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Articles

An approach for spatial analysis on the medieval Ust-Voikar settlement (subarctic Western Siberia) using macroremains and non-pollen palynomorphs

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The settlement of Ust-Voikar is one of the unique multilayered archaeological sites of north-west Siberia. The settlement was inhabited in the late Middle Ages and the early modern period by the Ob Ugrian or northern Khanty ethnographic group. Due to the presence of a frozen cultural layer ruins of wooden residential buildings and other organic materials are well preserved. Plant macroremain, pollen and non-pollen palynomorph (NPP) analyses were applied to samples of the cultural layer from different parts of buildings and from space between them to establish the vegetation cover, plants used by the population, and differences between functional zones in the buildings. For the first time, the NPP analysis combined with statistical methods were used to clarify the settlement planning and human economic activity. Plant communities around the Ust-Voikar settlement were typical for the northern taiga subzone, some settlement's areas were overgrown with weed vegetation. Residents did not engage in agriculture and used local plant resources for construction, medicinal and food purposes. According to macroremain and NPP data were reconstructed (i) the use of spruce branches and cereal bedding indoors and outdoors on wet sites; (ii) the careful use of fire indoors; (iii) the presence of animals indoors; and (iv) whipworm infection. The cluster analysis and principal component analysis of NPPs helped to clarify the planning affiliations of several samples with the unclear origin and to suggest ways in which archaeological objects were used by the inhabitants.

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Keywords

North-west Siberia, Middle Ages, Ob Ugrians, Khants, plant macroremains, pollen, human activity, non-pollen palynomorphs

Introduction

Ust-Voikar is a multilayered archaeological settlement that belongs to a group of unique archaeological sites that provide information about the culture of the ancestors of the indigenous peoples of northwestern Siberia. Its uniqueness is due to the presence of a frozen cultural layer, which ensures a high degree of preservation of archaeological objects and objects made of organic materials, including archaeobiological remains.

The Ust-Voikar settlement is located in the south-west of the Yamal-Nenets Autonomous District, Tyumen Region, Russian Federation (65º40' N, 64º38' E), approximately 130 km south-west from Salekhard the capital of the district (Fig. 1).

The history of excavations in the settlement is divided into two periods. The first was in 2003-2008, and the second in 2012–2016 (Garkusha 2020), carried out by the Institute of Archaeology and Ethnography SB RAS under the direction of A.V. Novikov (Novikov and Garkusha 2017). To date, the excavations have revealed about thirty well-preserved ruins of wooden dwellings. Based on the locations of the buildings, it is possible to reconstruct the planography of the settlement in different periods of its history.

The ethnic composition of the settlement inhabitants, taking into account the ethnic history of the region, can be characterised as Ugrian-Samoyeds, with the presence of a Komi-Zyrians component. This substratum served as a basis for the formation of the Ob Ugrian ethnographic group - the Northern Khanty (Martynova 1998; Perevalova 2004).

Dendrochronology has been used to determine the age of the buildings. A general period of settlement inhabitation has been established: from the boundary of the thirteenth and fourteenth centuries to the end of the nineteenth (Gurskaya 2006, 2007, 2008). New dendrochronological studies allowed to clarify that the period of active construction in the settlement ended in the middle of the eighteenth century (Garkusha 2022).

In archaeological research on the Middle Ages worldwide, non-pollen palynomorph (NPP) analysis is mostly used to estimate anthropogenic impact and the availability of agriculture or grazing activity (Jankovská and Pokorný 2002; Schofield and Edwards 2011). In the majority of such studies, spores of coprophilous fungi (Mazier et al. 2009; Gauthier et al. 2010; Feeser and O’Connell 2010) and cyanobacterial cyst content in lakes (van Geel et al. 1994; Riera et al. 2006) are examined in addition to pollen. Studies on parasite remains are conducted to assess the spread of disease and the level of contamination in ancient populations (Mitchell et al. 2011; Brinkkemper and van Haaster 2012). Interesting data have been obtained from the pollen and NPP studies of hoard contents (Chichinadze and Kvavadze 2013), helping to establish the use of the artefacts in question.

Despite the widespread study of NPP as an indicator of various human activities, most studies use samples taken from vertical sections of sediments or pointwise sampling from archaeological objects or burials. Previously, issues related to the spatial organisation of settlements and the planning of individual buildings have not been considered by using NPP data in most studies (Gavrilov et al. 2016).

