Local landscape evolution related to human impact of an early medieval pre-urban center in the Upper Dnieper region (Central Russian Plain): an interdisciplinary experience

Maria A. Bronnikova[1,*], Elya P. Zazovskaya[1], and Anatoliy A. Bobrov[2]

[1]*Department of Soil Geography and Evolution, Institute of Geography, Russian Academy of Sciences, Pyzhevskiy per., 29, 109017, Moscow, Russia.*
[2]*Soil Science Dpt., Moscow State University, Vorobiovi gori, Moscow, Russia.*
* *mbmsh@mail.ru*

ABSTRACT

Subatlantic landscape changes were reconstructed by correlating independent results of pedological studies, pollen, phytolith, and micropaleontological analyses of flood plain soil-sedimentary and sedimentary sections in the Upper Dnieper region within an early medieval pre-urban center and in its close vicinities. Major phases of Subatlantic landscape evolution were defined as follows. A phase of low and dispersed human impact (approximately 3,000 BP–1,100 BP) is remarkable by widespread zonal forest ecosystems and periodic slight increases of cultivated plants and others favored by culture. The phase included a stage of active floodplain sedimentation changed by a drier period (not earlier than 2,400 BP) of no sedimentation and formation of Luvisols in the floodplain. The next phase of intensive local human impact occurred during early medieval settlement (1,100–1,000 BP) and is characterized by extensive deforestation, wide introduction of variable human-related plants and deep transformation of original soils within the settlement's area: formation of Urbi-Anthropic Regosols. A phase of no local human impact but generally higher anthropogenic pressure in the region (later than 1,000 BP) started after a decline of the settlement. The number of settlements increased sharply in the region in the 11th – 13th centuries. This caused extensive anthropogenic deforestation and re-establishment of human impact indicators after a slight forest invasion and sharp but short drop in human-related plants. Floodplain sedimentation sharply increased. Garbi-Urbic materials of the settlement and Luvisols beyond the settlement's borders were buried under floodplain alluvium about 1,000–800 BP. At the end of this phase, formation of contemporary Fluvisols took place due to declining sedimentation rates (200–150 BP).

Key words: alluvial, paleosol, sedimentary sequences, human impact, athropogenic materials.

RESUMEN

Los cambios en el paisaje subatlántico se reconstruyeron correlacionando registros independientes, tanto pedológicos como de polen, fitolitos y análisis micropaleontológicos de la planicie de inundación pedo-sedimentaria y de secciones sedimentarias en la región superior del Dnieper, dentro de un centro pre-urbano del Medioevo temprano y en sus vecindades cercanas. Las fases mayores de evolución del paisaje subatlántico se definieron como sigue: Una fase de impacto humano bajo y disperso (aproximadamente 3,000 AP–1,100 AP), notable por la extensión de ecosistemas forestales zonificados y aumentos ligeros y periódicos de plantas cultivadas y otras de tipo cultural. La fase incluyó una etapa de sedimentación activa en la planicie de inundación, que cambió debido a un periodo más seco (no anterior a 2,400 AP), de no sedimentación y formación de Luvisoles en dicha planicie. La siguiente fase de intenso impacto humano local ocurrió durante el asentamiento medieval temprano (1,100–1,000 AP) y se caracteriza por deforestación extensa, amplia introducción de varias plantas relacionadas con la

humanidad y profunda transformación de los suelos originales dentro del área de asentamiento: formación de Regosoles Urbi-Anthropic. Otra fase sin impacto humano local, pero generalmente con más alta presión antropogénica, en la región (no después de 1,000 AP) inició después de la declinación del asentamiento. El número de asentamientos aumentó fuertemente en la región en los siglos XI–XIII. Esto provocó una amplia deforestación antropogénica y el restablecimiento de indicadores de impacto humano, después de una ligera invasión forestal y aguda así como un ligero decremento de plantas relacionadas con el hombre. La sedimentación en la planicie de inundación aumentó intensamente. Los materiales garbic-urbic del asentamiento y los Luvisoles ubicados fuera de los límites del mismo, quedaron sepultados bajo aluvión de la planicie inundada en 1,000–800 AP. Al final de esta fase, tuvo lugar la formación de Fluvisoles contemporáneos debido a la disminución de los promedios de sedimentación (200–250 AP).

Palabras clave: secuencias sedimentarias, paleosuelos, aluvial, impacto humano, materiales antropogénicos.

INTRODUCTION

Reconstruction of climatic and human-induced landscape evolution is one of the key aims of paleopedology. General Holocene climatic trends are already well known (Khotinskiy, 1984; Berglund *et al.*, 1996; Alexandrovskiy, 2002; and others). Though the results obtained by different methods are still contradictory to a certain extent. Much less is known about climatic changes at a higher scale of resolution: within one to three thousand years. Efforts of researchers in the last decades have concentrated on this problem (Lyakhov, 1984; Krenke *et al.*, 1989; Klimanov *et al.*, 1994). Data on climatic landscape changes within a historical time frame are especially important with respect to their possible influence on economic activities of ancient humans and migration processes. At the same time, human impact also is known to induce sufficient landscape changes during prehistory (Ralska-Jasiewiczowa, 1977; Behre, 1988). Studies of interactions between prehistoric and historic people and environment are well established in paleoecology and in pollen analysis in particular (Birks *et al.*, 1988; Simmons and Tooley, 1981; Chambers, 1993; and many others). Ancient human-induced changes of soil systems are still beyond the main scope of most research, with only a few notable works (Sycheva, 1994; Hiller, 2000; Alexandrovskiy, 2002).

There are a variety of methods applied to reconstruct paleoclimates and paleolandscapes including pollen analysis, analysis of plant tissues, seeds and phytoliths, analysis of different macro- and micro-faunal residues, soil studies, studies of lithology, stable isotope analysis, glaciological methods, and so forth. Considering that each of these methods has its own advantages, difficulties and restrictions, the most fruitful approach is to use a number of methods and correlate their results. This study is an effort to reconstruct the local landscape for the periods before, during and after an intensive local early-medieval phenomenon of human impact by independently applying and correlating soil data, sediment lithology, pollen analysis, and analysis of siliceous

biomorphs. The aims were: 1) reconstruction of Subatlantic landscape evolution and, in particular, reconstruction of landscape conditions for establishment and development of the early medieval pre-urban centre Gnezdovo; 2) revealing human-induced environmental changes of related time as recorded in soil systems and pollen spectra.

Preliminary results of this study were discussed earlier (Sedov *et al.*, 1999). The flood plain location was chosen as a key site for studies due to a number of reasons. First, Holocene climatic changes are recorded in a flood plain as alternating Fluvisols, alluvial sediments of different facies, and zonal soils (the alternation is conditioned by changes of sedimentation rate). This stratified rhythmic record of floodplain environmental changes has a high resolution. Here even short-term environmental fluctuations are registered in changes of sedimentation and soil formation (Sycheva, 1999; Alexandrovskiy, 2002), as well as in pollen spectra and fossil fauna. This advantage is especially important for the site under investigation, because sandy soils of surrounding river terraces have low-sensitivity to recording environmental changes and the absence of peat bogs to core for pollen analysis limit the possibilities for paleoenvironmental reconstruction. However, conditions within the borders of the early medieval settlement were favourable for soil studies, pollen analysis and other paleoecological studies. In addition, soil profiles related to the time of settlement functioning are to a certain extent isolated from contemporary soil forming processes in the flood plain in so far they are buried under recent alluvium.

GEOGRAPHICAL LOCATION AND GENERAL DESCRIPTION OF STUDY SITE

The site under investigation is situated in the center of the Russian Plain (54⁰ 46' N, 31⁰ 50' E) 15 km from the regional center Smolensk, along the right bank of Dnieper river. Gnezdovo, one of the largest early-medieval pre-urban centers in Eastern Europe is located here. The site includes

a settlement, a fortress, and several thousand of burial mounds situated mostly on a late Pleistocene Dnieper terrace; the settlement also occupies a part of the Holocene floodplain (Figure 1). The Dnieper floodplain is 200–500 m up to 1 km wide and 7–9 m high. It is quite regularly flooded in spring. There are many active and overgrown oxbow lakes here. The region belongs to the south taiga (mixed forests) subzone. Total annual precipitation is about 650 mm (ranging 350–900 mm), annual temperature in the region is +4.6ºC. Currently, pine (*Pinus*) and birch (*Betula*) dominate the forests of the Dnieper terraces. Openness of the landscape is considerable due to contemporary human activities. Dry and floodplain meadows occupy the area of the settlement itself and neighboring areas on the first Dnieper terrace and floodplain respectively. Meadow vegetation and the forest floor is considerably transformed and exhausted by pasturage. The natural soil mantle is composed of Umbric Podzols and Umbric Gleyic Podzols on the upland and Dnieper terraces, and different Fluvisols of the flood plain. Weakly transformed by contemporary soil processes, Anthropic Regosols occupy the area of the early-medieval pre-urban center. These paleosols are buried under 50–80 cm of sediments in the floodplain.

The history of Gnezdovo is related to the period of the formation of the Russian State and the establishment of the first large pre-urban settlements in the Central Russian Plain. Gnezdovo is well studied archaeologically. Its habitation deposits are highly-reliably dated, based on the evidence assemblage of artifacts, as pertaining 9th – 11th centuries AD. The settlement had a well developed trade–handicraft profile: blacksmith and jewelers crafts, pottery, and bone carving were elaborated here. The cultural evidence also suggests agricultural activities of the inhabitants, but until now there were only a few agriculture-related finds in the habitation deposits.

