3; Fig. 7

The dimensions, consistence, sculpture (Fig. 7) and cell shape of the SPR material completely agree with those of seeds of *N. borysthenica* from the type locality Kholmec (Velichkevich & Zastawniak, 2003). The hardly distinguishable *N. pilosella* is described by Nikitin (2006). The seeds of all modern Eurasian species differ for the shape of the testa cells.

**Distribution:** *N. borysthenica* has been known hitherto from the Gelasian (Velichkevich & Zastawniak, 2007) locality of Kholmec and from central Russia (Velichkevich & Zastawniak, 2003). This is the first occurrence in Italy.

#### 4.3 Vegetation analysis

The most frequent diaspores represent typical aquatic plants of standing - or slowly flowing - water (*Najas major-pliocenica*, *Nuphar* aff. *lutea*), but some wetland plants (helophytes, such as *Carex* and *Menyanthes*) are also not rare. As a whole, these freshwater macrophytes permit to accurately characterise the ancient autochthonous vegetation of the basin, where deposition took place. The mesic plants are represented by a few taxa which produce wind- or animal- transported fruits (*Acer* spp., *Carpinus betulus*, *Pinus peuce*, *Tilia tuberculata*, *Vitis* sp.). These provide a very partial picture of the ancient mesic vegetation once growing around the depositional basin, that can be improved by the comparison with the palynological record.

Two different 2D Plant Community Scenarios (PCSs) for pollen and macrofossils have been built up by subdividing the environmental transect in three zones according to the ecological characteristics of the taxa. The frequency data of every taxon have been propor-

tionally reported into the PCSs, according to the approach introduced by Martinetto & Vassio (2010), as to represent 50 plant symbols and 25 taxa names. The two PCSs put forth the different qualitative and quantitative (and complementary) information provided by the two records: a *Pinus*-dominated mesic sector and a Cyperaceae/Taxodiaceae-dominated hygrophilous sector for the pollen-PCS (Fig. 8a), and a freshwater macrophyte-dominated aquatic sector in the carpological-PCS (Fig. 8b). The huge percentage of conifers (*Pinus* and *Picea*) within the pollen record is not surprising, as well as *Betula* and *Artemisia* occurrence. Usually they represent taxa growing at a certain distance (and possibly at higher altitude, in similar contexts) from the deposition site, which may reach significant percentages in the Southalpine area, even in warm-temperate phases (e.g., Pini et al., 2010). *Tilia* and *Alnus* are detected within both records, but in very low percentages, hence a limited presence can be hypothesized, as well as for *Carpinus* and *Acer* (absent in the pollen assemblage). *Quercus* and *Corylus* pollen grains, allow to increase the knowledge about mesic woody taxa occurring in the San Pietro di Ragona palaeoflora (in addition to few grains of *Ulmus*, *Fraxinus*, *Carya* and Juglandaceae); the lack of their diaspore may be explained either by their large size, decay-prone structure or the sedimentary context. An interesting difference, deals with the Taxodiaceae, detected within the palynological association but completely absent in the carpological assemblage: this can not be explained only by the characteristics of their seeds (small, wind-dispersed and decay-resistant). Therefore, Taxodiaceae should have grown outside the deposition area.

## 5. DISCUSSION

### 5.1 Vegetation reconstruction

The palaeobotanical record of San Pietro di Ragona can be interpreted from the dissimilar results of the PCS structure for pollen and macrofossils, which are conditioned by well-known taphonomical biases; macroremains usually reflect local plant communities better than other records, also from a quantitative point of view (Watts & Winter, 1966; Burrows, 1980; Collinson, 1983; Thomasson, 1991; Sims & Cassara, 2009; Vassio, 2012). Pollen assemblages provide a better record of the regional vegetation, yet with relevant biases. In the SPR sample, the high pollen percentage of *Pinus*, reflected by the dominance of this plant in the PCS, is probably affected by overrepresentation, due to high pollen production and/or lakeshore concentration. However, excluding other taphonomical factors such as distal sedimentation, the abundance of *Pinus* pollen may also be ascribed to the widespread occurrence of this plant in the carbonate Prealpine relief of the surrounding area. For sound interpretation of the mesic palaeovegetation, we therefore take into account the presence of several broad-leaved trees (e.g., *Betula*, *Carya*, *Quercus*, *Tilia*, *Ulmus*), which should be considered more relevant in the palaeovegetation than indicated by the relatively low pollen percentages. The PCS structure for the carpoflora shows a poor contribution from this mesic vegetation to the fruit and seed assemblage (e.g., *Acer*, *Carpinus*, *Pinus*, *Tilia*), as fre-