Figure 1. *Map of the Ust-Voikar settlement's location.*

Archaeobotanical researches at archaeological sites in the north of Western Siberia are limited (Vizgalov et al. 2013). Plant macrorest studies have been carried out on the indigenous settlements of Nadym Fort (Korona 2015; Vizgalov et al. 2013) and Polui Cape town (Korona 2013); on an Ust-Polui ritual complex chronologically related to the boundary of ages (Bachura et al. 2017); and on samples of thecultural layer of Mangazeya (Vizgalov et al. 2013). Accumulations of plant remains from two thirteenth-century burials at the Zeleny Yar site have also been studied (Korona 2005; Vizgalov et al. 2013: 310). Pollen analysis has been carried out on materials from the settlement of Tiutei-Sale 1 (Panova 1998; Vizgalov et al. 2013: 247–249) and the ancient settlement of Yarte 6 (Panova 2008), as well as the abovementioned ritual complex at Ust-Polui (Panova and Yankovska 2008). These studies mainly focused on vertical sections.

Examples where the results of archaeological and botanical analyses are interpreted in terms of settlement planning are mostly related to plant macrorest data. Plant macrorest samples from the Nadym Fort reveal an uneven ratio between a small amount of birch seeds and abundances of birch wood and barkwood at different depths (Vizgalov et al. 2013). This finding allowed the authors to assume that some of the samples could indicate the places previously located under the roof. The composition of the filling between the decks of one building was also analysed (Vizgalov et al. 2013: 295, 297). In Mangazeya, along with the vertical columns, accumulations of plant remains obtained across the horizontal plane were also studied. However, this factor was not considered in the interpretation of the results (Vizgalov et al. 2013: 337–339).

This publication presents the first archaeobotanical study of the cultural layer of the Ust-Voikar settlement. The analyses of plant macroremains, pollen and NPPs were conducted. The study aimed to establish the site’s vegetation cover and to determine the peculiarities of the plants used by the population. The combination of NPP analysis and a statistical approach also clarified the issues of territory planning and human economic activity at the Ust-Voikar settlement.

Materials and methods

Site description

The Ust-Voikar settlement is located within the boundary of the the Voikar Landscape Province in Ural-Yenisei Taiga Region of the Nizhneobskaya Lowland. It falls within the northern taiga subzone of Siberia (Larin 2004). The Ob Valley in the Yamal-Nenets Autonomous District corresponds to the Ob-Irtysh Floodplain Province. The climate is continental and is characterised by long, cold winters with strong winds and blizzards; short, cool summers with long, light days; and spring floods lasting 70–80 days. The average temperature is −22ºC in January and +14ºC in July, and the average annual precipitation is about 400 mm.

The settlement is located in the vicinity of Lake Voikarsky Sor, on the left bank of one of the branches of the Malaya Ob river (the Gornaya Ob). It occupies the residual hill of the terrace. Most parts of the residual hill are characterised by flat rise, and its southern part by an elevation. The elevation and the flat rise on which it is located are free from woody vegetation and covered with high grass.

The elevation has a length of about 90–100 m (at the bottom) and a width of up to 50 m. Its flattened peak is over 60 m long and 15–20 m wide. The maximum height of the eastern slope is about 8–9 m, and it has swampy lowland at its base. The western slope is 4–5 m above a flat rise (Figs 2a, b, c). That elevation was the site of all excavations. It is arguably composed entirely of a thick layer of shreds and other woodworking waste.

This kind of cultural layer formation is associated with active use of wood and shrub vegetation in the economy and life of the local population. The accumulation of wood and shrub remains was quite fast; the layer had heat isolation properties and had not been thawed completely, and part of it was in a constant frozen state. Along with the accumulation of a cultural layer, the permafrost rose up; as a result, most of the layer was gradually turning to a frozen state (Vizgalov et al. 2013).

In the vicinity of the archaeological settlement grows a mixed forest of deciduous (mainly birch) and coniferous (spruce) trees. According to Gurskaya (2006, 2008), the average age of the spruce trees is 120–150 years. There is a larch forest on the northern bank of Lake Voikarsky Sor, and old Siberian pines grow on the wetland. According to Dunin-Gorkavich (1910), at the turn of the nineteenth and twentieth centuries the Voikar river, which flows into the lake, was considered the border of Siberian pine; to the north of that border, the species hardly appeared. Low, marshy areas at the settlement site are occupied by willow shrubs and marsh communities (Fig. 2d).

Architecture and planning structure of the settlement

The settlement's architecture is represented by residential buildings of rectangular shape. In terms of size, these can be divided into two groups: one group of small buildings with walls 2.5–3 m long, and a second group of larger buildings with walls 6–8 m in length. Residential buildings can be identified by the presence of a fireplace. These dwellings had either a frame-and-pillar structure or took the form of classic log houses.