SOIL STUDIES

Materials and Methods

Field description of soil-sedimentary sections was conducted for a floodplain area of the archaeological site and its close vicinity. Sections in the territory of the settlement (back and central flood plain) included surface contemporary Fluvisols, buried Anthropic Regosols of early medieval time. In some cases, where the habitation deposit (different anthropogeomorphic soil materials in WRB, 1998) is thin, remains of a natural pre-anthropogenic profile, which was transformed by early-medieval human activities. A section located in riverside escarpments, beyond the settlement borders, included contemporary surface Fluvisols and buried soils presumably correlative in time to residues of natural soils under anthropogeomorphic soil materials on the settlement. These buried soils were undisturbed by early medieval habitation activities.
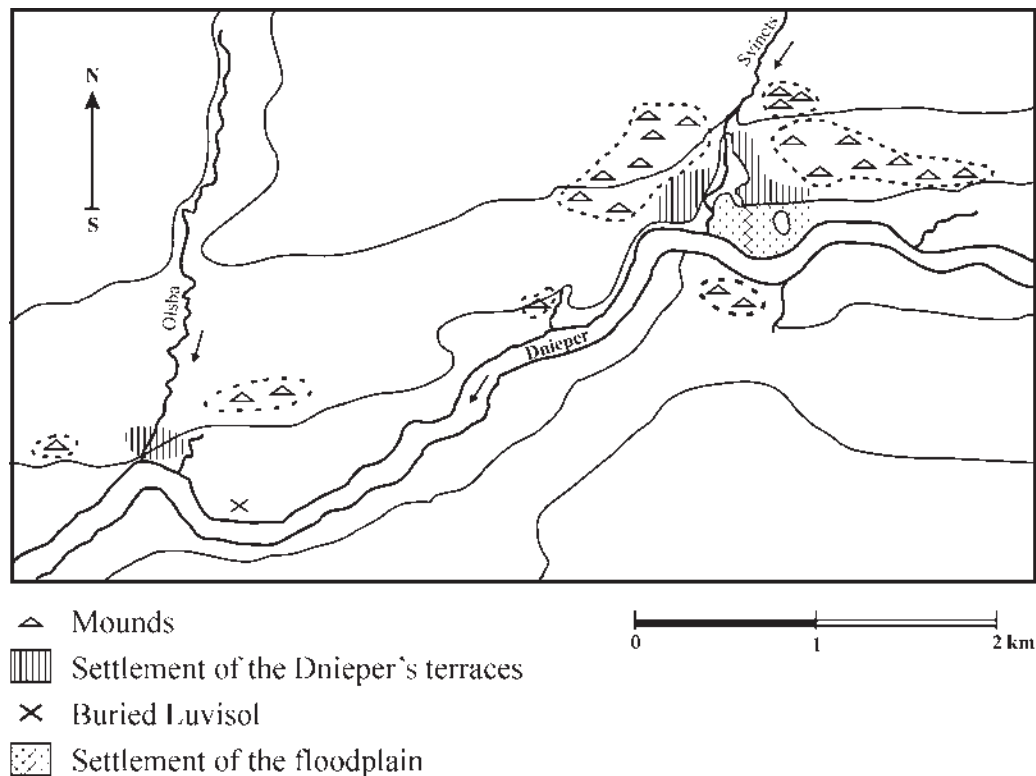

Figure 1. Geomorphological scheme of the site.

Laboratory research included evaluation of pH in water, organic carbon (by oxidation with dichromate in acid environment), particle size analysis by the pipette method, and valuation of oxalate- and dithionite-extractable iron according to standard procedures. Thin sections of undisturbed specimens from genetic horizons of studied profiles were investigated under a polarizing microscope. Clay mineralogy of the <1 μ fraction was studied with X-ray diffraction.

Results and Discussion

The following types of soil profiles were described within the settlement's borders:
A) A-ABg-Uhb[1]-Cg;
B) A-ABg-Bg-(Cg)-U1hb-(U2↓↑b)-(Egb)-Btgb-Cg.

Surface soils are Distri-Gleyic Fluvisols similar for both types of sections and varying mostly in thickness of the profile and horizons. All sections included an early medieval (on account of archaeologically dated artifacts) anthropogeomorphic soil material buried under 40–90 cm of younger flood deposits. Anthropogeomorphic material is composed of numerous residues of habitation activities: wood and charcoal, fragments of pottery, oven stones, slugs, glass, metal articles and other artifacts, included in a black organic mineral matrix. This matrix is usually heterogeneous in texture both laterally and vertically. Sometimes thin intermittent layers of sandy flood deposits occur within the anthropogeomorphic material. Micromorphologically, organic matter is represented by black sub-globular microaggregates; strongly deformed residues of plant tissues; and charcoal particles of different sizes (Figure 2), often fragmented into charcoal dust. Described anthropogeomorphic material normally contains both a lot of organic wastes (wood, charcoal, bones, straw and probably already decomposed organic tissues) and at the same time building materials and artifacts, classified by the FAO as Garbi-Urbic soil material (WRB, *1998*) or Uh-Urbic horizon rich in humus (Stroganova *et al.*, 1998). Anthropogenically transformed buried soils are Urbi-Anthropic Regosols (Garbic).

In A-type sections (in the central and low flood plain) the horizon of Garbi-Urbic material is up to 70 cm thick. There are no obvious remains of pre-anthropogenic natural profile below it. Lamellar, well-sorted alluvial sands underlie Garbi-Urbic material. In B-type sections (central flood plain), the thickness of anthropogeomorphic material is not more than 20–40 cm. It is typically Garbi-Urbic in its upper part. In the lower part it sometimes contains fewer artefacts and includes fragments (more than 3%) of an Albic horizon.

Figure 2. Micromorphology of anthropogeomorphic material.

The Garbi-Urbic soil material is substituted for Aric material in the lowest part (WRB, *1998*), or Urbic horizon including fragments of natural diagnostic horizons (U2↓↑) (Stroganova *et al.*, 1998). Aric materials here have strong gley features. Remnants of Luvisols were described below the horizon of anthropogeomorphic material: fragments of an Albic horizon and an Argic horizon developed in loamy sand. Numerous clay coatings were identified in thin sections of Btgb horizons: yellowish-brown impure clay coatings or reddish-brown slightly speckled ones (in the section P-3 which is somewhat richer in sand), both with probable admixture of humus compounds and iron oxides. Clay coatings are anisotropic, have yellow or reddish-yellow interference colours and diffuse extinction (Figure 3). Well-sorted alluvial fine sands underlie the profiles.

Fluvisols of all described sections are developed in loamy sand or sandy loam (Figure 4). Contents of silt and especially clay fractions (<0.001 mm, 0.001–0.005 mm, 0.005–0.01 mm and 0.01–0.05 mm) increase in horizons

Figure 3. Clay coating in residual Btgb horizon of Luvisol below Garbi-Urbic soil material.

---

[1]A system of indexes for anthropomorphic soil materials has not developed yet in the frame of WRB. As far as anthropogenically transformed early medieval soils were formed in pre-urban environment we use here indexes developed on the basis of new Russian classification (Shisov *et al.*, 1997) for Urbic diagnostic horizon in a contemporary urban environment (Stroganova *et al.*, 1997).
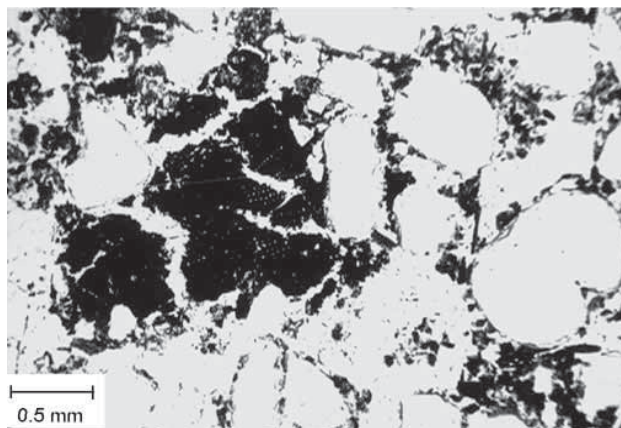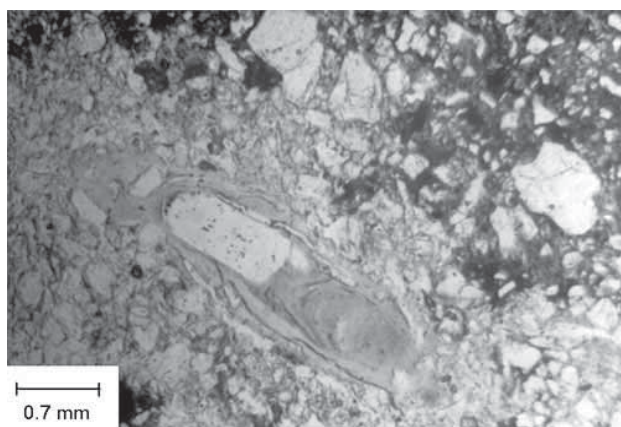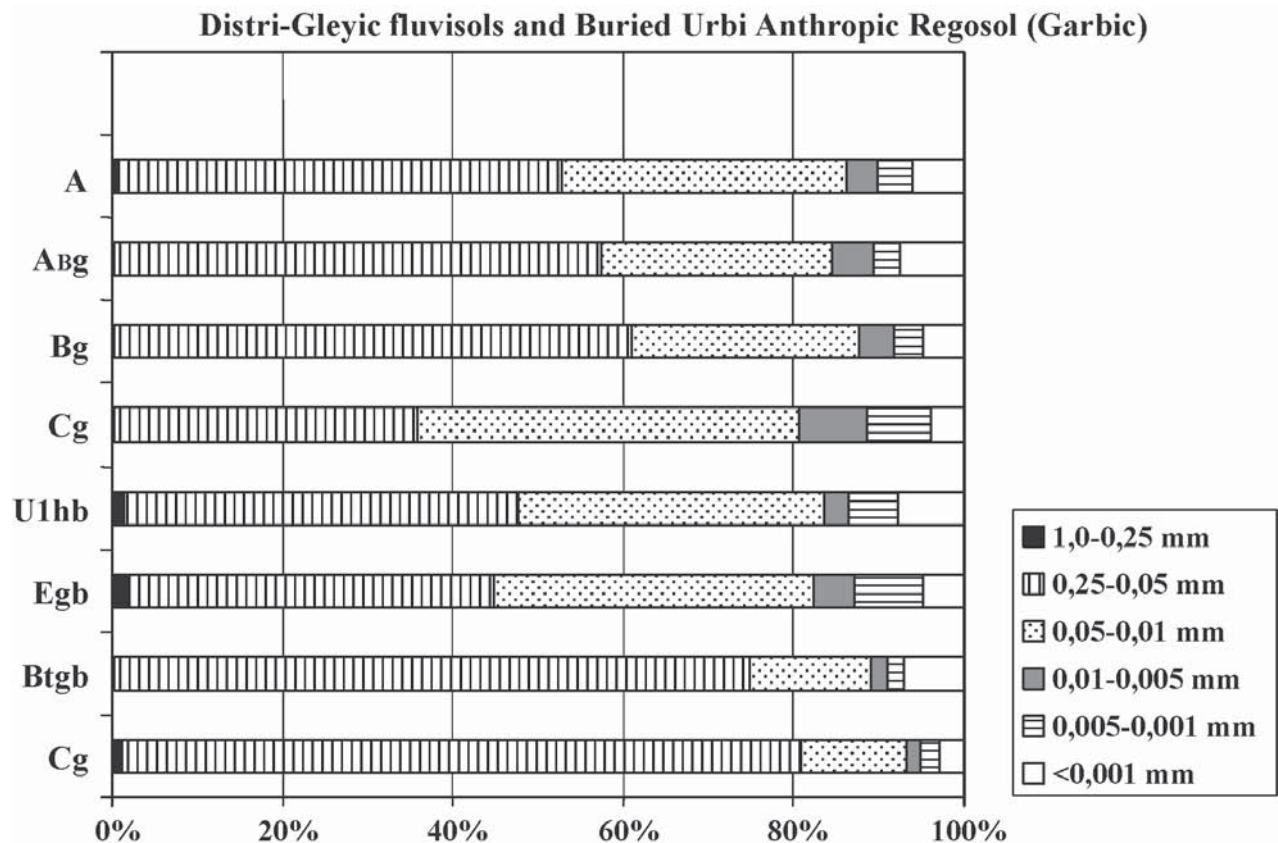
Figure 4. Particle size distribution in the soil-sedimentary section within borders of the settlement.

of Garbi-Urbic and Aric materials mostly at the expense of fine sand (0,05–0,25 mm). In B-type sections eluvial fragments of Eb horizons are depleted by clay (< 0.001 mm) and, in the opposite, an accumulation of clay is registered in Btgb horizons. Contemporary Fluvisols are slightly acid throughout a profile (Table 1).

