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# First palynological results from the archaeological site of Sopot, Croatia

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## ABSTRACT

This paper presents the first results of pollen analysis at the eponymous archaeological site of Sopot. Cultural layers have been examined for the presence of pollen grains and spores as well as the other palynomorphs. The palynological analysis of the cultural layer provides significant data on the presence of phytopathogens that had an influence on the Neolithic agriculture.

**Keywords:** Palynology, Neolithic, Sopot culture, Croatia

## 1. INTRODUCTION

### 1.1. General background

The arrival of food-producing economies in the Neolithic started the transformation of the natural landscape into the cultural landscapes we see today (LECHTERBECK et al., 2014). The study of past human activities and their environmental effect is high on the agenda of global change research. A record of pollen assemblages is one of the most common proxies employed for detecting the impact of human activities on the landscape. However, it is often difficult to detect and quantify human activities contained in palaeorecords due to their uncertainty and complexity. Since the 1980s, with the publication of several influential monographs by DIMBLEBY (1985), BEHRE (1986) and BIRKS et al. (1988), there has been increasing interest in the pollen records related to human activities.

Though pollen is universally considered one of the best tools for environmental reconstructions and high resolution climatic inferences (e.g. FAEGRI & IVERSEN, 1989; ROBERTS et al., 2011, MERCURI et al., 2012), the palynology of archaeological sites has peculiarities which could make plant landscape reconstructions difficult to obtain. Human disturbance, poor pollen preservation and consequent low pollen concentrations are the most common reasons for the difficulties encountered when dealing with environmental reconstructions in archaeological contexts (DIMBLEBY, 1985; HOROWITZ, 1992).

### 1.2. Location, physical environment and vegetation

This paper presents the first results of research drilling for pollen analysis at the eponymous archaeological site of Sopot. Drilling was conducted in 2010 to provide an overview of the spatial relationship of the „tell" with the immediate surroundings and preliminary data on the geological and cultural layering of Sopot.

The archaeological site investigated in this study is located in eastern Slavonia in the vicinity of Vinkovci, Croatia (Fig.1). The Sopot – 8 core (X=5013673,1; Y= 6560667,1) contains three cultural layers, and the total length is 335 cm.

Sopot is located in the Slavonian region in eastern Croatia on the southern banks of the river Bosut. The basement of the site are the sedimentary rocks of Quaternary age, mainly loess and loess-like deposits (Fig.1).Climazonal vege-

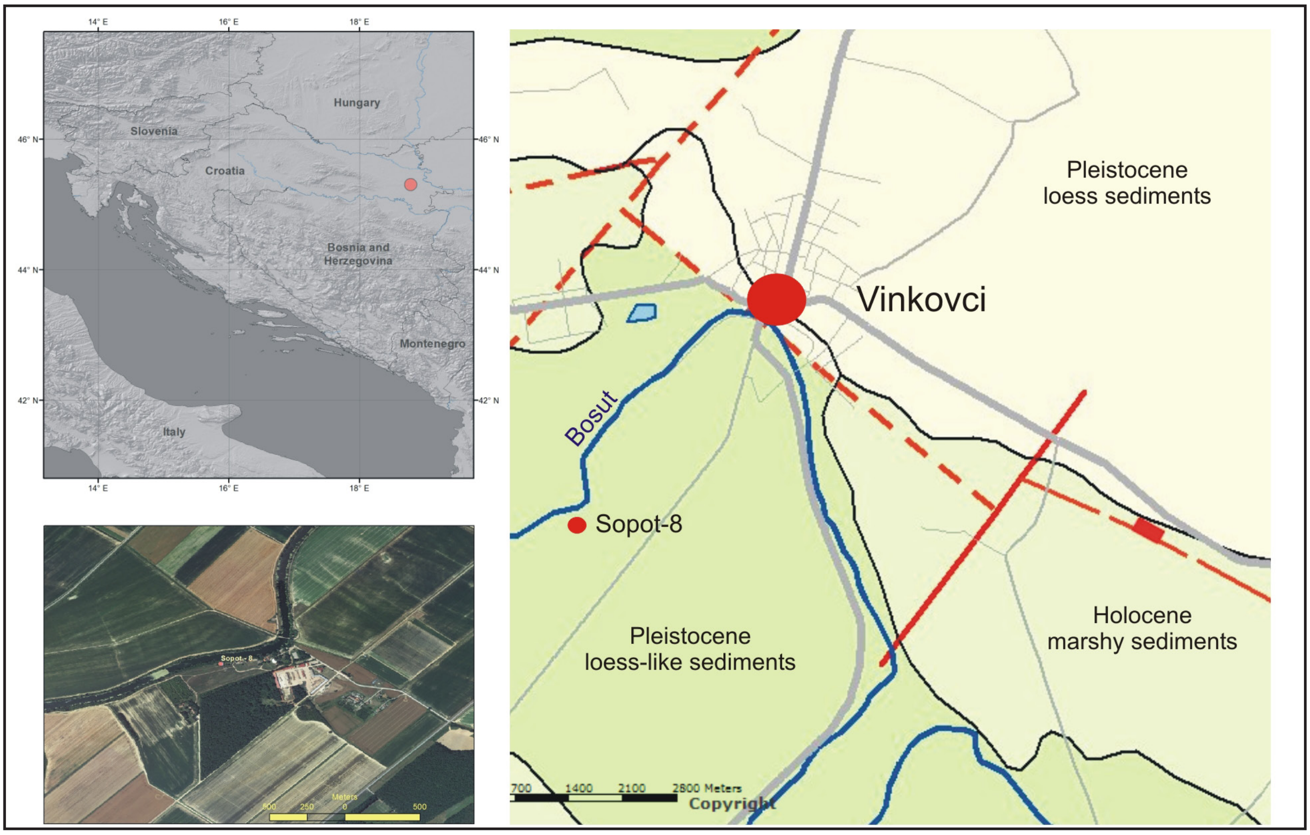


Figure 1: Location of Sopot coring site: a) Location of the study area within Croatia; b) Satellite image; c) Geological map of the Vinkovci area modified after the Geological map of Croatia M1:300.000 – Croatian Geological Survey – Department for Geology, 2009).