The buildings' arrangement in the excavated areas suggests the presence of a central street, located along the hill. The buildings were presumably located opposite each other. It should be noted that such spatial organisation is assumed for the late stages of the settlement's existence.

The large frame-and-pillar houses are similar to the two-chambered buildings at Nadym Fort, Polui Cape town. Such houses consist of a heated inner room and a corridor (or 'gallery') located along the perimeter of the inner room. The outer wall of this 'gallery' is also the outer wall of the house (Kardash 2009, 2013). For the large buildings, a special principle regarding their location has been established, while for small buildings none was noted. This principle consists of building a particular dwelling in the same place, over and over again, for a long period of time.

After partial dismantling of the earlier construction, a new house was built on its remains, and the borders of the houses were often very close. Thus, several tiers were gradually formed from the remains of the abandoned houses on the site chosen for construction. The houses might have different constructions: often, some structural elements were kept in the dismantled building and became part of the new house. In such cases, their original purposes may have changed: for example, the lower wall beams of an early log house became a support for the floor deck in a new house.

Figure 2. *Plain view of the Ust-Voikar settlement.* ***A*** *– View of the hill from the north. The image was taken from the northern part of the elevated site.* ***B*** *– View of the hill from the west. The image was taken from the edge of the floodplain during flooding.* ***C*** *– Top of the hill. View from north to south.* ***D*** *– Mixed forest outside the elevated site. View from the northern end of the hill.*

The tiers of house remains often demonstrated continuity in the organisation of the interior space. For example, the fireplaces located in the centres of the buildings retained their location on many tiers. There was thus a continuous accumulation of combustion residues within the fireplace areas. The location of doorways in the dwelling structures was also preserved, and a smooth transition was discovered between the last levels of a lower construction's wooden floors and the first levels of the floor of an upper construction. An example of such construction are complexes formed from tiers of separate buildings: nos. 7, 7/1, 7/2 and nos. 9, 9A, 11 (Figs 4–7).

When a large frame-and-pillar dwelling structure was transformed into a log house, the internal walls were dismantled. The house thus became a single-chamber building. In the place of the former 'gallery', boardwalks (plank-beds) were created and can be interpreted as places for sleep and rest. In fact, the filling of one building was smoothly transferred to the subsequent one. In such cases, it is difficult to correlate different levels of filling with specific buildings.

The main types of wood used in construction were spruce (*Picea obovata* Ledeb., 60%); larch (*Larix sibirica* Ledeb., 28%); Siberian pine (*Pinus sibirica* Du Tour, 4%); and birch (*Betula* sp., 8%) (Gurskaya 2008). The vast majority of construction wood is derived from spruce.

Sampling principles

For the macroremain (seeds, leaves, fruits, fragments of roots, wool, etc.) and microremain (pollen, spores, non-pollen palynomorphs) analyses at the settlement, forty samples were collected during fieldwork in 2012–2016.

This paper presents not the vertical column analysis, but instead, the horizontal distribution of macro- and microremains from functionally different parts of the residential buildings and inter-building space. Through this approach, we test the hypothesis that the distribution of different archaeological remains depends on the functional zone of the dwelling house.

The samples selected for analysis can be categorised according to the constructions to which they belong, as follows:

1. The remnants of building tier nos. 7/2, 7/1 and 7 (from bottom to top). The first two buildings are frame-and-pillar, and the last is a log house. There are no clear signs that sampling places can be attributed to the filling of nearby buildings; however, their belonging to the allocated space-functional zones is precisely defined. Sample nos. 1–10 and 22–28 relate to this group (Figs 3, 4). Sample nos. 22–25 were obtained from filling a wooden 'box'. It refers to the building number 7/1 (Fig. 7a).

2. Building no. 9, log house. Sample nos. 11, 12 and 14 belong here (Fig. 5).

3. Tiers from the remnants of building nos. 11 and 9A (from bottom to top). The first building is frame-and-pillar and the second is a log house. Again, it is difficult to differentiate adjacent building fillings. Sample nos. 31–36 belong here (Fig. 6).

4. Building no. 10, log house. Sample nos. 39 and 40 were collected here.

5. Inter-building space. Sample nos. 13, 15, 17–21, 37 and 38 were collected here.

6. Object 5. Sample no. 29 (Fig. 7b) belongs here.

7. Object 6. Sample no. 30 belongs here.

Space-functional zones (henceforth 'functional zones') were also distinguished. Samples of the cultural layer were grouped according to these zones. Six zones were allocated directly in the area of dwellings, while two zones are associated with separate objects located outside dwellings. The functional zones were distinguished on the basis of analysis of interior features and distribution of artefacts; ethnographic materials were used for specification of the obtained observations. Characteristics of the allocated zones are listed below.