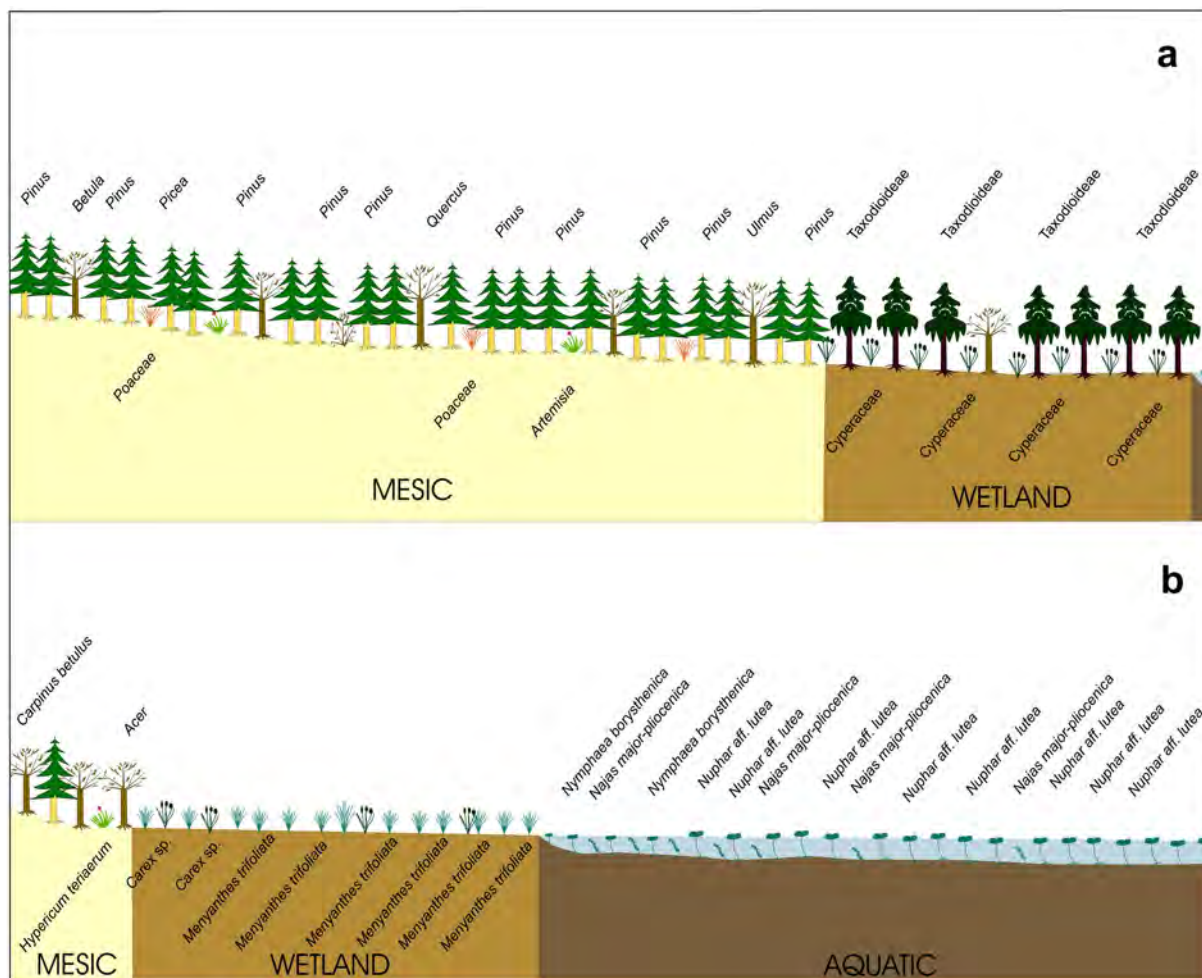


Fig. 8 - Plant Community Scenario diagrams provided by a) pollen and b) carpological records from San Pietro di Ragogna. Notice that the PCSs do not represent actual reconstructions of the paleoenvironment and palaeovegetation, rather they are simply a graphical representation of quantitative data. Each typology of plant symbol is referred to a group of taxa that shares habitus and ecological features (Martinetto & Vassio, 2010; Vassio, 2012). Fifty plant symbols (and 25 taxa names, among the most frequent) have been reported into the diagram by taking into account their ecological requirement; their proportions reflect the frequencies of taxa belonging to these groups (growth forms) within the fossil assemblages.

quently occurring in lacustrine environments (Birks, 1973; Collinson, 1983; Dieffenbacher-Krall & Halteman, 2000).

The wetland vegetation is more consistently represented in both PCSs, but even in this case the macrofossil record lacks the important Taxodioidae contribution, which could even be interpreted as a pollen influx coming from outside the sedimentary basin, possibly from a nearby coastal environment. On the other hand, the herbaceous component shows a consistent agreement between the two PCSs suggesting a rather extended sedge belt, possibly hosting relevant patches of *Menyanthes*, based on the frequency of seeds.

The predominance of freshwater macrophytes requiring more than 1 meter of water depth (*Nuphar*, *Nymphaea*, *Najas*) would suggest an open standing-water environment. Furthermore, actupalaeobotanical studies on modern lakes (Dieffenbacher-Krall & Halteman, 2000) detected seed assemblages with concomitant high frequencies of *Carex* and *Najas* diaspores in 0.5-1.5 m deep bottoms.

## 5.2 Biochronological and biogeographical signals

The San Pietro di Ragogna brown coal represents a spot on the knowledge of the vegetation in the south-eastern Alps, before the expansion of the Tagliamento glacier piedmont lobe during the middle Pleistocene cold phases (Monegato et al., 2010). The chronological attribution of the coal deposit was