Horizons of anthropogeomorphic material are neutral (pH = 7.0–7.2). In buried fragments of the albic horizon and below, pH values decrease substantially. Two maximums of organic carbon content are present in all studied sections. The first one is in the surface A horizon; another is related to horizons of anthropogeomorphic material.

Both citrate-dithionite-extractable iron (Fe d) and acid-oxalate-extractable iron (Fe ox) reveal complicated distribution in the described soil-sedimentary sections. A maximum of Fe d and Fe ox is registered for all sections in A horizons of contemporary Fluvisols. Lower, in ABg–Cg showing gleyic features, contents of Fe d and Fe ox decrease. Then the content of iron rises substantially in U horizons. The ratio Fe ox to Fe d is at a maximum in these horizons. The Fe ox:Fe d ratio is known to characterize the amount of amorphous or weakly crystallized iron oxides–hydroxides. Higher content of organic matter could inhibit crystallization of iron in Garbi-Urbic materials (Vodyanitskiy, 1992). In sections B, below U horizons, distribution of iron

reveals eluvo-illuvial pattern: fragments of the E horizon are impoverished both by Fe d and Fe ox iron, at the same time illuvial horizons reveal accumulation of the iron.

Mineralogical analysis of clay (size class <0.001 mm) generally exhibited a similar mineralogical composition. The clay fraction is composed of three major components: smectite, illite, and kaolinite (Table 2). It is diagnostically important in B-type sections that the content of smectite decreases in the clay fraction of buried fragments of E horizons, producing a residual accumulation of kaolinite.

Buried Luvisols were found in riverbank escarpments beyond the borders of the early medieval settlement. A soil-sedimentary section in an escarpment had an arrangement as follows: A-AC-C-Ab-Egb-Btgb. A surface Haplic Fluvisol is formed on alluvial sandy-loam, which is 70–80 cm thick. The buried Luvisol has no obvious signs of anthropogenic transformations. The Luvisol was developed in alluvial loams. The profile is satisfactorily differentiated: a dark-gray A horizon having cloddy structure and containing 1–1.2% of organic carbon, a bleached platy Albic horizon with redoximorphic features underlain by yellowish-brown horizon with gley mottles having blocky structure and somewhat heavier texture. Studies of thin sections from the B horizon showed numerous textural pedofeatures: microlaminated clay and impure clay coatings and infillings,

Table 1. Some analytical features of contemporary soil and paleosols in the soil-sedimentary section within borders of the settlement.

Horizons	Depth (cm)	pH_{H_2O}	pH_{KCl}	C_{org} (%)	Fe (%)	
					Dithionite extractable	Oxalate extractable
Distri-Gleyic Fluvisols and buried Urbi-Anthropic Regosols (Garbic)						
A	5-11	6.40	5.15	1.28	1.65	0.85
ABg	11-20	6.72	4.20	0.58	0.92	0.53
Bg	20-30	6.63	4.30	0.40	1.27	0.69
Cg	30-57 (59)	5.52	4.12	0.31	1.36	0.85
U1hb	57-85	7.00	4.25	1.37	1.18	1.10
U2↓↑b	57-85 (98)	6.58	4.02	0.52	1.37	0.99
Egb	85-98	5.50	3.65	0.46	0.59	0.42
Btgb	98-150	6.10	4.30	0.06	0.99	0.53
Cg	150-175	6.55	4.45	0.06	1.28	-
Distri-Gleyic Fluvisols and buried Urbi-Anthropic Regosols (Garbic)						
A	0-4	6.20	5.20	1.27	1.55	0.78
Abg	4-176	6.00	4.35	0.98	0.93	0.47
Uhb	17-95	7.20	5.00	2.21	1.24	1.15
Cg	95-150	6.50	4.35	0.21	0.87	-

some of them containing distinct organic layers (Figure 5), allowing their classification as Argic horizons. Coatings and infillings usually have diffuse extinction between crossed polarizers. This testifies to the relatively poor orientation of the clay due to the admixture of coarse particles and amorphous compounds. Textural pedofeatures are generally similar to these described in Bt horizons below the Garbi-Urbic materials. Analysis of particle size distribution has demonstrated a slight increase of clay content in the Bt horizon on a background of lithologically differentiated Albic and Argic horizons (Figure 6).

The age of the buried Luvisol is presumably similar with one of the Luvisols (their remains) below the Garbi-Urbic materials of the early medieval settlement. Thus both of these soils should correspond to a pre-anthropogenic period of soil formation. A ^{14}C date obtained on humus acids of the Ab horizon were 1,200±100 (IGAN-2265). The mean residence time of humus acids in A horizons of boreal Luvisols is 100–300 years (Chichagova *et al.*, 1985), so we estimate approximately the same residence time of humus for Ab horizon of the buried Luvisol. Thus we can conclude that the Luvisol could have been buried by alluvial sediments about 900–1,000 B.P.

Three major periods are evident in the local soil-sedimentary system evolution within the Subatlantic: 1) a pre-anthropogenic period earlier than 1,100 BP (undisturbed Luvisols buried under recent alluvium and remnants of Luvisols below Garbi-Urbic material corresponds to this period); 2) a period of intensive human impact (corresponding to the Anthropic Regosols, 1,100–1,000 BP); 3) a period following the decline of the early medieval settlement in the last 1,000 years (this period is subdivided in two phases: active alluvial sedimentation recorded in well-stratified loamy and sandy alluvium covering habitation deposits and Luvisols beyond the settlement's borders; pedogenic phase recorded in formation of surface Fluvisols).

Luvisols were widespread in the floodplain during the first period: before and at the time of settlement establishment. These soils are typical of loamy watersheds in the region. They could not occur in regularly flooded landscapes where continuous water logging takes place within a soil profile. Currently, spring floods in the area are relatively regular and Luvisols do not occur in the contemporary soil mantle of the floodplain. Thus, these soils were formed during a relatively drier period when spring floods were very rare, low and short-term, and the floodplain functioned most of the time as an unflooded terrace. This period concluded by accumulation of Garbi-Urbic materials in the inhabited area (1,100–1,000 BP, according to archaeological data). Luvisols beyond the settlement's borders located along the riverbank were buried by alluvium due to enhanced floodplain sedimentation rates 100–200 years later (1,000–800 BP, based on the ^{14}C date of humus acids).

Anthropic Regosols buried under the recent alluvium are distributed within the area of early medieval settlement. These soils correspond to the period of intensive human impact. Specific composition of the Garbi-Urbic material is governed both by natural resources and the cultural context of the settlement. The composition differs from one of contemporary anthropogeomorphic materials; there are no synthetic products, all are made of natural components that are sufficiently transformed by human activities. When the settlement was established, natural forests in the floodplain were at least partly cut down, and Luvisols were transformed to different extents by habitation and economical activities. Different kinds of human-introduced

Table 2. Mineralogical composition of clay (< 1 μm).

Horizon	Depth (cm)	Smectite (%)	Illite (%)	Kaolinite (%)
A	5-11	56	22	22
Abg	11-20	42	33	25
Bg	20-30	56	22	22
Cg	30-57(59)	55	18	27
U1hb	57-85	44	22	34
Egb	85-98	40	21	39
Btgb	98-150	43	38	19
Cg	150-175	53	24	23

organic and mineral materials accumulated on an original surface. Both burial of the surface (simple accumulation of the Garbi-Urbic material) and active transformation of the original soil profiles (removal or/and turbation) took place. The thickness of Garbi-Urbic layers and the presence or absence of natural soil profile remnants are conditioned most probably by an original mesorelief, and the functional zone of the settlement. Thin layers of well-sorted alluvial fine sand occur rhythmically within the Garbi-Urbic material. This supports the conclusion that spring floods were re-established during accumulation of anthropo-geomorphic materials. Most probably the area at that time was not flooded annually and the floods were still relatively low, so landscape conditions probably did not hinder habitation activities.

The last stage the of soil-sedimentary system formation started about 1,000–800 by intensive alluvial sedimentation. Both undisturbed Luvisols of Early-Middle Subatlantic age, and Urbi-Anthropic Regosols formed between 1,100–1,000 BP were buried under floodplain sediments. Then sedimentation slowed, allowing pedogenesis of contemporary Fluvisols.

POLLEN ANALYSIS

Materials and Methods

The site for pollen analysis is a small oxbow lake situated at the foot of the slope between the terrace and the floodplain. It is located directly under the early medieval Central Hillfort. A core of oxbow lake sediments, 335 cm deep, was sampled for pollen analysis. The upper part of the core stratigraphy is gyttja with variable amounts of plant remains, and a mineral composition of both sand and silt particles. Beginning at 94 cm it is peaty gyttja and peat. At 155 cm, the character of material changes qualitatively to more or less mineral sediments: clays, silty clays and silts with FeS and plant remains.

A volume of sample was measured and recent *Lycopodium* spores in tablets were added to determine the concentration of pollen. Sample preparation followed the stand-ard procedure described in Moore *et al.* (1991). After chemical treatment, samples were mounted in glycerine and stained with basic fuchsine before counting. A magnification of 250x was used for routine counting. Increased magnification (1000x) supported by the phase-contrast equipment was applied for problematic cases. The pollen reference collection of the Department of Earth Sciences, Uppsala University, together with keys by Fýgri and Iversen (1989) and Moore *et al.* (1991) were used for pollen identification. To ensure representative pollen counts, about 1,000 tree pollen grains (for rare samples with extremely low pollen concentration not less than 200) were counted at every level (Berglund and Ralska-Jasiewiczowa, 1986).

Pollen percentages were calculated using the "TILIA" program (Grimm, 1991), which is based on the sum of tree pollen plus non-arboreal (herbaceous plants) pollen. Black areas on the diagram show the registered pollen in percentages, while white areas show the actual percentages with equal exaggeration. Anthropogenic indicators were defined according to Behre (1988) and Berglund *et al.* (1996). Plants were grouped using the system of Königsson *et al.* (1995). Pollen assemblage zones were determined visually on the graph, on the basis of distinct changes in the vegetation.