1. **Inter-building space.** This area is associated with the samples derived from places that were reliably located outside the buildings. This area includes sample nos. 13, 15, 17–21, 37 and 38 (Fig. 4b, 5b).

2. The **central part** of the building, traditionally formed around the central fireplace. In large frame-and-pillar houses, this part of the building was demarcated by the internal wall. It is assumed that most of the population's lives and activity took place here. It is also possible to allocate sites directly around the fireplace and along the inner wall; the latter could be used as a place of rest.

There were no internal walls in the log houses. In these buildings, the boundaries of the central part of the room were determined by the location of wooden planks along the walls. Such planks are usually interpreted as places for sleep and rest (plank-beds). This area includes sample nos. 1, 2, 5, 9, 10, 12, 28, 31 and 32 (Fig. 3b, 4b and 5b).

3. **Gallery.** This was the unheated part of a frame-and-pillar house, located at the perimeter of the

interior room and bordered by the exterior walls of the house. It could be used as a place to store various belongings. This area includes sample nos. 3, 6, 8 and 27 (Fig. 3b, 4b).

4. **Entrance zone.** This was the area inside the living room in front of the doorway leading to the street. This zone includes sample nos. 4, 7, 16, 26 and 40 (Fig. 3b, 4b).

5. **Plank-beds.** These, ranged along the walls of log houses, were used for sleeping and resting. This area includes sample nos. 11 and 14 (Fig. 5b).

6. The **corridor** led from the street into the house. It was a wooden construction about 2 m long and as wide as the doorway. This area includes sample nos. 35 and 39 (Fig. 6b).

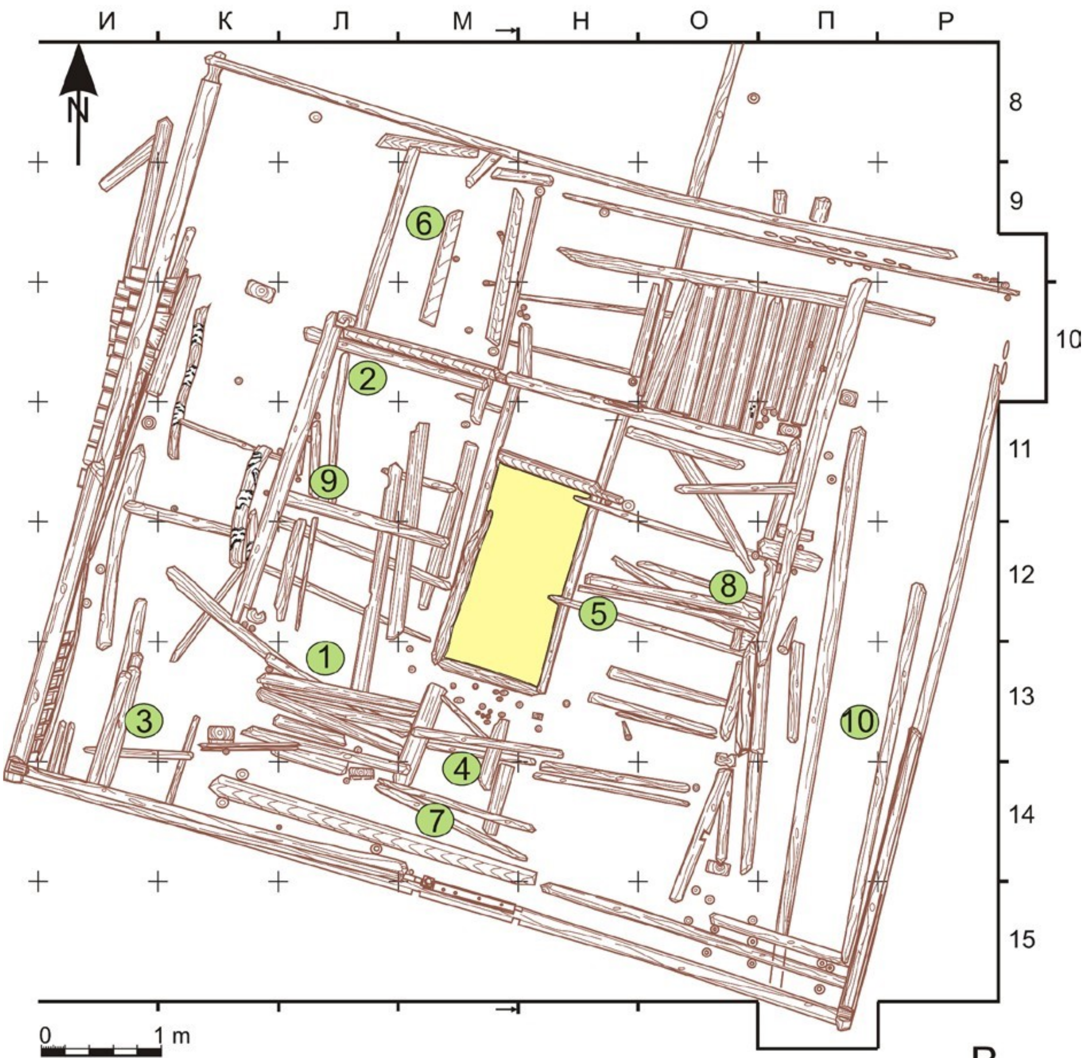
7. **Box.** This structure comprised a long, narrow box of boards, closed at the top. The dimensions of the box were as follows: it had a length of about 2 m, a width of 0.3 m and a height of 0.2 m. The box was outside a residential building, but it began indoors, at floor level, perpendicular to the wall, and pointed down the slope.