not precisely assessed from a stratigraphical point of view, because of its position at the base of a coarse-grained unit, the San Pietro di Ragogna Conglomerate (Zanferrari et al., 2008), which is bounded by angular unconformities between the Messinian Montello Conglomerate (Zanferrari et al., 2008) and the middle Pleistocene alluvial units of the Arzino alluvial fan (Paiero & Monegato, 2003). So, the dating of the SPR brown coal could encompass the Pliocene-middle Pleistocene time span.

The pollen assemblage (Tab. 1) reduces the possible chronological attribution, excluding a Pliocene age because of the lack of some thermophilous taxa, usually associated to the Taxodioidae (such as *Engelhardia*, *Itea*, *Myrica*, *Nyssa*, *Symplocos*, etc.), that experienced

a significant reduction at the end of Pliocene (Bertini, 2010). Nevertheless, the SPR assemblage contains a high percentage of Taxodioidae, which are described in Northern Italy till the Early Calabrian (Bertini, 2010 and references therein), whereas the rest of the taxa of the SPR record are present in the middle Pleistocene (*Carya*) or in the late Pleistocene. The models of Early Pleistocene climatic/vegetation cycles in Italy (e.g., Combourieu-Nebout, 1993; Bertini, 2001; Leroy, 2007) suggest that the SPR spectrum (Fig. 4) could be included within an interglacial period, possibly within a "Deciduous forest" phase (Bertini, 2001), even if a single spectrum may be unreliable for a firm attribution.

The macrofossil assemblage of SPR documents a set of freshwater macrophyte genera with relevant similarity to the ones of modern north Italian lakes. Also the living species *Menyanthes trifoliata* and *Potamogeton natans* are firmly documented by the carpological record. Nevertheless, the detailed morphological analysis of fossils fruits and seeds of the SPR site allows to recognize precise morphospecies (*Eleocharis microstylosa*, *Hypericum tertiaeum*, *Myriophyllum praespicum*, *Najas major-pliocenica*, *Nymphaea borysthenica*), reported only in Pliocene and early Pleistocene localities of Eastern Europe (Velichkevich & Zastawniak, 2003, 2006).