Results and Discussion

The full pollen diagram worked out for oxbow lake sediments is presented in Figure 7 a-e. Though the sediment was not ^{14}C dated, on the evidence of pollen spectra it undoubtedly corresponds to the late Holocene. Pine (*Pinus*), spruce (*Picea*), and alder (*Alnus*) dominate among tree pollen throughout the diagram only changing their proportion. The lowermost part of the diagram corresponds to the early Subatlantic (SA1), showing a slight predominance of spruce (*Picea*) pollen, which is characteristic for the region (Nejshtadt, 1957). Then birch
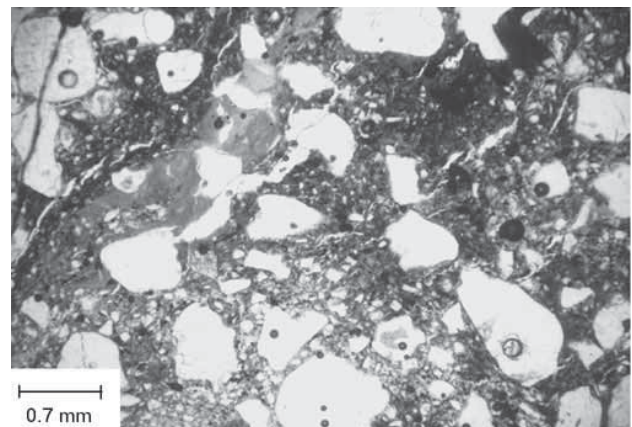

Figure 5. Clay coatings and infillings in Btgb horizon of buried Luvisol.
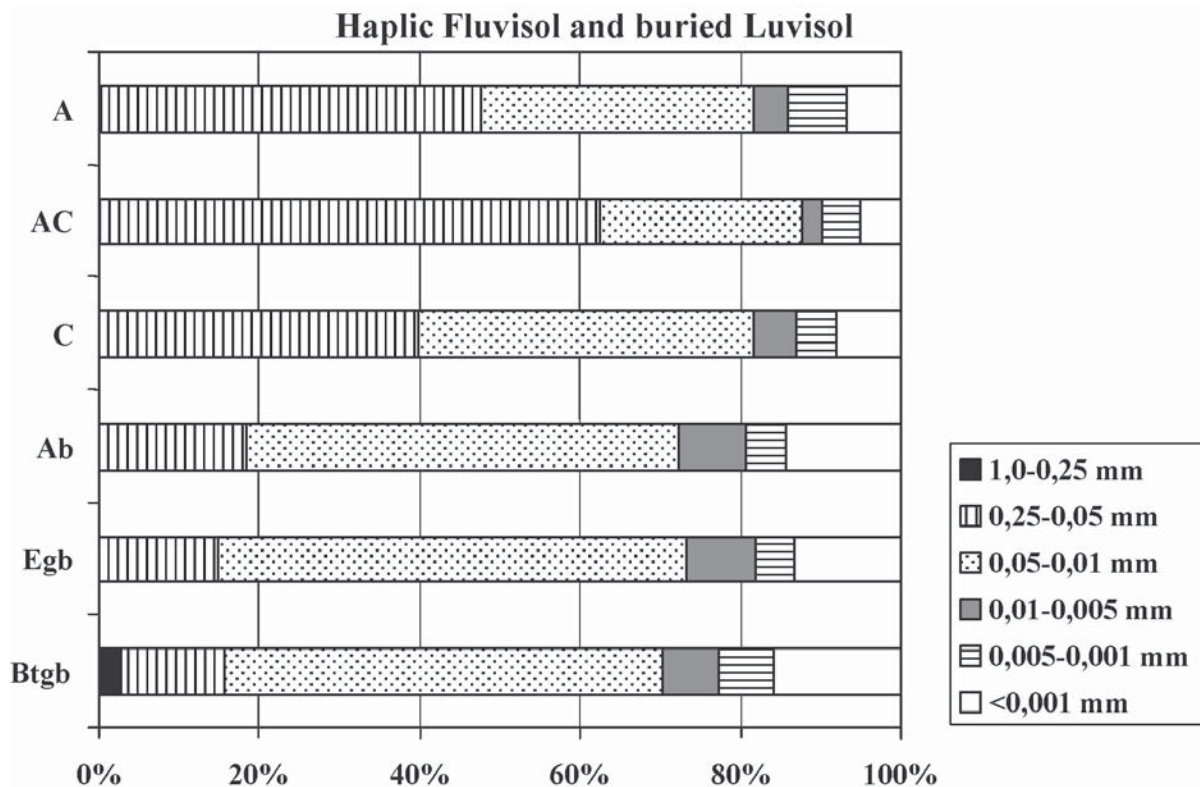
Figure 6. Particle size distribution in the soil-sedimentary section of riverbank escarpment (beyond borders of the settlement).

(*Betula*) becomes dominant among tree pollen followed by *Alnus*, *Pinus,* and *Picea*. The last significant phase is marked by the dominance of *Pinus* and general decrease of arboreal pollen, indicating extensive deforestation.

First, the diagram was divided into zones and subzones corresponding to major and minor stages of natural (climatic, successive) and, especially, human-induced landscape development. Here, the only major zones generally corresponding to large divisions in lithostratigraphy of the core are discussed. These pollen assemblage zones correspond with the basic phases of landscape development.

Zone I: 335 – 155 cm

This part of the core is characterized by high amounts of tree pollen. Originally, the area was densely forested and the presence of broad-leaved trees, mainly oak (*Quercus*) and elm (*Ulmus*) was still considerable. Human impact is not very significant here but nearly constant based on percentages of cultivated plants and plants favored by culture (Hemerophilous). Wheat dominates in this zone among the cultivated crops, but buckwheat, rye and hemp are also present. There are also some indicators of grazing, namely *Achillea, Pteridium*, and *Melampyrum,* accompanied by an observable amount of ruderal plants and weeds (*Polygonum aviculare*, *Chenopodeaceae*, *Artemisia, Rhinanthus-type, Rumex acetosa*). Human impact ceased

in the middle of the zone indicated by a short stage of landscape recovery and forest invasion. Here a rise of *Betula*, together with an increase of *Alnus* at the expense of *Pinus* and *Picea*, most probably resulted from human induced successions. Willows (*Salix*) and ferns (*Polypodiaceae*) are components of the alder forests.

Presence of typical aquatic plants such as *Nuphar* and *Nymphaea*, and much algae testifies to limnic conditions in the sampling site. Low concentrations of pollen and high values of the destruction coefficient indicate high sedimentation rates.

Stratigraphically, this part of the core is composed mostly of mineral sediments. A number of hiatuses appear in the lowermost part, which together with the repeated occurrence of sharp-bordered sandy-silty layers, most probably formed through repeated high spring floods of the Dnieper River.

Zone II: 155 cm – 110 cm

This pollen assemblage zone generally coincides with the next big stratigraphic division represented by peaty gittjia and peat with a relatively low admixture of mineral matter. The curve of pollen concentration indicates a heavy increase here and reaches its maximum. Such an abrupt change in pollen concentration, together with the rapid decrease of algae and all taxa of aquatic plants followed by
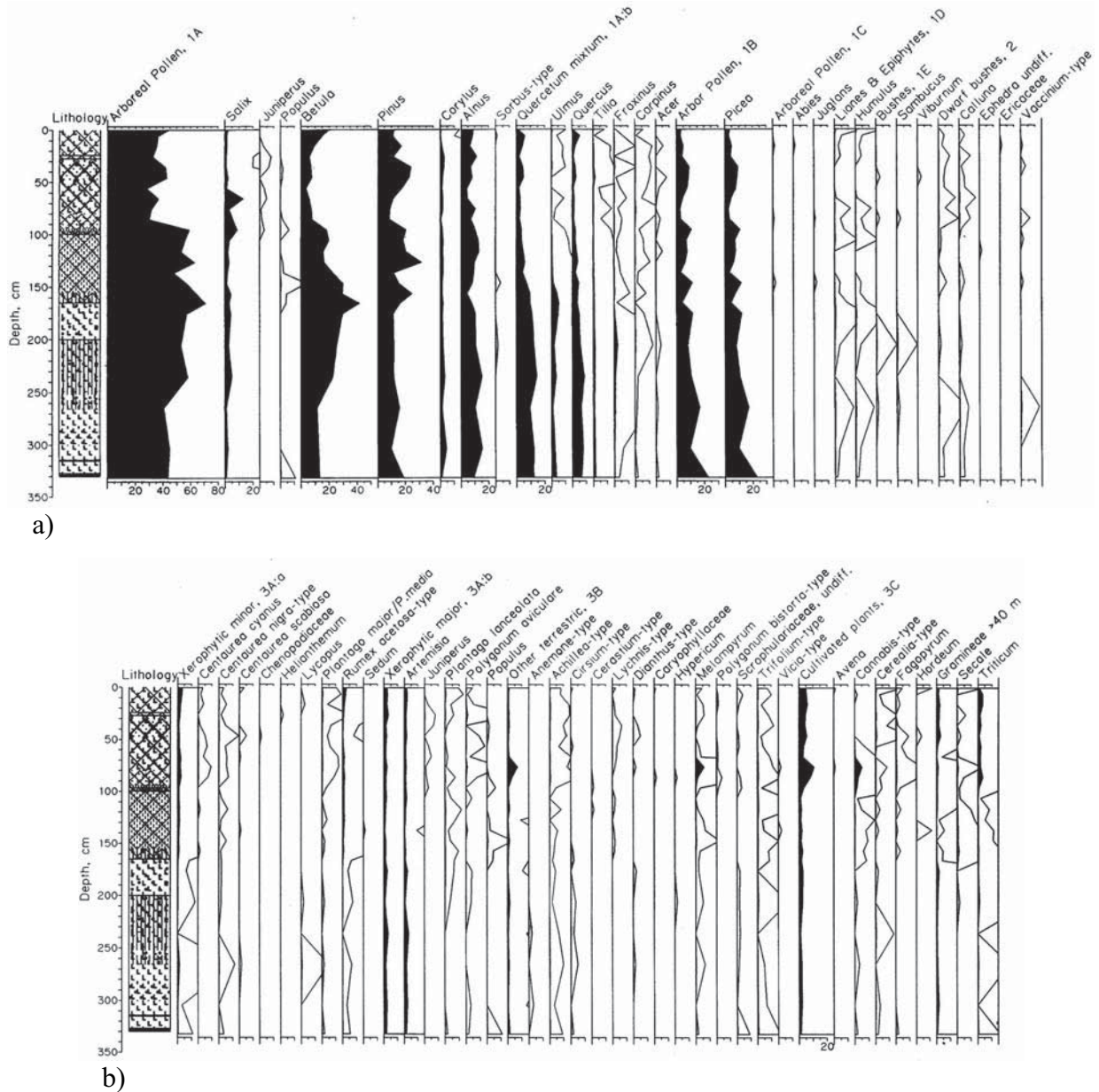
a)

b)

Figure 7. Pollen diagram.

their complete disappearance, point to a critical change in the character of sedimentation. The oxbow lake dried up and peat formation was established. Curves of some xerophytic plants increase steadily. These elements point to a climatically dryer phase of landscape development, characterized by low sedimentation rates, and low and irregular spring floods that did not affect the sampling site. Agricultural activities diminished at this time but still took place according to the curves of cultivated plants and other culturally induced plants.