tation in the area of Vukovar-Srijem is composed of floodplain oak forests and mixed oak-hornbeam forests. It belongs to the European-planar vegetation belt of the Eurosiberian-Northamerican region (TRINAJSTIĆ, 1998). Today, forests cover about 28% of the area in the county, and most of the area (about 62%) is agricultural land suitable for intensive farming (arable land), and active rural and urban areas (Službeni vjesnik – Službeno glasilo Vukovarsko-srijemske županije (2006). Eastern Croatia has a moderate continental climate characterized by sunny and hot summers and cold and snowy winters. The climate in Vinkovci, which is warm and temperate, is according to Köppen and Geiger classified as Cfb. There is significant rainfall throughout the year with-average annual rainfall of 663,7 mm for the period 1971-2000. Even the driest month (February) still has a lot of rainfall (36,9 mm). The average annual temperature in Vinkovci is 11.2 °C. The warmest month of the year is July with an average temperature of 21.3 °C. The lowest average temperature is in January (0.4 °C).

### 1.3. Archaeological and historical background

Sopot, the eponymous site of the Sopot culture, is placed 3 kilometres to the southwest of Vinkovci on the right bank of the river Bosut (Fig. 1). It is a tell type structure 113 by 98 metres and about 3 metres in height.

Dating of the Sopot culture samples has so far provided three groups of dates (KRZNARIĆ ŠKRIVANKO, 2011). The oldest objects are dated at 5050 to 4550 cal. BC, the middle group at 4790 to 4360 cal. BC and the youngest objects from 4340 to 3940 cal. BC. A newly discovered Starčevo culture layer forms the fourth group of dates being dated as 6060 to 5890 cal. BC. They are also the oldest non Sopot culture dates from the site itself.

In all of the horizons the houses were built on the same places with just a slight horizontal deviation. Density in the spatial arrangement of buildings is increased towards the-centre of the settlement and it is obviously a planned structure of the settlement (KRZNARIĆ ŠKRIVANKO, 2015). The youngest horizon of houses was partially destroyed by the digging of ditches and smaller pits and holes, and the typological characteristics of the pottery found in them suggests that they belong to the eneolithicperiod (KRZNARIĆ ŠKRIVANKO & BALEN, 2006; KRZNARIĆ ŠKRIVANKO, 2011). Between 1996 to 2006, excavations at Sopot for archaeobotanical analysis revealed a comprehensive list of both domestic and wild plant species (KRZNARIĆ ŠKRIVANKO & REED, 2008). 71% of the identified plant remains were domestic cereals, including *Triticum monococcum* (emmer), *Triticum dicoccum* (einkorn) and *Hordeum vulgare* (barley). Other crops present include *Pisum sativum* (pea), *Lens* sp. (lentil), and *Linum* cf. *usitatissimum* (flax), (2% of the assemblage). Also recovered were a number of fruit (10%) and weed species (17%) including a relatively large deposit of *Physalis alkekengi* seeds in the floor of the house. Both the domestic and wild species recovered indicate that a fully integrated agricultural system was practiced at Sopot, supplemented by local wild resources.