In the Italian context, the SPR palaeoflora shows a characteristic association between taxa of Miocene origin (*Hypericum tertiaeum*, *Myriophyllum praespicum*) and "younger" ones (*Carex cf. elata*, *Menyanthes trifoliata*, *Nuphar aff. lutea*), which appear in the Italian floras after the Piacenzian/Gelasian boundary. This characteristic association would restrict the chronostratigraphical bracket of the SPR site to the Gelasian. A hypothetical Piacenzian age is much unlikely due to the occurrence of *Carex cf. elata* (see above); conversely, the rejection of a possible Calabrian age relies on the Gelasian extinction of *Eleocharis microstylosa*, *Hypericum tertiaeum*, *Myriophyllum praespicum* and *Nymphaea borysthenica*, which should actually be better documented. In fact it has been proved that, in the Pliocene, several species disappear later in Italy than in central Europe (Martinetto, 2001).

Partial support to the Gelasian age is provided by the recovery of a very similar palaeofloral association in the "Trapa layer" flora of Buronzo, also interpreted as Gelasian (Martinetto, 2001). In the Calabrian comparable assemblages of freshwater macrophytes have been found in the Pietrafitta site (Fusco, 2007; Martinetto, unpublished data), but despite of the occurrence of the same genera, the species are distinct. In the late Pleistocene neighbouring site of Valeriano Creek (Monegato et al., 2010; Vassio, 2012) the genera *Nuphar* and *Nymphaea* are already represented by the species which grow nowadays in this area, respectively *N. lutea* and *N. alba*.

The presence in the SPR assemblage of *Hypericum tertiaeum*, *Myriophyllum praespicum*, *Najas major-pliocenica*, *Nymphaea borysthenica*, *Potamogeton cf. panormitanoides*, *Schoenoplectus cf. lacustroides* points to a singular east-European affinity. For this reason, the SPR assemblage, even if relatively species-poor, assumes a peculiar character in the framework of the several carpological assemblages known in northern and central Italy (Martinetto, 1999; Martinetto & Vassio, 2010). The geographic position of the site in the Vene-

tian-Friulian plain played an important role, because it was confined in the northeastern margin of the Adriatic Gulf, isolated from the Po Plain (Massari et al., 2004; Muttoni et al., 2010), but close to the low elevated relieves at the Alps-Dinarides junction. Due to such a location the site was under the major influence of the palaeofloral changes occurred during the Plio-Pleistocene transition, when the migration of plant taxa from Eastern Europe may have reached only the easternmost part of Northern Italy.

## 6. CONCLUSION

The San Pietro di Ragogna record, in spite of its limited chronological extension and its position far from other sites with carpological documentation, represents an important site for the occurrence of a peculiar palaeobotanical assemblage, characterised mainly by *Hypericum tertiaeum*, *Myriophyllum praespicum*, *Najas major-pliocenica*, *Nymphaea borysthenica*, *Potamogeton cf. panormitanoides*, *Schoenoplectus cf. lacustroides*, which points out definite affinities with the Gelasian flora of Kholmeh (Belarus). Most of these species have been recorded for the first time in Italy, despite the rich macropalaeobotanical documentation available.

On the basis of the known chronological distribution of the foregoing taxa, and the occurrence of "younger" ones (*Carex cf. elata*, *Menyanthes trifoliata*, *Nuphar aff. lutea*), which appear in the Italian floras after the Piacenzian/Gelasian boundary, we recognise a characteristic association that points to a Gelasian age, possibly during a deciduous forest phase.

The concomitant high frequency of diaspores of *Carex* and *Najas* suggests that the deposition of the San Pietro di Ragogna brown coal took place on a lacustrine bottom at a depth ranging from 0.5 to 1.5 meters, as suggested by studies on modern lake bottoms. This ancient lake was occupied by a diverse community of freshwater macrophytes, passing to a distinct sedge belt in the marginal area. Due to the lack of macrofossils of Taxodioidae, that are abundant in the pollen record, we conclude that these plants should have grown outside the basin, possibly in the neighbouring coastal area.

Finally, the mesic vegetation in the surrounding plain and the prealpine relief is reconstructed as a temperate broad-leaved mixed forest with *Acer*, *Betula*, *Carpinus*, *Carya*, *Pinus*, *Quercus*, *Tilia* and *Ulmus*.

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