Zone III: 110 cm – 70 cm

The zone corresponds to the most extensive human impact reflected in the diagram. A particular feature of this

zone is the extraordinary amount of *Cannabis* in the pollen spectra (more than 5% of pollen sum). High quantities of *Cannabis* are regarded to be a specific characteristic of the Viking Age in the Baltic region (Fries, 1962; Huttonen and Tolonen, 1972; Andersen, 1984). Well ^{14}C dated diagrams were worked out recently for Novgorod and Ryurikovo Gorodische, where layers dated between the 9th and 12th centuries AD also revealed an extreme peak of *Cannabis* (Königsson *et al.*, 1997). All this allows us to consider the zone III as corresponding to the time of Early Slavonic/ Viking Age settlement at Gnezdovo.

The zone starts from an abrupt and drastic deforestation event interpreted from a significant rise in the charcoal curve. All percentages of tree pollen go down
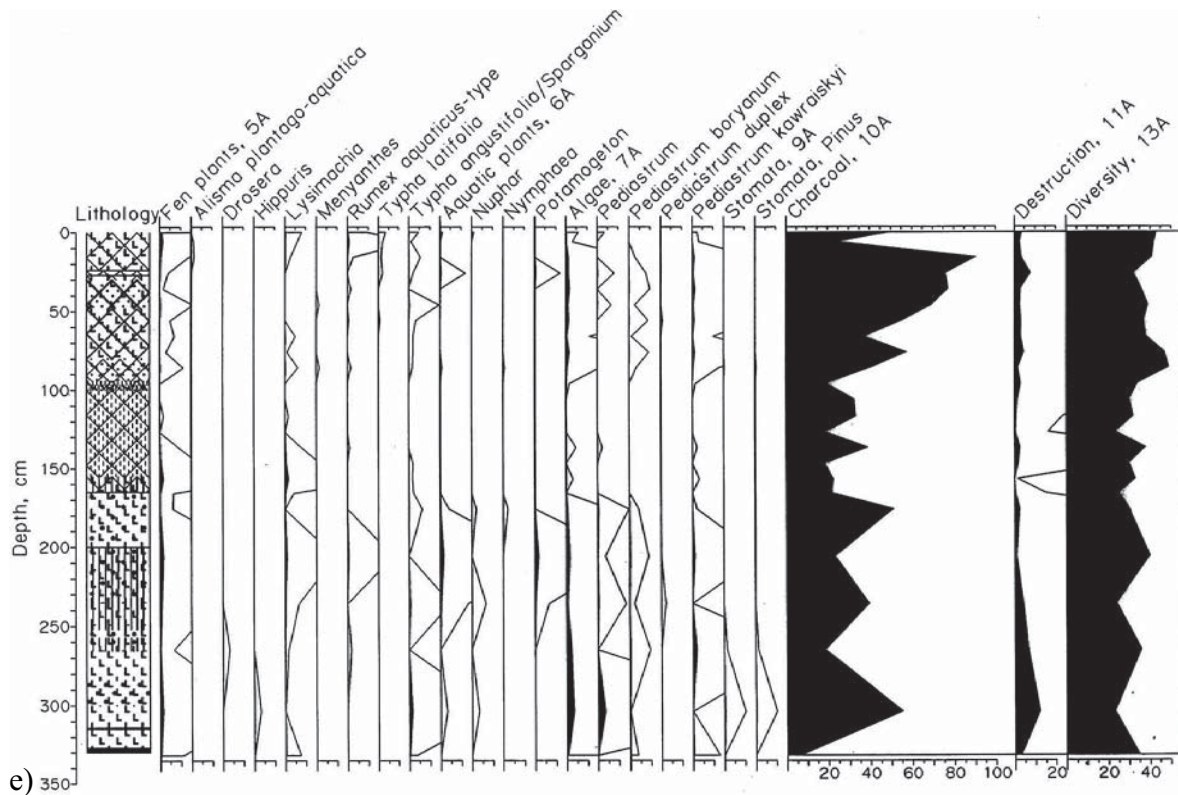
Figure 7. Continued.

c)

d)

Figure 7. Continued.

steeply. The curve of deciduous trees reaches its minimum. The sum of tree pollen is less than 35%. Thus, the originally forested area was turned into a more or less open landscape. Outstanding maximums of wheat and hemp, with a considerable share of buckwheat pollen, show their remarkable place in the economy of the settlement. Evident peaks in the curves of ruderal taxa, weeds, and grazing indicators emphasize variable and extensive land use. Consequently, this period is particularly remarkable for all types of human impact: deforestation related to everyday needs (fuel wood, timber etc.), fire clearance for husbandry, extensive and variable crop production, pastoral economy, as well as other habitation-related activities.

An important point is that the zone of the most intensive human impact falls at the very end of the climatically dryer period when the Dnieper floods ceased, and the floodplain surface was relatively dry and stable. This is obvious both from stratigraphy and pollen spectra. At a depth of 94 cm peaty sediments are replaced by clay gyttja and then silty clay gyttja. Algae, and aquatic plants appeared again which points to a re-establishment of limnic condotions in the oxbow lake after the previous stage of overgrowth.

Zone IV: 70 – 0 cm

This part of the diagram exhibit signs of a slight landscape recovery after the diminishing of early medieval settlement (decrease of cultivated plants accompanied by a rise of the tree pollen curve) followed again by enhanced human impact. After extensive deforestation in early medieval time the curve of tree pollen never reaches its initial values. All anthropogenic indicators show a considerable drop in the beginning but nevertheless persist in the upper part of the diagram.

Total pollen concentration decreases heavily in the beginning of zone III indicating an increase in sedimentation rates. Sediments contain more and more silty and even sandy particles. The subsequent rise of pollen concentration in the uppermost horizon is most probably due not only to an increase in sedimentation rates, but also high activity of soil biota feeding on pollen. Considerable amounts of algae and aquatic plants are registered in this zone. Thus, this last phase of landscape development is characterized by limnic conditions in the sampling site (or its closest vicinity), re-established intensive floodplain sedimentation, and persisting human impact.

Landscape development of the Gnezdovo microregion, as reflected in the pollen diagram, was strongly affected by land use activities of population throughout the investigated period. Originally, the area was densely forested. These were mixed forests with a considerable proportion of broad-leaved trees (10–15% of pollen sum), especially oak. Phases of slight deforestation and increased human impact (increase of cultivated plants, grazing indicators, plants favored by culture in the pollen spectrum)

correspond to periods of population influx. These periods alternate with phases of landscape recovery after the decline of land use activities.

Signs of natural climatic change are evident in the middle part of the section. This was a period of slight precipitation decrease and reduced sedimentation on the flood plain, reflected by a change of sedimentation regime, the character of sediments and overgrowth of the oxbow lake, slight natural deforestation, and the rise of dry-meadow plants.

The zone of the most significant and variable human impact is referred as the Slavonic/Viking Age Gnezdovo settlement (1,100–1,000 BP) and falls at the end of a climatically dryer period when Dnieper's floods ceased; the floodplain surface was relatively dry and stable. Deforestation reached a dramatic extent at this time. Forests were most probably superseded by that time, particularly due to land use activities of the population. A heavy rise of cultivated plants in the pollen curve testifies to the importance of local crop production in the economy of the settlement. Wheat, hemp and buckwheat predominated among cultivated crops. Grazing activities also took place.

The decline of the settlement is marked by the drop in cultivated plants and plants favored by culture, with a slight forest invasion. This phase of landscape recovery is followed by the next stage of deforestation and expanded agricultural pressure, which corresponds to the contemporary state of the landscape.

STUDIES OF BIOGENIC SILICA

Materials and Methods

A section in a low part of the floodplain was sampled for the analysis of biogenic silica: frustules of diatoms, shells of testate amoebas, spicules of freshwater sponges and plant phytoliths. The lower part of the section (170–42 cm) is Garbi-Urbic soil material that originated from early medieval habitation activities. There is an irregular alternation of relatively thin (15–30 cm) sandy layers and peaty layers 10–60 cm thick. Both sandy and peaty layers include anthropogenic organic material (straw, wood chips, charcoal) and different mineral artifacts. The upper part of the section (42–0 cm) is Distri-Gleyic Fluvisol developed in flood loam.

Every 10 cm of the section was sampled. Water suspension (50 mL of water for 5g of a soil sample) and sifting was undertaken to separate coarse mineral grains and organic residues (using a 0.5 mm sieve). A micropipette was used to recover suspended materials. The assemblage of species, quantity of testate amoebas, density of diatoms and sponge spicules were detected in an aliquot. Soil samples for phytolith analysis were boiled for 1 hour in 20% H_2O_2, then 10% HNO_3 was added and washed with distilled water. Samples were sifted to separate coarse mineral grains. Three hundred phytoliths were counted for every sample under 200x and 400x magnification. Scanning electron microscopy was applied to reference morphology of testate amoebas and phytoliths. A cluster analysis using Statistica 5.0 for Windows (StatSoft Inc., 1996) was used to estimate similarities of the phytolith assemblages.

Biogenic silica in soils is represented by mineral formations related to different groups of organisms: diatoms, *Heliozoa*, testate amoeba, freshwater sponge and plants. Morphology of frustules, shells, and spicules is an important systematic criterion, since it is determined genetically (controlled by the genome). Morphological features of biogenic silica of lower plants and protozoan as well as the composition of their communities are determined also by the ecological conditions of their habitats. The well-established systematics and ecology of silica-accumulating organisms served as the basis for the development of such paleoecological methods as diatom analysis, phytolith analysis and rhizopod analysis.

Environmental indicator characteristics of the taxonomic groups of silica-accumulating organisms are different. Freshwater sponge spicules (except the ones inherited from ancient hydromorphic stages of parent material formation) testify to an obligatory water phase of ecosystem development. Stratigraphy of the section and archaeological data in our case allow us to explain rises of spicule numbers only by intensification of spring floods. Diatoms are widespread in litters and automorphic topsoil horizons, in addition to hydromorphic habitats. Nevertheless, layers with maximal density of diatoms in floodplain soil-sedimentary sections indicate increased wetness. At the same time, increased density of both diatoms and sponges can be conditioned by their influx with waters of spring floods. Testate amoebas inhabit essentially all types of aquatic and terrestrial ecosystems. Their interpretative nature, in contrast to other silica-accumulating organisms, is very restricted and cannot indicate re-deposition due to the fragility of shells. Therefore testate amoebas (rhizopods) are regarded as bioindicators of local ecological conditions. Rhizopods are a relatively small group of organisms. Currently studies of their ecology are based on the application of quantitative methods, so that data on species composition of a paleocenosis allow correct environmental reconstruction and, particularly, reconstruction of water regime (Bobrov *et al.*, 1999; Schirrmeister *et al.*, 2002). Rhizopods were subdivided into three major ecological groups: 1) aquatic species; 2) soil and euryoecic species; 3) bog species (Figure 8). The soil group includes some species of the genus *Centropyxis*, for instance, *C. plagiostoma*, and all samples contained species of the genus *Plagiopyxis*.