A similar construction had previously been encountered in one of the houses and interpreted as a drain for liquid waste. It was probably used for hygiene purposes since coprolites were fixed in its filling (Fedorova 2006). This zone includes sample nos. 22–25 (Fig. 4b, 7a).

8. **Objects 5** and **6** are fenced areas with tightly placed poles of about 1.5 x 1.5 m. The objects are adjacent to one of the outside walls of building no. 7, and are located close to one another. One side of the fence was not closed and was directed towards the lateral wall of the house. It is supposed that the objects were used for economic purposes (in the broad sense). This area includes sample nos. 29 and 30 (Fig. 7b).

9. **Samples of doubtful origin.** This zone represents the contact zone between building no. 9A and building no. 11, located on the lower level. It includes sample nos. 33, 34 and 36 (Fig. 7b). This group was created by necessity, as the samples' places of selection could not be reliably attributed to any functional zone of the buildings. In terms of their planning and stratigraphic positions, they may belong to the 'gallery' of building no. 11, or to the 'zavalinka' of building no. 9A. A 'zavalinka' is a light wooden fence around a building's walls, in this case filled with a cultural layer. It is a source of additional thermal insulation for the walls. Here, the remains of building no. 11's vertical walls became the walls of building no. 9A's 'zavalinka'.

A



B

Figure 3. *Plain view (a) and scheme (b) of building no. 7 (building tier no. 7/1). The photo was taken from the south. The places where samples for the analyses were collected are marked by green circles with the sample's number; yellow marks indicate the fireplace.*