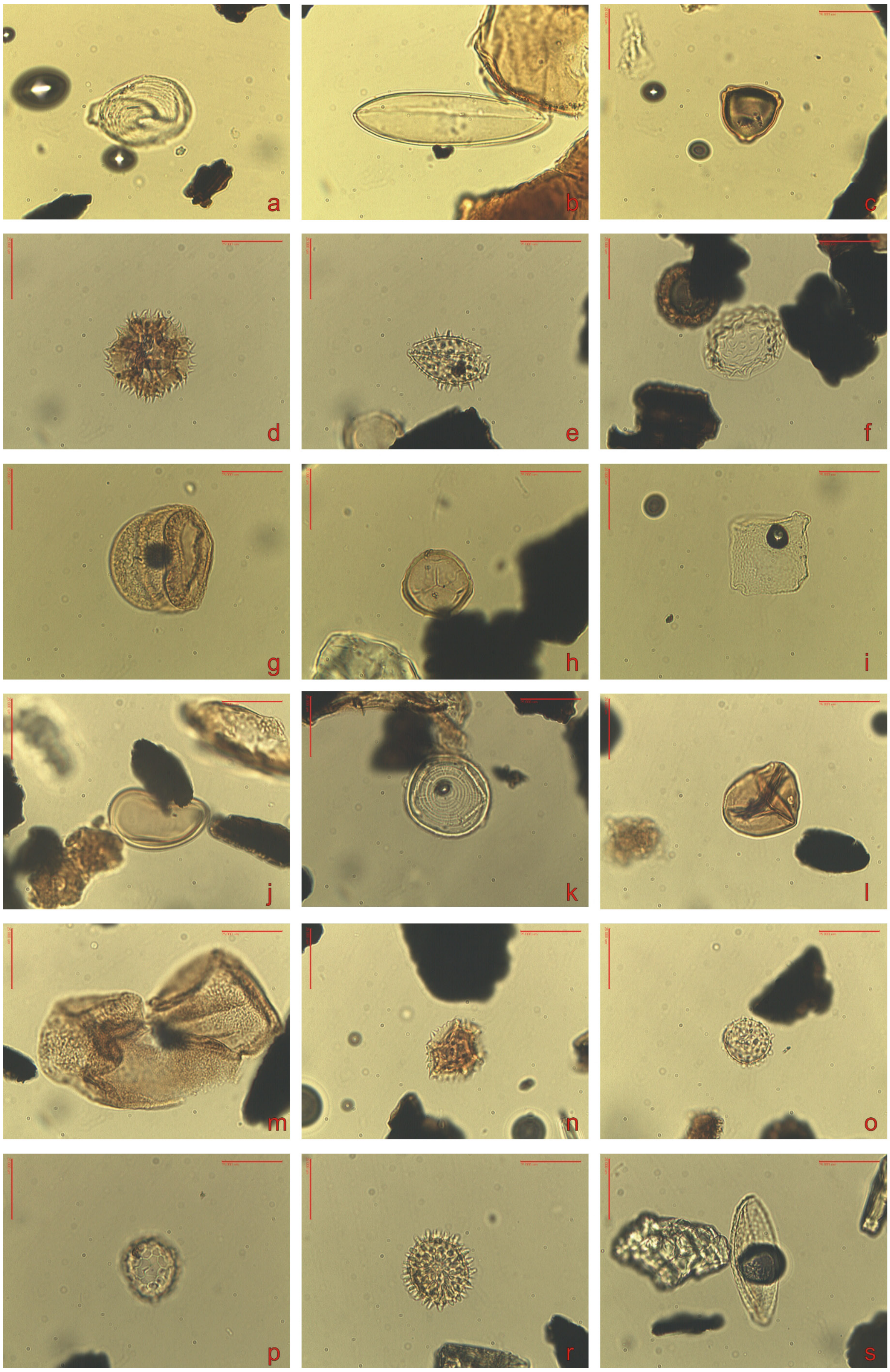


**PLATE I**

Sample 49-60 cm: a) *Chomotriletes circulus* (WOLFF, 1934) FENSOME et al., 1990, b) *Spirogyra* Type 1 van GEEL & van DER HAMMEN 1978, c) *Betula*,
Sample 70-80 cm: d) Cichoriaceae, e) *Nuphar*, f) *Zygnema*;
Sample 80-90 cm: g) Pinus, h) *Sphagnum*, i) *Mougeotia*;
Sample 100-110 cm: j) *Polypodium*, k) *Chomotriletes circulus* (WOLFF, 1934) FENSOME et al., 1990, l) Poaceae;
Sample 120-130 cm: m) *Abies*, n) Cichoriaceae, o) *Elodea*;
Sample 140-150 cm: p) *Tilletia*, r) *Nymphaea*, s) *Spirogyra* Type 3a van GEEL & van DER HAMMEN, 1978.