A composite of phytoliths separated from soil allows the reconstruction of a type of vegetation or, in some cases, gives an opportunity to determine certain species of plants. In this study, phytolith analysis was based on morphotypes of phytoliths, which allows proper identification of a species or a superior taxon of plants. Mostly these are phytoliths of sedges and grasses. Phytoliths of *Phragmites australis*
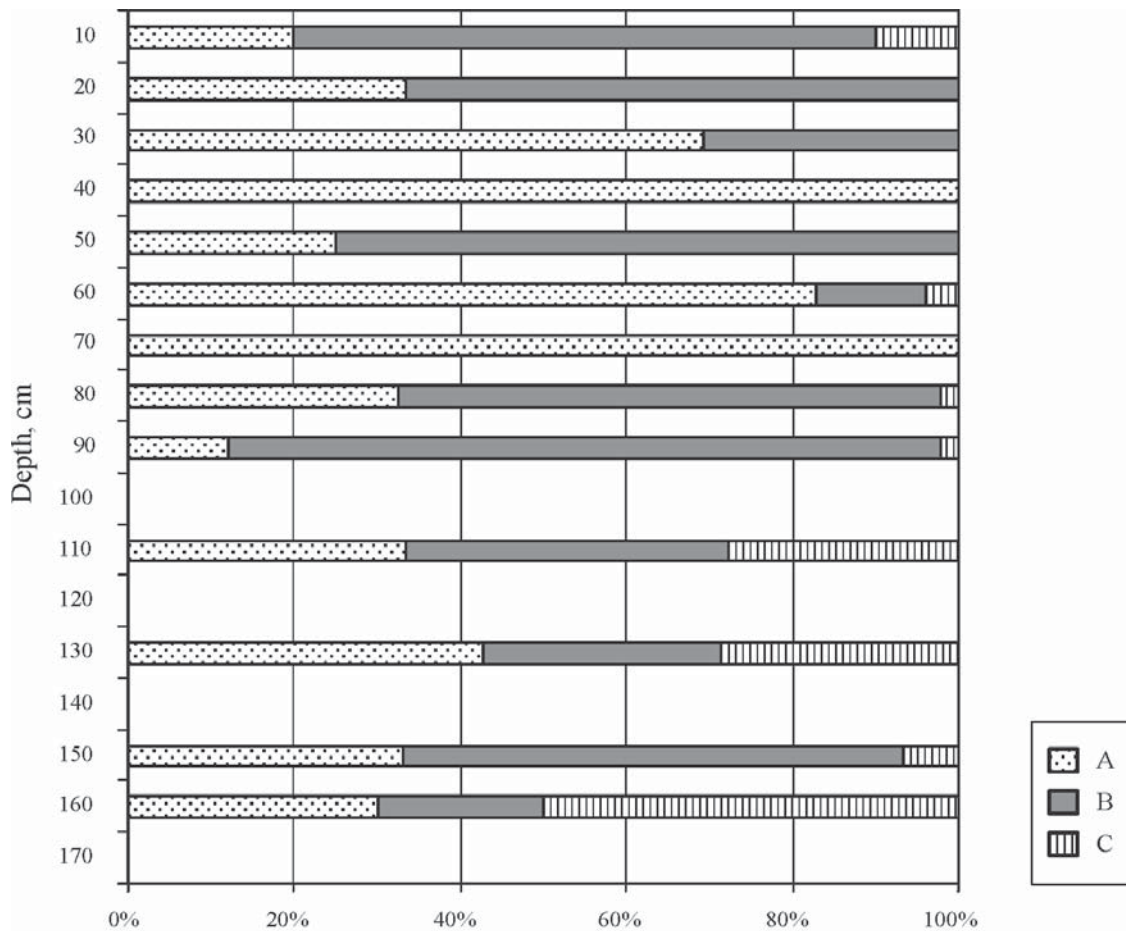
Figure 8. Testate amoebas: A) aquatic species; B) soil and euryoecic species; C) bog species.

Results and Discussion

The density of diatoms (Figure 9) in samples from the analyzed section varied from 0 to 150 thousand specimens per 1 g of dry soil. The density of sponge spicules is relatively low: from 0 to 6,752 specimens per 1 g of dry soil (Figure 9).

There were 87 species, varieties and forms of testate amoebas belonging to the genera *Arcella, Centropyxis, Cyclopyxis, Plagiopyxis, Heleopera, Hyalosphenia, Nebela, Difflugia, Cucurbitella, Quadrulella, Phryganella, Assulina, Valkanovia, Euglypha, Trinema* and *Difflugiella* registered in the samples. Representatives of *Centropyxis* (19 species) and *Difflugia* (20 species) prevailed. These genera are of key importance for reconstruction of the paleo-water regime. Many representatives of *Centropyxis* and *Difflugia*, particularly some species of *Centropyxis*, are indicators of mesotrophic habitats. Some species of *Difflugia* are typical

– a plant inhabiting margins of lakes and rivers in the central part of European Russia – were considered individually.

dwellers of aquatic habitats. The number of species in samples where the concentration of rhizopods was maximal (60–80 cm) corresponds to the number of species in contemporary undisturbed habitats. Diversity of rhizopods is correlated with their concentration (Figure 10).

Analysis of results was carried out in correspondence with zones defined for the soil-sedimentary section.

Zone I: 170 – 140 cm

Single finds of diatoms were registered. Sponges and rhizopods have not been found (Figure 9) within the zone. A great number of hexagonal phytoliths belonging to some species of sedges (*Carex acutiformis*, *C. timentosa*, *C. stenophylla*, *C. distan;* Bobrov *et al.*, 2001) were registered in the sample between 170–160 cm. A part of these species is related to the hydrophilous group. Taking this into account, it is possible to suppose increased wetness while Garbi-Urbic materials of the layer 170–160 cm were accumulating. Hydrophilous species of rhizopods are dominant in the layer 160–150 cm; soil species of *Centropyxis* and *Plagiopyxis* were registered in the layer 150–140 cm. This indicates a slightly disturbed habitat as the layer

contains a considerable proportion of species belonging to the genera *Arcella*, *Hyalosphenia* and *Euglypha*, *Trinema* are typical of well-developed litters of boreal forest soils. The zone is generally characterized by a maximal number of species related to three ecological groups: soil, bog and hydrophilous. Thus while Garbi-Urbic materials of the layer 170–140 cm were accumulating, conditions were shifting from hydromorphic to more or less automorphic.

Zone II: 140 – 90 cm

Rhizopods were not been found at the depths 140–130, 120–110 or 100–90 cm. The absence of rhizopods is likely attributable to short and fast periods of natural or anthropogenic sedimentation or to the elimination of paleocenosis due to rising biological activity and destruction of rhizopod shells. Hydromorphilous species of rhizopods were registered in all samples of the zone where rhizopods are found. In the layers 130–120, 110–100 cm all ecological groups of rhizopods indicate a probable shift to more automorphic conditions at the corresponding time.

Finds of diatoms in all samples of the zone provide additional evidence of mainly hydromorphic conditions. High concentrations of diatoms in the layer 120–110 cm justify the assumption of extremely wet conditions. One more argument for that are the numerous phytoliths of reed (*Phragmites*) occurring in this zone. The first quantitative

maximum of phytoliths was registered in layer 140–130 cm. These were mostly phytoliths of grasses with a considerable quantity of reeds. Layers where reed phytoliths are accumulated are located at the depths 140–130, 120–110, 90–40 cm (Figure 11). Neither reed phytoliths nor diatoms and rhizopods were found in the sample 100–90 cm (probably this sample corresponds to a phase of intensive sedimentation). Presumably hydrological conditions during the accumulation of Garbi-Urbic material were changing sharply compared to the conditions recorded in Zone I.

Zone III: 90 – 42 cm

The maximal densities of rhizopods were registered in the samples 90–80, 80–70, 60–50 cm (Figure 10). At these depths, their density is comparable to that of contemporary soils in the boreal forest zone (Schönborn 1966). Such a density is typical of undisturbed habitats. The most flexible communities of rhizopods, including all ecological groups, were described at the depths 90–80, 80–90 cm. All ecological groups other than the hydrophilous group were suppressed in the layer 70–60 cm. This layer was most likely formed in conditions of enhanced wetness, as it was inhabited by the typical hydrophilous species of *Difflugia*. All ecological groups of rhizopods occur at the depth 50–40 cm. Then diversity decreases and only hydro-philous species remain. A maximum of reed phytoliths was
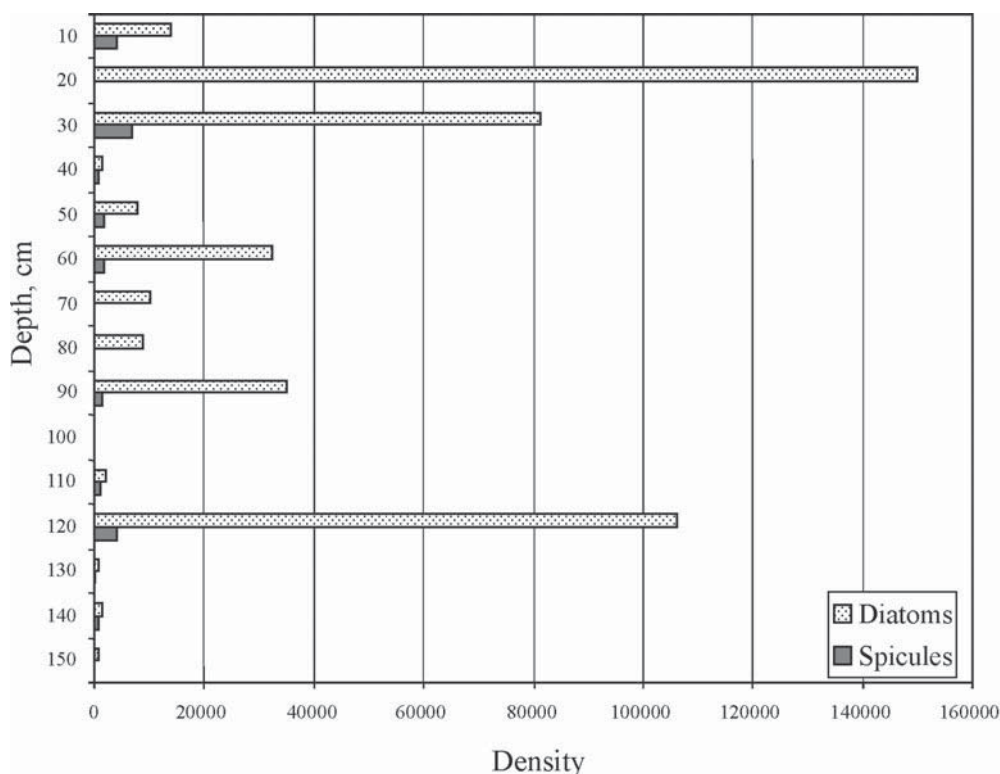