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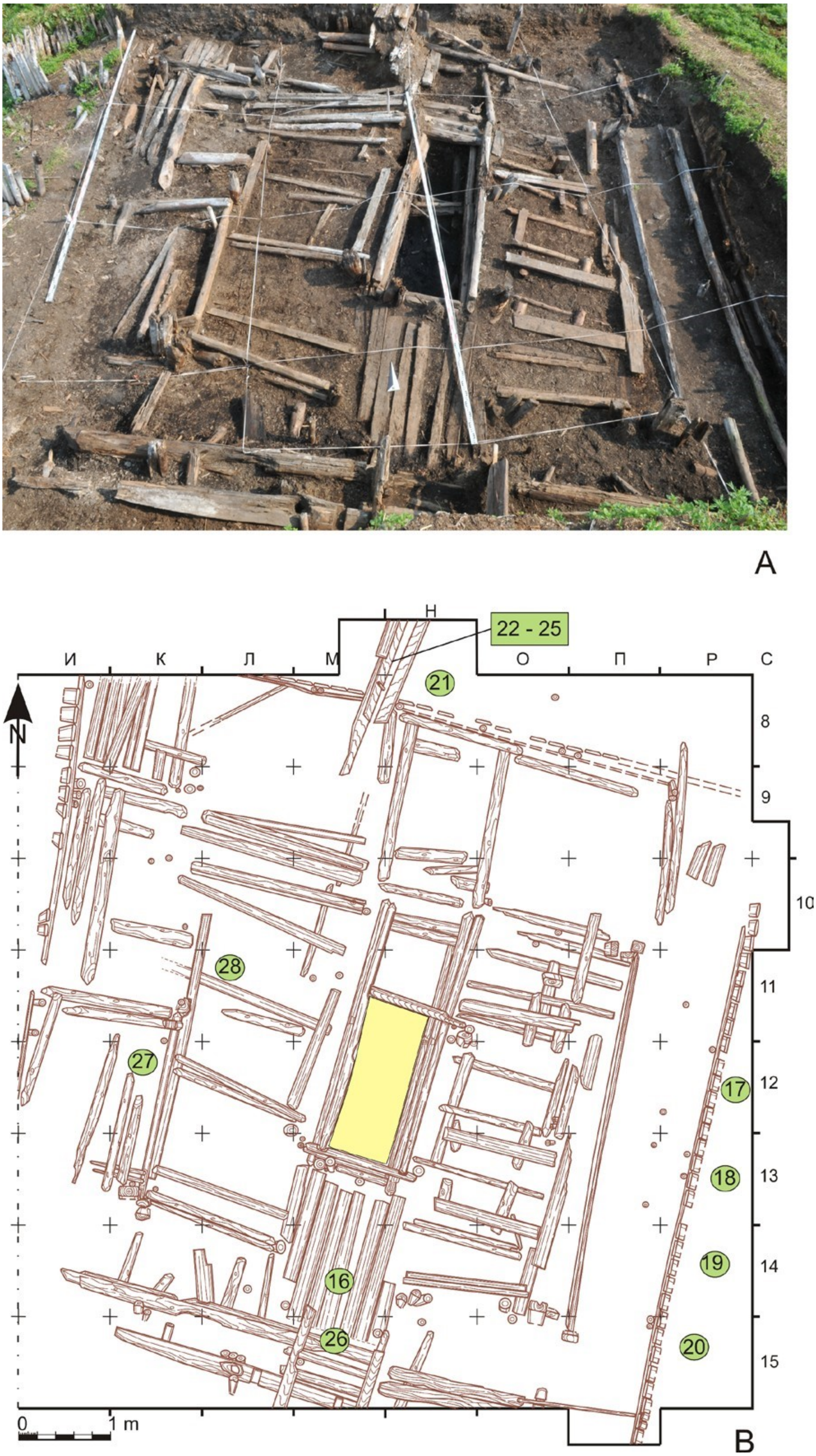
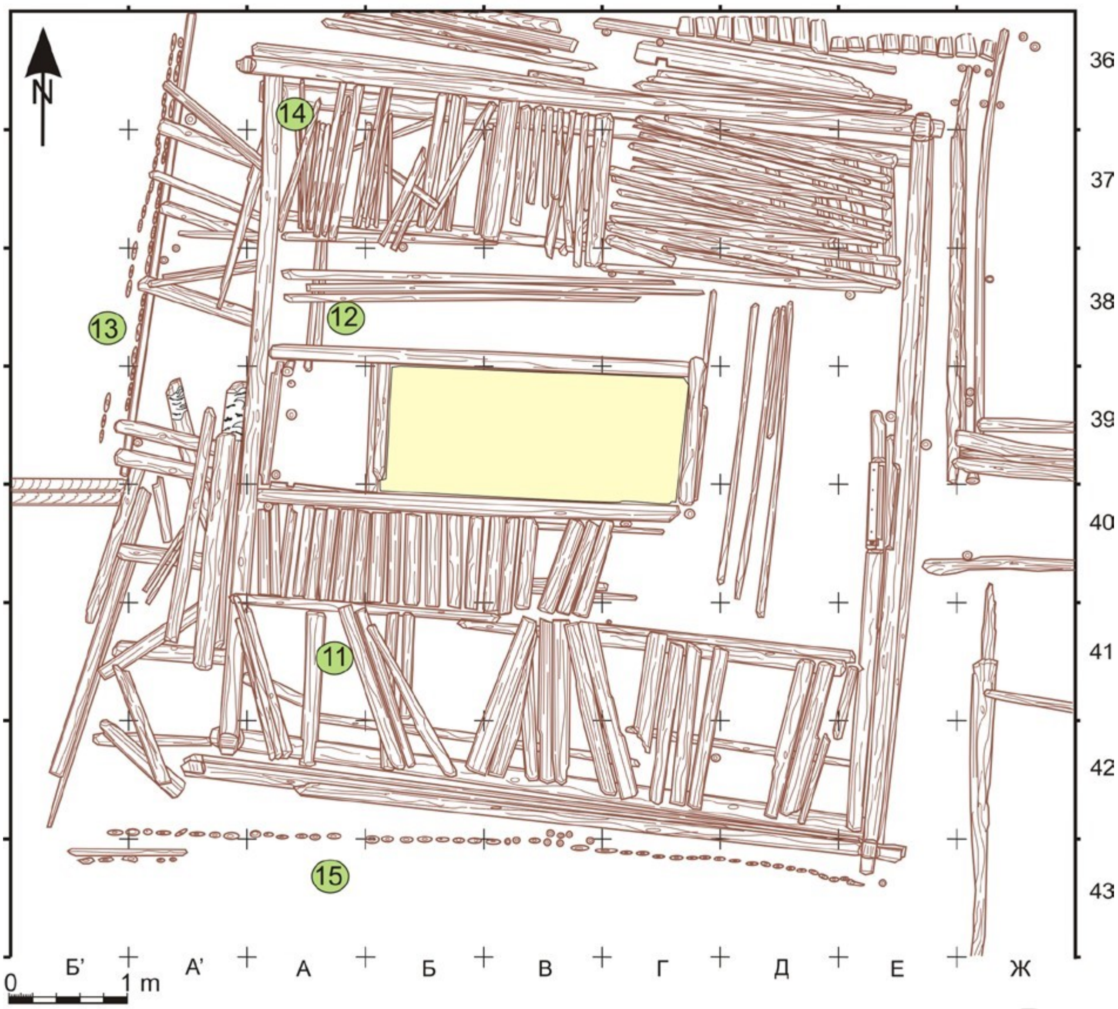