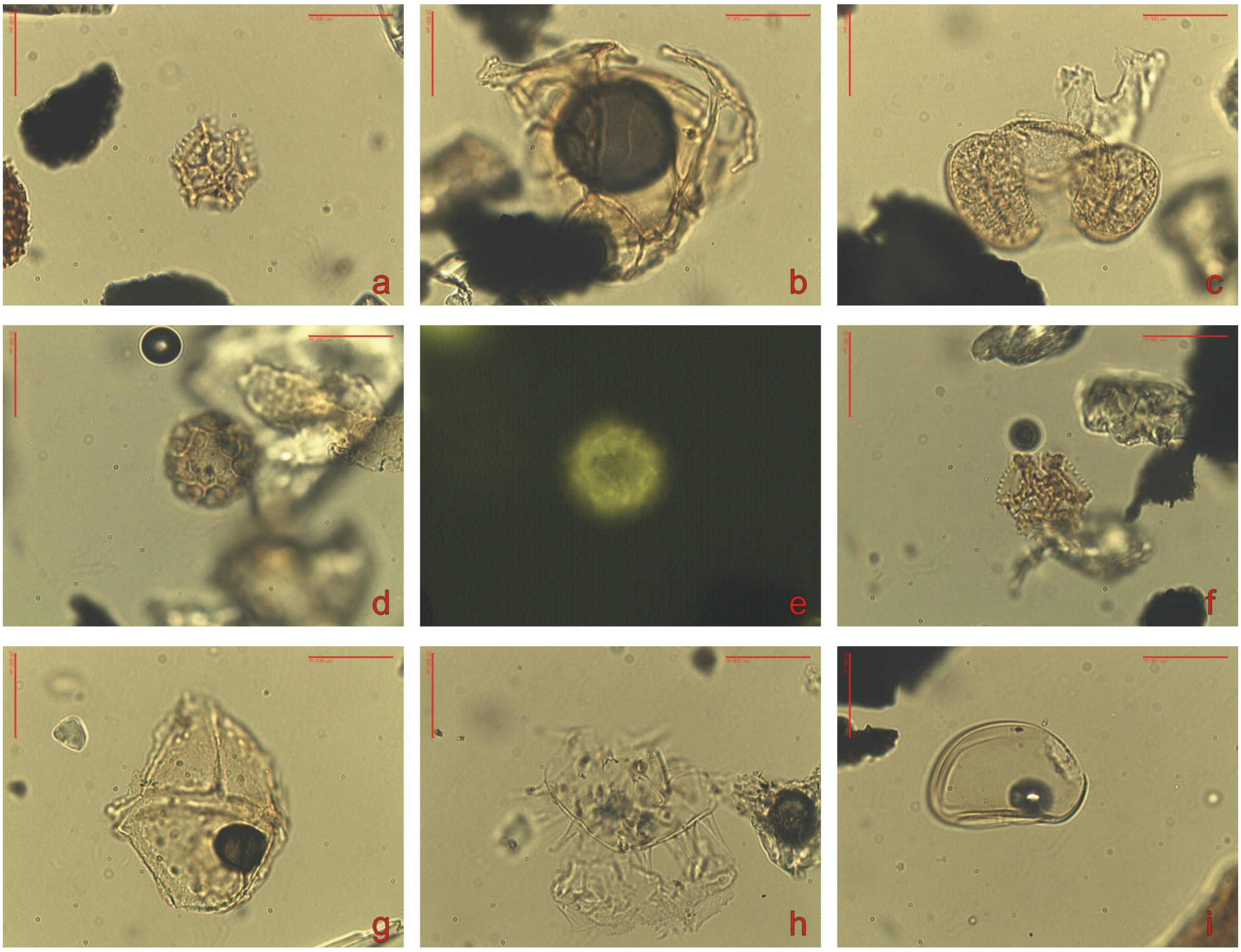


**PLATE II**

Sample 180-190 cm: a) Cichoriaceae, b) dinocyst, c) *Pinus*;
Sample 190-200 cm: d) *Tilletia*, e) *Tilletia* in fluorescence, f) Cichoriaceae;
Sample 260-270 cm: g) *Virgodiniumpelagicum* (SÜTŐNÉ SZENTAI, 1990) SÜTŐNÉ SZENTAI, 2010, h) *Lingulodinium machaerophorum* (DEFLANDRE & COOKSON, 1955) WALL, 1967, i) Polypodium.

## 2. METHODS

### 2.1. Field-work

Sites were cored using a gasoline powered percussion hammer Vibrokorer Eijkel kamp Cobra TT RD32 equipped with percussion gouges, used to take reasonably undisturbed samples from depths to about 7 metres, without the use of a drilling liquid (so samples were suitable for chemical analysis). Samples were extracted from the piston corer in the field, wrapped in cling film, aluminium foil and plastic sheeting and stored in a cold store at 4°C.

### 2.2. Pollen

For the pollen analysis, a minimum 1 $cm^3$ of the sediment was subsampled every 10 cm down the core using a metal volumetric subsampler.

Standard palynological processing techniques (FAEGRI & IVERSEN, 1989; MOORE et al., 1991) were used to extract the palynomorphs. The residues were stored and mounted in silicone oil. Slides were counted using an Olympus BH-2 transmitted light microscope at x400, x600 and x1000 (oil immersion), magnifications combined with the interference contrast. A fluorescence technique was used in order to distinguish reworked palynomorphs. Whole slides were counted for palynomorphs. The pollen concentration was too low to count 300 pollen grains per sample (< 900 pollen grains per 1 g of sediment). Photos were taken using a Moticam 2300. Identification of pollen grains was performed by comparison with the pollen reference collection of the Department of Botany and Botanical garden, Faculty of Science, University of Zagreb, and by consulting the pollen key: MOORE et al. (1991). Palynological residues and slides are stored in the collection of the Croatian Geological Survey. Pollen diagram (Fig. 2) was plotted using the software C2 Version 1.5 (JUGGINS, 2007). All terrestrial pollen and spores were included into the pollen calculation sum.

## 3. RESULTS

After a review of material from eight wells (Sopot-1 to Sopot-8) drilled in the area of the archaeological site of Sopot, borehole Sopot-8 (as the deepest borehole containing cultural layers) was selected for palynological analysis. Based on macroscopic observations 15 samples were tested for their palynology. Generally, in all the analysed samples, there is relatively little organic residue with a high proportion of opaque or semi-opaque phytoclasts – black particles with or without any visible structure belonging to the inertinite maceral group (TYSON, 1995) as well as resinite. Most palynomorphs (spores and pollen grains, fresh-water algae) show a moderate intensity while dinocysts have a low intensity of fluorescence. Pollen was found in all the samples but pollen preservation and the level of pollen identification wasn`t good. Besides crumpled pollen, many grains had a slightly reworked exine. In almost all cases pollen is identifiable at the genus level, some at the family level, and plants which have only one species in a genus are identifiable up to the species level. Unfortunately, pollen counts didn’t reach the predetermined total of 200 grains. These are still much too low for any reliable environmental interpretation.

The results of pollen analysis at Sopot-8 site are presented as a percentage pollen diagram (Fig.2). The main characteristic is a low pollen concentration (from 35 to 871 pollen grains per 1 g of sediment) and a high percentage of degraded pollen. The main taxa are *Pinus*, Cichoriaceae and *Tilletia*. In most samples there is a freshwater alga *Chomotriletes circulus* (Pl.1.a, k).

According to a visual examination of the pollen diagram (Fig. 2) it reveals at first sight, four zones corresponding to the cultural layers. The main characteristic of zone SOP-1 is a high percentage of *Pinus* (~40–80%), which increases towards the top of the zone, whereas *Tilletia* and Poaceae decrease towards the top of the zone which belong to the I. cultural layer. The main characteristic of zone SOP-2 is a high percentage of Cichoriaceae (~20–30%) and again *Tille-*