Figure 9. Frustules of diatoms and spicules of sponges: distribution along the profile (exemplars per 1 g of absolutely dry soil).
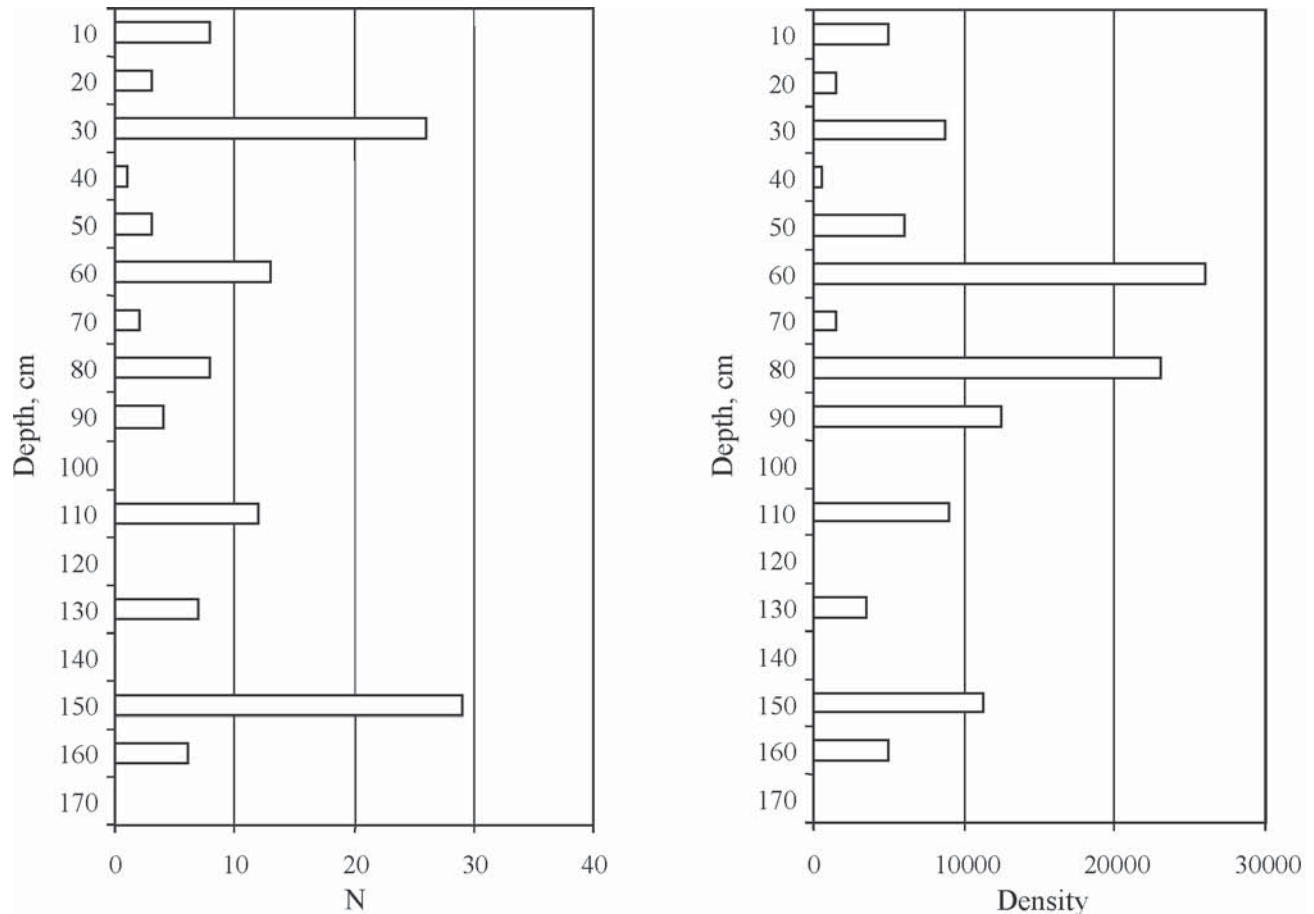
Figure 10. Distribution along the profile: A) number of testate amoebas' species (N); B) density of testate amoebas (exemplars per 1 g of absolutely dry soil).

observed at the depths 70–60 and 50–40 cm. This supports the results of rhizopod analysis that consider this layers as very wet habitats.

Zone IV: 42 – 0 cm

Sediments are represented by alluvial loam. This zone corresponds to the post-anthropogenic period of enhanced alluvial sedimentation. The zone was subdivided into a number of layers based mostly on the results of rhizopod analysis. This zone reflects the most dynamic and contrasting changes in the water regime.

Layer 1 (40 – 30 cm). Rare finds of hydrophilous species of rhizopods, diatoms and sponge spicules occur here. A sharp increase of grass phytoliths (excluding reeds) and an increase in general diversity of phytoliths were observed in respect to the samples immediately above and below (Figure 11). This layer probably records changes in the water regime, sharply diminished human impacts, and changes in the ecological situation in general.

Layer II (30 – 20 cm). This layer is characterized by a sharp rise in density of diatoms and the diversity of rhizopods (Figures 9, and 10) on the background of abundant hydrophilous species belonging to *Difflugia* (Figure 8) and sphagnicole species of the genera *Hyalosphenia* and *Heleopera*. The water-bog group makes up nearly 90%. Suppression of hydrophilous species is registered at the depth 20–10 cm. This layer probably records a low phreatic line.

Layer III (20 – 10 cm). Reed phytoliths indicating wet conditions were not found at this depth. Based on the results of rhizopod analysis, hydrological conditions here were the most automorphic within the zone.

Layer IV (10 – 0 cm). In this layer, hydrophilous organisms are re-established, but soil and euryoecic species are dominants in the community of rhizopods.

Thus, repeated changes in the water regime from hydromorphic to more or less automorphic occurred in this part of the floodplain within the period when Garbi-Urbic materials were accumulated. Alternation of wet and dry phases were interrupted by intensive sedimentation at the depth 100–90 cm and, probably, also at the depths 120–110 and 140–130 cm. Phases of intensive influx of biogenic silica with spring floods were registered at the depths 70–60 and, perhaps, 50–40 cm as based on data of rhizopod
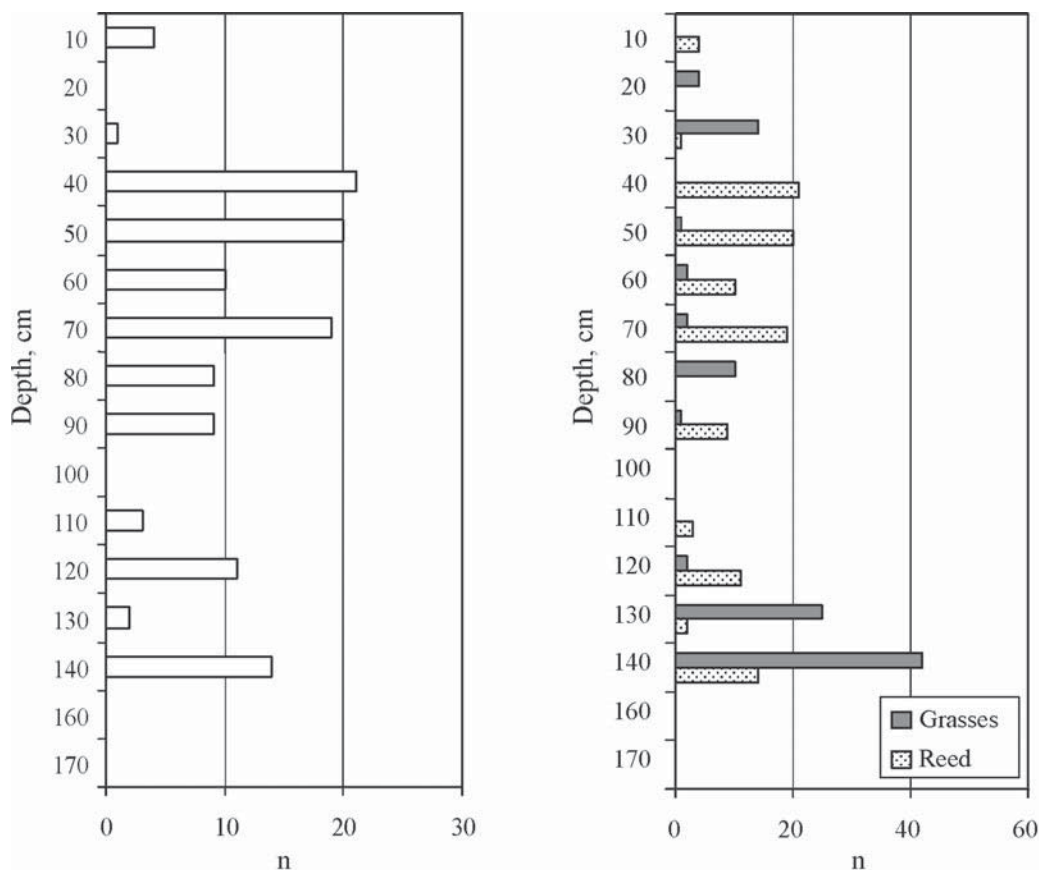
Figure 11. Phytoliths: A) distribution of phytoliths along the profile; B) distribution of grass (reeds in particular) phytoliths along the profile. n: number of grass phytoliths per 300 phytoliths.

analysis. These phases end with a period of relatively dry conditions in the floodplain. Then human impact ceased, alluvial loam was deposited and surface Distri-Gleyic Fluvisols developed in it. This last period of the soil-sedimentary section formation is characterized by the most dynamic and contrasting changes in water regime according to the evidence of biogenic silica studies.

GENERAL CONCLUSIONS

The following general conclusions have been drawn regarding the evolution of the local landscapes during the Subatlantic period of the Holocene. Landscapes of the Early Medieval pre-urban centre Gnezdovo area changed significantly during the Subatlantic. Both human impact and climatic changes led to this evolution. Subatlantic history of human impact as imprinted in the floodplain soil-sedimentary systems agrees well with archaeological data on cultural development of the region (Bronnikova *et al.*, 1998). Short but concentrated and intensive early medieval human impact related to settlement caused crucial changes in vegetation and floodplain soil-sedimentary systems.

Therefore this was a key period for subdividing the Subatlantic into evolutionary phases. Major phases are defined as follows.

Phase I

Characterized by low and dispersed human impact (approximately 3,000–1,100 BP). This phase is generally marked by widespread zonal forest ecosystems. Forests were only slightly and periodically disturbed by dispersed human land-use activities: habitation, pasturing and crop growing (periodical slight rises of cultivated plants and accompanying weeds, grazing indicators, other culturally-induced plants). Within the phase, climate conditions became less humid. This caused the following changes in vegetation: modest natural deforestation, a rise in dry-meadow plants, and the elimination of water plants and algae from floodplain ecosystems.

The phase included a stage of active floodplain sedimentation followed by a drier period when sedimentation ceased and the floodplain was functioning most of the time as an unflooded terrace. As long as sedimentation processes

stopped, normal zonal pedogenesis began in the floodplain and Luvisols formed. We have no local data to judge about the beginning of the drier period. According to recent data obtained in adjacent regions of the Dnieper's basin (Sycheva, 1999), alluvial deposits underlying buried Subatlantic paleosols in soil-sedimentary sections of floodplains are ^{14}C dated to 2,400 BP. This leads to the conclusion that the period of ceased alluvial sedimentation gave a way to Luvisol formation in the floodplain not earlier than 2,400 BP.