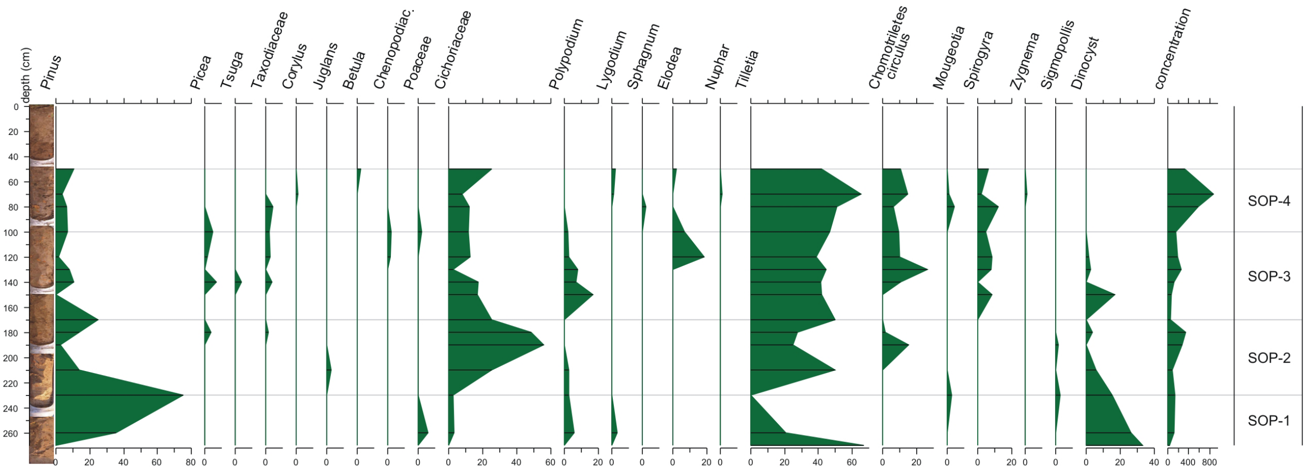


**Figure 2:** Percentage pollen diagram.

*tia*, with a marked decrease in *Pinus* towards the top of the zone. Zone SOP-3 is dominated by *Tilletia* (~40– 65%) and aquatic plants. A very similar assemblage is from the last zone SOP-4 where the previously dominant taxa *Tilletia* increase even more to ~65%.

Only a few palynomorphs exist in the oldest zone SOP-1 (290-230cm). There are teliospores of *Tilletia*, though only a small number, unlike the later cultural layers. There are pine pollen (*Pinus*), grass pollen from the family Poaceae (perhaps a wild crop, but due to poor preservation of the grain cannot be more specific) and fern spores from the family Polypodiaceae (Pl.2.i). There are also relatively numerous dinocysts: *Lingulodinium* (Pl.2.h)*, Virgodinium* (Pl.2.g) and *Spiniferites*, largely mechanically damaged, from the Miocene era.

The second zone SOP-2 (230-170cm) reveals the dominance of the Cichoriaceae (Pl.2.a,f) pollen. In this layer, the ratio of teliospores of the *Tilletia* (Pl.2.d-e) genus is increased, as well as those of the freshwater algae *Chomotriletes circulus*. The proportion of resedimented dinocysts had decreased. At the base of the zone the most abundant pollen is pine (*Pinus*) (Pl.2.c), but its proportion reduces as the proportion of Cichoriaceae pollen increases. Fern spores are from the family Polypodiaceae.

In the third zone SOP-3 (170-100cm) the proportion of Cichoriaceae pollen (Pl.1.n) decreases, while teliospores of the genus *Tilletia* (Pl.1.p) increases. Freshwater algae (Pl.1.s) increase, while dinocysts decrease in their relative proportions. There are also pollen of aquatic plants *Elodea* (Pl.1.o)*, Nymphaea* (Pl.1.r) and spores of ferns from the family Polypodiaceae. At the end of the zone, *Tilletia* spores slightly decrease while at the same time grass pollen (Pl.1.l) increases in proportion.

In the youngest zone SOP-4 (100-50cm) the proportion of Cichoriaceae pollen (Pl.1.d) is more or less the same around 10%, grass pollen decreases, while teliospores of the genus *Tilletia* greatly increase. There is a significant proportion of freshwater algae: *Mougeotia* (Pl.1.i), *Zygnema* (Pl.1.f) and *Spirogyra* (Pl.1.b), while dinocysts completely disappear. There is also the pollen of aquatic plants and ferns from the family Polypodiaceae. Birch trees, *Betula* (Pl.1.c) and hazel, *Corylus* slightly increase in the upper part of the zone.

## 4. DISCUSSION

Relatively little organic residue with a high proportion of the opaque or semi-opaque phytoclasts indicate an oxic environment in which other organic compounds are selectively destroyed. The absolute domination of structured phytoclasts of the total organic residue of all the analysed samples indicates the pronounced fluvial input of terrestrial organic components which often breaks down into smaller opaque particles during transport. Inertinite with the fine preservation of the microstructure indicates its charcoal origin (ERCEGOVAC & KOSTIĆ, 2006). Inertinite is very abundant in stream and lacustrine deposits. It can be abundant or dominant (or common) in delta-front and prodelta, fresh water swamp, lagoon, lake and river sediments. Inertinite is generated by the alteration of wood in an oxidising environment at normal or elevated temperatures.

Mechanical damage, especially of dinocysts, is the result of redeposition. Moderate fluorescence intensity of lipid-rich palynomorphs confirms the weak oxidation of the organic component (TYSON, 1995). Phytoclasts mostly belong to the vascular tissue of gymnosperms, which together with a high proportion of the resin in the total organic residue suggest the existence of coniferous forests in the vicinity.

Gymnosperm pollen, unfortunately, has a small proportion partly due to post-degradation oxidation processes within subaerial conditions. Exine thickness and the amount of sporopolenine is important (HAVINGA, 1964, BIRKS & BIRKS, 1980, DIMBLEBY, 1985). Cichoriaceae pollen is well known for its resistance to corrosion, whereas some tree pollen types with thin exina can be very easily degraded.

Generally at the Sopot site, a reduction in the proportion of conifers and an increase in herbaceous pollen could be observed. Deforestation for agriculture and firewood could be the reason for the reduced forest content, and the increased proportion of pollen of herbaceous plants of the family Cichoriaceae and especially teliospores of *Tilletia*.

The dominance of the genus *Tilletia* teliospores is observed in all four cultural layers. Mildew as parasites occur primarily on plants from the grass family (Poaceae), and therefore represent one of the most dangerous pathogens on cultivated species from this family (wheat, barley, rye, oats, corn, etc.). Bunt is a disease caused by the fungus *Tilletia tritici* (syn. *T. caries*) and *T. laevis* (syn. *T. foetida*). The disease occurs primarily in wheat, although *T. tritici* and *T. laevis* can attack barley and rye. The rusts and smuts of cereals have afflicted us since the first Neolithic farmers planted cereals 10,000 years ago (MONEY, 2007). „Smelly“ or „hard“ blight is a disease known since the world's first granary, from Mesopotamia and Egypt (about 4000 BC), where man began to consciously grow grain as the first crops (JOHNSSON, 1990). There is also „written evidence“ from that time on the attempts of treating grain soaking in sea water. Similar research was presented by MAZURKIEWICZ-ZAPAŁOWICZ & OKUNIEWSKA-NOWACZYK (2015) for the medieval cultural layers from Poland. In the youngest layer (zone SOP-4) the proportion of *Tilletia* spores is more than 60%. Maybe disease was a possible cause of migration from the area for a while. In the meantime, the progressive succession occurs because of the lack of anthropogenic impacts on agricultural and grassland areas. It could gradually turn into broadleaved forest (*Corylus* and *Betula* as pioneer species appear).

In Europe, the replacement of woodland by farmland and pasture was marked by the decrease of tree pollen with the rise of cereal and cropland weeds pollen including *Plantago, Aster* and Graminae (BIRKS et al,, 1988). A decline in tree pollen may be due to human activities, climatic change or both. The former would be manifested by the decline of selected tree pollen in different sites of the same region; the latter would usually cause a pollen decline for many types of trees on a large spatial scale. Deforestation, hunter-gathering, cultivation and settlement were common human activities during prehistoric times. These activities led to a variety of landscapes with distinctive vegetation and hence different pollen assemblages. In temperate forests, LI YIYIN et al. (2008) distinguish five stages which can be observed: stage 1: a period of primeval vegetation growth; stage 2: deforestation for farming; stage 3: cultivation; stage 4: abandonment of the cultivated land; stage 5: restoration of primeval forest. This is not so easy to differentiate in Sopot because of the poor pollen preservation and low concentration. It is supposed that only stage 3 (cultivation) and stage 4 (abandonment of the cultivated land) could be distinguished. All four cultural layers (zones) represents stage 3 (cultivation), while stage 4 (abandonment of the cultivated land) could possibly be recognized between the cultural layers.

The occurrence of zygosporesof *Spirogyra*, *Mougeotia*, and *Zygnema*in the Quaternary deposits indicates a shallow eutrophic water body with warm pluvial periods which supplied fluvial sediments (MEDEANIC, 2006, VAN GEEL et al., 1989, WOROBIEC, 2014). In the Zygnemataceae, zygospore formation occurs mostly in the spring in clean, oxygen rich, shallow fresh water (VAN GEEL, 1976). The optimal temperature for *Zygnema* is 15–20°C, and for most species of *Spirogyra* the optimum is 14–22°C (HOSHAW, 1968). Such high temperatures are easily reached in shallow water exposed to direct solar radiation, at least during the warm season (VAN GEEL, 1978). A pH value of 7.0–8.0 was inferred from the zygospores of *Spirogyra* (GROTE, 1977).

The strong presence of Cichoriaceae pollen in the archaeological layers could be explained by two different interpretations (FLORENZANO et al., 2015): a) selective corrosion of the less resistant exines (BOTTEMA, 1975; DIMBLEBY, 1985) resulting in their overrepresentation in conservative and poor sediments, as in some layers from archaeological sites; b) the presence of pasturelands reflecting animal breeding and grazing areas (BIRKS et al., 1988, BEHRE, 1986, MERCURI et al., 2010, FLORENZANO et al., 2012) in which these pollen grains are abundant as they are linked to herbivore action and animal browsing leading to a certain selection of plants. In general, Cichoriaceae well represent the xeric environments that developed as a result of continuous human pressure, especially in the mid and late Holocene (MERCURI et al., 2010, 2012). In the Mediterranean and arid zones, and namely in archaeological sites, these pollen grains have been observed both in spectra with selective deterioration and in deposits influenced by human activities. The overrepresentation of Cichoriaceae pollen in southern Italy sites is properly linked to the presence and the practice of grazing (MERCURI et al., 2010).

The results of this study indicate that the landscape at Sopot was dynamic, with significant changes of vegetation composition and hydrology. Because of the low pollen concentration and poor preservation we can only make suppositions about the vegetation cover. Initially, the study area around Sopot was probably covered by conifer and deciduous trees and stagnant water (based on fresh-water algae). It turned into an herb-dominated environment during the cultural phases (pastures and cultivated fields). Abandoned agricultural fields probably turned into bushy vegetation, oak and hornbeam forest and eventually beech forest. At the time of deposition of the studied sediments, controlled or uncontrolled burning (based on the charcoal particles in most samples) frequently occurred, together with intensive erosion of the surrounding sediments, which confirms that at the time the climate was humid and that there were cleared areas susceptible to erosion (confirmed by resedimented palynomorphs). It is assumed that the studied area was inhabited since the time of deposition of the sediments at depths of 2.60-2.95 m. Previously determined C14 dates of the layers from archaeological material (KRZNARIĆ ŠKRIVANKO, 2011) could be correlated with the cultural layers from the Sopot-8 core. According to this the oldest cultural layer from the zone SOP-1 could be from the Starčevo culture dated as 6060 to 5890 cal. BC,while the cultural layer from zone SOP-2 could be from the oldest Sopot culture dated as 5050 to 4550 cal. BC, cultural layer from zone SOP-3 could be from 4790 to 4360 cal. BC and the cultural layer from zone SOP-4 could be from 4340 to 3940 cal. BC.