Phase II

Intensive and locally concentrated human impact marked this phase of the early medieval settlement (1,100–1,000 BP). This phase lasted only about 100–150 years, but caused crucial local transformations in vegetation and the soil-sedimentary systems. The area of the settlement and vicinities suffered extreme deforestation due to extensive habitation and agricultural activities. Culturally induced plants favored by culture took a major place in plant communities. Pastures and arable lands where a great variety of crops were grown (wheat, hemp, buckwheat and others) were widespread here.

The water regime in the floodplain during formation was relatively dynamic. Alternation of short wet and dry phases were sometimes interrupted by alluvial sedimentation, especially towards the end of this phase. This should be considered as a result of gradual enhancement of floodplain sedimentation at that time. Nevertheless spring floods were still relatively irregular. This made possible functioning of the settlement in the floodplain.

Urbi-Anthropic Regosols were forming within the settlement borders due to partial or complete removal and/ or turbation of original Luvisols and the introduction of Garbi-Urbic materials. These anthropogenic paleosols are highly specific in their morphology, arrangement and composition.

Phase III

Cessation of local human impact but generally enhanced regional human impact (after 1,000 BP). This phase starts with a decline of the early medieval Slavonic settlement. Cessation of the local human impact resulted in a slight forest invasion (both on terraces and in the watershed), and a sharp but short decrease in cultivated plants and other plants favored by culture. It is known that after the decline of the settlement at Gnezdovo, between the 11th – 13th centuries, the number of settlements in general increased sharply in the Upper Dnieper region. This again caused deforestation and the re-establishment of indicators of human impact in the vegetation cover.

Floodplain sedimentation increased sharply. Garbi-

Urbic materials of the settlement and Luvisols beyond the settlement borders were buried under floodplain alluvium about 1,000–800 BP. This data supports a proposal that a number of years with high spring floods in the Dnieper basin occurred around the 12th century (Shvets, 1972). Enhancement of alluvial sedimentation could be explained both by a climatic change and by increased human impact. Paleoclimatic data for the territory of the Russian plain testify to a considerable increase in humidity at that time (Borisenkov, 1988; Klimanov *et al.*, 1994). Widespread deforestation and ploughing could be additional reasons for active sedimentation during the last thousand years (Alexandrovskiy, 2002).

At the end of this phase, the formation of contemporary Fluvisols took place due to a new decrease in sedimentation rate and to the stabilization of the floodplain surface. According to Sycheva (1999), recent Fluvisols in the basin of Dnieper have an age of no more than 200–150 years BP.

ACKNOWLEDGEMENTS

REFERENCES

Alexandrovskiy, A.L., 2002, Development of soils of eastern Europe in Holocene: Moscow, Russian Academy of Sciences, Institute of Geography, Doctoral Thesis, 48 p. (In Russian).

Andersen, S.Th., 1984, Forests at Løvenholm, Djursland, Denmark, at present and in the past: København, Det Kongelige Dansk Videnskabernes Selskab, Biologiske Skrifter, 24, 1.

Behre, K.E., 1988, The role of man in European vegetation history, *in* Huntley, B., Webb, I.T. (eds.), Vegetation history: Dordrecht, Kluwer, 633-672.

Berglund, B.E., Ralska-Jasiewiczowa, M., 1986, Pollen analysis and pollen diagrams, *in* Berglund, B.E. (ed.), Handbook of Holocene Palaeoecology and Palaeohydrology: Chichester, U.K., Wiley, 455-484,

Berglund, B.E., Birks, H.J.B., Ralska-Jasiewiczowa, M., Wright, H.E. (eds), 1996, Paleoecological Events During the Last 15,000

Years; Regional Syntheses of Palaeoecological Studies of Lakes and Mires in Europe: Chichester, U.K.,Wiley, 764 p

Birks, H.H., Birks, H.J.B., Kaland, P.E., Moe, D., 1988, The cultural landscape – past, present and future: Cambridge, U.K., Cambridge University Press, 544p.

Bobrov, A.A., Charman, D.J., Warner, B.G., 1999, Ecology of Testate Amoebae (Protozoa: Rhizopoda) on Peatlands in Western Russia with Special Attention to Niche Separation in Closely Related Taxa; Protist: Frankfurt am Main, Fischer Taschenbuch Verlag, 150, 125-136.

Bobrov, A.A., Bobrova, E.K., Alexeev, J.E., 2001, Biogenic Silica in Biosystematics – Potential Uses. Phytoliths; Applications in Earth Sciences and Human History, Proceedings: Lisse, A.A. Balkema Publishers, 279-288.

Borisenkov, E.P. (ed.), 1988, Climatic variations during the last 1,000 years: Leningrad, Glavnov Geofizica Observatory, "Gigrometeoizdat", 408 p. (In russian).

Bronnikova, M.A., Pushkina, T.A., Königsson, L.K., 1998, Gnezdovo: Slavonic early medieval pre-urban center, *in* 4th Annual meeting of the European Association of Archaeologists, Succession of cultures and landscape development in the region, Book of abstracts: Göteborg, Sweden, 136.

Chambers, F.M., 1993, Climate change and human impact on the landscape, studies in palaeoecology and environmental archaeology: London, Chapman and Hall, 270 p.

Chichagova, O.A., Gerasimov, I. P., Targul'ian, V.O., 1985, Radiocarbon dating of soil humus: Moscow, Nauka, 158 p. (In russian).

Fries, M., 1962, Studies of the sediments and the vegetational history in the Ösbysjön basin, north of Stockholm: Copenhagen, Oikos, 13, 76-96.

Fáegri, K., Iversen, J., 1989, Textbook of Pollen Analysis: København, 4th ed., 293 p.

Hiller, D.A., 2000, Properties of urbic anthrosols from an abandoned shunting yard in the Ruhr area, Germany: Catena, 41, 249-259.

Huttonen, R.E., Tolonen, K., 1972, Pollen analytical studies of prehistoric agriculture in northern úngermanland, Early Norrland 1: Uppsala, Sweden, Kungliga Vitterhets Historie och Antikvitets Akademien.

Grimm, E.C., 1991, TILIA and Tilia graph: Springfield, U.S.A., Software available from Illinois State Museum.

Khotinskiy, N.A., 1984, Holocene climatic change, *in* Velichko, A.A., Wright, H.E., Barnosky, C.W. (eds.), Late Quaternary environments of the Soviet Union: Minneapolis, University of Minneapolis Press, 305-309.

Klimanov, V.A., Khotinskiy, N.A., Blagoveshenskaya, N.V., 1994, Short-term climatic fluctuations within the historical period in the centre of Russian plain, *in* Short-term and Sharp Landscape–climatic Changes of the Last 15,000 Years: Moscow, 150-158. (In russian)

Krenke, A.N., Zolotokrylin, A.N., Popova, V.V., Chernavskaya, M.M., 1989, Reconstruction of dynamic in moisturising and air temperature within the historical period (based on natural indicators), *in* Khotinskiy, N.A. (ed.), Paleoclimates of the Late Glaciation and Holocene: Moscow, Nauka, 34-38. (In russian).

Königsson, L.K., Atanasova, J., Possnert, G., 1995, Construction and publication of diversified pollen records – a practical and economic dilemma: Bruxelles, PACT 50.

Königsson, L.K., Possnert, G., Hammar, T., 1997, Economical and cultural changes in the landscape development at Novgorod: Tor , Sweden, 29, 353-387.

Lyakhov, M.E., 1984, Climatic extremes in the central part of European USSR in the 13th to 20th centuries: Izvestiya Akademiya Nauk, SSSR (Academy of Sciences of USSR), Seriya Graficheskaya 6, 68-74. (In russian)

Moore, P.D., Webb, J.A., Collinson, M.E., 1991, Pollen Analysis: London, Blackwell Scientific, 2nd ed., 206 p.

Nejshtadt, M.I., 1957, History of forests and paleogeography of the USSR in Holocene: Moscow, Academy of Sciences of USSR, 404 p. (In russian)

Ralska-Jasiewiczowa, M., 1977, Impact of prehistoric man on natural vegetation recorded in pollen diagrams from different regions of Poland: Folia Quaternaria, 49, 75-91.

Schirrmeister, L., Siegert, Ch., Kuznecova, T., Kuzmina, S., Andreev A., Kienast, F., Meyer H., Bobrov, A., Wetterrich S., 2002, Paleoenvironmental and paleoclimatic records from permafrost deposits in the Arctic region of Northern Siberia: Quaternary International, 89, 97-118. 89, 97-118.

Schönborn, W., 1966, Beschalte Amoben (Testacea): Wittemberg, Ziemsenverlag, Lutherstadt die neue Brehm–Bucheri, 357, 112 p.

Sedov, S.N., Zazovskaya, E.P., Bronnikova, M.A., Kazdym, A.A. and Rozov, S.Y., 1999, Late Holocene man-induced environmental change in central Russian plain: paleopedological evidences from early-medieval archaeological site, *in* Climatic Change; Paleopedological and Soil Rock Magnetic Approaches: Chinese Science Bulletin, Supplement, 44 (1), 159-165.

Shishov, L.L., Dobrovol'skij, G.V. (eds.), 1997, Russian Soil Classification: Moscow, V.V. Dokuchaev Soil Science Institute, Dokuchaev Society of Soil Scientists of Russian Academy of Sciences, 236 p.

Shvets, H.I., 1972, The salient events of hydrologic in the south-west of USSR: Leningrad, Gidrometeoizdat, 244 p. (In russian).

Simmons, I.G., Tooley, M.J., 1981, The environment in British prehistory: Ithaca, Cornell University Press, 334 p.

Stroganova, M., Myagkova, A., Prokof'eva, T., Skvortsova, I., 1998, Urban soils; genesis, classification and functions, *in* Dobrovolskij, G.V. (ed.), Soils of Moscow and Urban Environment: Moscow, PAIMS, 24-50.

Sycheva, S.A., 1994, Soil-geomorphologic aspects of cultural layer formation in ancient settlements: Soil Science (Pochvovedenie), 3, 28-33. (In russian).

Sycheva, S.A., 1999, Cycles of soil formation and sediment accumulation in the Holocene (according to ^{14}C data): Eurasian Soil Science, 32 (6), 613-624.

Vodyanitskiy, Y.N., 1992, Formation of iron oxides in soil: Moscow, Russian Academy of Agricultural Sciences, Dokuchaev Soil Science Institute, 275 p. (In russian).

World Reference base for soil resources (WRB), 1998, *in* World Soil Resources Reports, 84: Italy, Rome, Food and Agricultural Organization of the United Nations, 88p.World Reference base for soil resources (WRB), 1998, *in* World Soil Resources Reports, 84: Italy, Rome, Food and Agricultural Organization of the United Nations, 88p.