Palynological research in Slovenia suggests that human impact on the Neolithic landscape was in the form of small-scale forest clearance, burning and coppicing, whereas major landscape-scale forest clearance occurred only after *c.* 3000 cal. BP (ANDRIČ & WILLIS, 2003). However, it seems that anthropogenic impact in the Neolithic period significantly altered the forest composition. Differences between individual phytogeographic regions of Slovenia became apparent after c. 8900 cal. BP and increasing palynological richness (biodiversity) after c.7000 cal. BP is presumably associated with the Neolithic transition to farming (ANDRIČ & WILLIS, 2003). The vegetation history at two small basins in Slovenia, located in the Bela krajina region, was investigated and compared using palaeoecological techniques (ANDRIČ, 2007).

Palynological research was undertaken in Bosnia (WOLTERS & BITTMANN, 2006) within the archaelogical excavation in the tell-settlement of Okolište in the hilly mountains of Central Bosnia (HOFMANN et al., 2008). The local cultural group is termed the „Butmir culture“ and dates to the Late Neolithic in terms of the local chronology. In calendar years this corresponds roughly to the period between 5200 and 4500 cal. BC. In cultural terms, Central Bosnia during the Late Neolithic is a kind of a hybrid of Adriatic and Carpathian influences, especially from the Vinča-Culture.

## 5. CONCLUSION

The results indicate that the landscape at Sopot was dynamic. Because of the low pollen concentration and poor preservation we can only make suppositions as to the type of vegetation cover. Initially, the study area around Sopot probably was covered by conifer and deciduous trees with stagnant water in the vicinity. It turned into an herb-dominated environment during the cultural phases (pastures and cultivated fields). Abandoned agricultural fields probably turned into bushy vegetation, oak and hornbeam forest and eventually beech forest. At the time of deposition of the studied sediments controlled or uncontrolled burningfrequently occurred, as well as intensive erosion. According to previously determined C14 dates, the oldest cultural layer from the zone SOP-1 could be from the Starčevo culture dated as 6060 to 5890 cal. BC, while the cultural layer from zone SOP-2 could be from the oldest Sopot culture dated as 5050 to 4550 cal. BC. Thecultural layer from zone SOP-3 could be from 4790 to 4360 cal. BC and the cultural layer from zone SOP-4 could be from 4340 to 3940 cal. BC.

This research suggests that these sediments from the cultural layers are not suitable for detailed pollen analysis and further sampling should be carried out from more promising sediment in the surrounding area. Detailed vegetation and environmental reconstructions must rely on multidisciplinary data.

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## REFERENCE

ANDRIČ, M. (2007): The Holocene Vegetation Development in Bela krajina (Slovenia) and the Impact of Fist Farmers on the Landscape.– *The Holocene* 17/6, 763–776.

ANDRIČ, M. & WILLIS, K.J. (2003): The Phytogeographical Regions of Slovenia: a Consequence of Natural Environmental Variation or Prehistoric Human Activity?– Journal of Ecology, 91, 807–821.

BEHRE K.E. (1986): Anthropogenic indicators in pollen diagrams. A.A.Balkema, Rotterdam, 232 p.

BIRKS, H.J.B. & BIRKS, H.H. (1980): Quaternary Palaeoecology. (Reprinted 2004 by the Blackburn Press, New Jersey) Edward Arnold, London.

BIRKS, H.H, BIRKS, H.J.B., KALAND, P.E. & MOE, D. (eds) (1988): The Cultural Landscape Past, Present and Future.– Cambridge University Press, Cambridge, 521 p.

BOTTEMA, S. (1975): The interpretation of pollen spectra from prehistoric settlements (with special attention to Liguliflorae).– Palaeohistoria, 17, 17–35.

DIMBLEBY, G.W. (1985): The Palynology of Archaeological Sites. London: Academic Press, 176 p.

ERCEGOVAC,M. & KOSTIĆ, A. (2006): Organic facies and palynofacies: nomenclature, classification and applicability for petroleum source rock evaluation.– Int. J. Coal. Geol., 68, 70–78.

FAEGRI, K. & IVERSEN, J. (1989): Textbook of Pollen Analysis. (4th Edition by FAEGRI, K., KALAND, P.E. & KRZYWINSKI, K.).– John Wiley & Sons New York, 328 p.

FLORENZANO, A., MARIGNANI, M., ROSATI, L., FASCETTI, S. & MERCURI A, M. (2015): Are Cichorieae an indicator of open habitats and pastoralism in current and past vegetationstudies?– Plant Biosystems, 149/1, 154–165. DOI:10.1080/11263504.2014.998311

FLORENZANO, A., TORRI, P., RATTIGHIERI, E., MASSAMBA N'SIALA, I. & MERCURI, A.M. (2012): Cichorioideae-Cichoriaceae as pastureland indicator in pollen spectra from southern Italy.– In: Atti del CongressoA.I.Ar. 2012 Modena. Modena, 22–24 Febbraio, 2012, BOLOGNA: Patron Editore, 342–353, ISBN/ISSN: 9788855531665

GROTE, M. (1977): Über die Auslösung der generativen Fortpflanzung unter kontrollierten Bedingungenbei der Grünalge Spirogyra majuscule.– Z. Pflanzenphysiol., 83, 95–107.

HAVINGA, A.J. (1964): Investigation into the differential corrosion susceptibility of pollen and spores.– Pollen et spores, 6, 621–635.

HOFMANN, R., KUJUNDŽIĆ-VEJZAGIĆ, Z., MÜLLER, J., RASSMANN, K. & MÜLLER-SCHEEßEL, N. (2008): Rekonstrukcija procesa naseljavana u kasnom neolitu na prostoru centralne Bosne.– Glasnik Zemaljskog Muzeja u Sarajevu (Nova Serija), 50/51, 2008/2009, 11–178.

HOROWITZ, A. (1992): Palynology of arid lands. Amsterdam.– Elsevier, 546 p.

HOSHAW, R.W. (1968): Biology of the filamentous conjugating algae. Algae, man and the environment.– In: Syracuse University Press, Syracuse. JOHNSSON, L. (1990): Survival of common bunt (*Tilletia caries* (DC) Tul.) in soil and manure.Journal of Plant Diseases and Protection, 97, 502–507.

JUGGINS, S. (2007): C2 Version 1.5: Software for ecological and palaeoecological data analysis and visualisation [program].– Newcastle upon Tyne: University of Newcastle.

KRZNARIĆ ŠKRIVANKO, M. (2011): Radiokarbonski datumi uzoraka sa Sopot, Panonski prapovijesni osviti Zbornik radova posvećenih Korneliji Minichreiteruz 65. Obljetnicu života, Institut za arheologiju, Zagreb, 209–227.

KRZNARIĆ ŠKRIVANKO, M. (2015): Rezultati Dimitrijevićevih istraživanja Sopota u svjetlu novih istraživanja".– Opvscvla archaeologica, 36, Zagreb (in press).

KRZNARIĆ ŠKRIVANKO, M. & BALEN, J. (2006): Osma, deveta I deseta sezona sustavnog istraživanja gradine Sopot (godina 2003., 2004., 2005.), Obavijesti Hrvatskog arheološkog društva, XXXVIII/1, 51–60.

KRZNARIĆ ŠKRIVANKO, M. & REED, K. (2008): The Late Neolithic site of Sopot, Vinkovci: results of the site stratigraphy, C14 dates, and the analysis of archaeo-botanical and osteological remains.– The European Archaeologist, Issue no. 28, Winter 2007/2008.

LECHTERBECK, J., EDINBOROUGH, K., KERIG, T., FYFE, R., ROBERTS, N. & SHENNAN, S. (2014): Is Neolithic land use correlated with demography? An evaluation of pollenderived land cover and radiocarbon-inferred demographic change from Central Europe.– The Holocene, 24/10, 1297–1307.

LI, YY., ZHOU, LP. & CUI, HT. (2008): Pollen indicators of human activity.– Chinese Sci Bull., 53, 1281–1293.

MAZURKIEWICZ-ZAPAŁOWICZ, K. & OKUNIEWSKA-NOWACZYK, I. (2015): Mycological and palynological studies of early medieval cultural layers from strongholds in Pszczew and Santok (western Poland).– Acta Mycologica, 50/1.

MEDEANIC, S. (2006): Freshwater algal palynomorph records from Holocene deposits in the coastal plain of Rio Grande do Sul, Brazil.– Rev. Palaeobot. Palynol., 141, 83–101.

MERCURI A, M., BANDINI MAZZANTI, M., TORRI, P., VIGLIOTTI, L., BOSI, G., FLORENZANO, A., OLMI, L. & MASSAMBA N'SIALA, I. (2012): A marine/terrestrialintegration for mid-late Holocene vegetation history and the development of the culturallandscape in the Po Valley as a result of human impact and climate change.– Vegetation Historyand Archaeobotany, 21, 353–372. DOI: 10.1007/s00334-012-0352-4

MERCURI, A.M., FLORENZANO, A., MASSAMBA N'SIALA, I., OLMI, L., ROUBIS, D. & SOGLIANI, F. (2010): Pollen from archaeological layers and cultural landscape reconstruction:case studies from the Bradano valley (Basilicata, southern Italy).– Plant Biosystems, 144/4, 888–901.

MONEY, N.P. (2007): The Triumph of the Fungi: A Rotten History.– Oxford University Press, 197 p. DOI: 10.1093/acprof:oso/9780195189711.001.0001

MOORE, P.D., WEBB, J.A. & COLLINSON, M. (1991): Pollen Analysis (second edition).− Blackwell Sci. Publication, London, 216 p.

ROBERTS, N., BRAYSHAW, D., KUZUCUOGLU, C., PEREZ, R. & SADORI, L.(2011): The mid-Holocene climatic transition in the Mediterranean: causes and consequences.– The Holocene, 21, 3–13.

SLUŽBENI VJESNIK – Službeno glasilo Vukovarsko-srijemske županije, Broj 18. God. XIV Vinkovci, 27. prosinca 2006; http://www.vusz.hr/Cms_Data/Contents/VSZ/Folders/dokumenti/sluzbeni_vjesnik/~contents/ZMV2ASW7N9CZZU2F/2010-2-10-329363-vjesnik18-06.pdf

TRINAJSTIĆ, I. (1998): Fitogeografsko raščlanjenje klima zonalne šumske vegetacije Hrvatske.– Šumarski list hr. 9, 10, (XXII, 407–421).

WOLTERS, S. & BITTMANN, F. (2006): Pollen analytische Untersuchungenzur Landschaftsentwicklungim Visokobecken/Bosnien-Herzegowina.– Bericht der Römisch-Germanischen Kommission, 87, 167–174.

TYSON, R.V. (1995): Sedimentary Organic Matter.– Organic Facies and Palynofacies. Chapman and Hall, London, 615 p.

VAN GEEL, B. (1976): Fossil spores of Zygnemataceae in ditches of a prehistoric settlement in Hoogkarspel (The Netherlands).– Rev. Palaeobot. Palynol., 22, 337–344.

VAN GEEL, B. (1978): A palaeoecological study of Holocene peat bog sections in Germany and The Netherlands.– Rev. Palaeobot. Palynol., 25, 1–120.

WOROBIEC, E. (2014): Fossil zygospores of Zygnemataceae and other microremains of freshwater algae from two Miocene palaeosinkholes in the Opole region, SW Poland.– Acta Palaeobotanica, 54/1,113–157. DOI: 10.2478/acpa-2014-0005

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