Figure 4. *Plain view (a) and scheme (b) of building no. 7 (building tier no. 7/2). The photo was taken from the south. The places where samples for the analyses were collected are marked by green circles with the sample's number; yellow marks indicate the fireplace.*

Plant macroremain analyses

During laboratory treatment, the sediments 400 ml volume were sieved in water using a set of different mesh sizes (minimum diameter: 0.25 mm). Plant macrofossils were studied using a Zeiss Stemi 2000-C stereomicroscope. Macrofossils were identified using the seed reference collection at the Institute of Plant and Animal Ecology UB RAS (Yekaterinburg), as well as atlases (Dobrokhotov 1961; Katz et al. 1965). A macrofossil diagram was made using the software TILIA 2.0.41 (Grimm 2015). In addition to plant fruits and seeds, samples from the cultural layer included fragments of the bark of coniferous trees and birches, pieces of wood, wood shavings, wood waste and coal. Animal remains were also present, including insects, fish bones and scales, mammal bones, and reindeer wool. Four samples included fragments of insects and of rodent excrement.

A



B

Figure 5. *Plain view (a) and scheme (b) of building no. 9. The photo was taken from the south. The places where samples for the analyses were collected are marked by green circles with the sample's number; yellow marks indicate the fireplace.*

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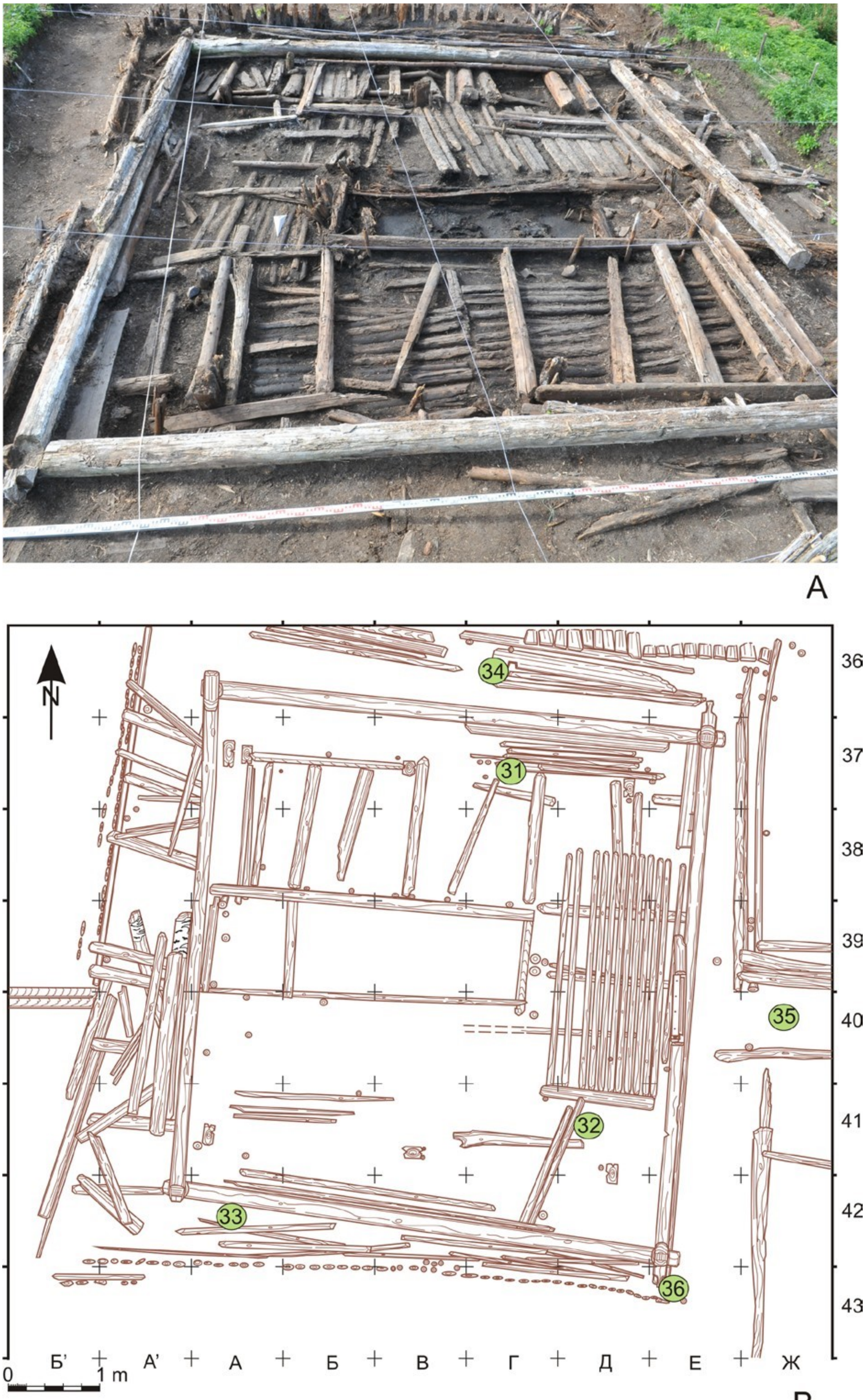

Figure 6. *Mutual spatial arrangement of building nos. 9A and 11. (a) The lower wall beams of log building no. 9A; in the log building, filling of the building no. 11. The photo was taken from the north. (b) Plan of building no. 9A. The places where samples for the analyses were collected are marked by green circles with the sample's number; yellow marks indicate the fireplace.*

Palynological analysis

For pollen analysis, the samples were chemically treated according to the renewed technique (Faegri and Iversen 1989). Samples of 10–15 g were sequentially treated with a 10% solution of hydrochloric acid (HCl) to dissolve carbonates, a 10% solution of potassium hydroxide (KOH) to remove humic acids, and repeated boiling in high-concentration hydrofluoric acid (HF, 36%) to remove silicates. Sample components over 200 µ and less than 7 µ were eliminated using sieves. The prepared sample was studied under a microscope with 400x magnification; microphotographs were made with an AxioCam MRc5 microscope camera. A *Lycopodium* spore tablet was added to each sample for calculating concentrations. For determining pollen species and genera, we used the reference collection of the Institute of Archaeology and Ethnography SB RAS and atlases (Reille 1992, 1995, 1998). The calculation of concentrations, cluster analysis and the construction of a pollen diagram was carried out using TILIA software (Grimm 2015). The pollen diagram was constructed with percentage ratios of taxa, where the total pollen sum of woody and herbaceous plants was taken as 100% (Suppl. material 1).

In addition to pollen, the samples included non-pollen palynomorphs (NPP) which were counted along with pollen grains. NPPs are microfossils that are not pollen or spores of land plants and mosses, and are present on slides prepared for pollen analysis. NPP are mainly represented by spores and residues of coprophilous and soil fungi, amoeba shells, algae and microscopic animal eggs. They and their indicative properties have been described in numerous articles (for instance, van Geel 1978, 1986, 2002; van Geel et al. 1995, 2003; van Geel and Aptroot 2006; van Geel and Grenfell 1996; Yeloff et al. 2007; Miola 2012). The definition of NPP used was based on available published sources and with the help of the information at Non-pollen palynomorphs image database (http://non-pollen-palynomorphs.unigoettingen.de/).

Numerical analyses

NPP concentrations in the samples were used for the analysis. After the samples were treated in the laboratory, they retained different volumes, as different samples contained different amounts of filling material (such as shavings, sand and macroremains). Concentrations are thus an objective parameter that allows comparison of samples with one another. Concentration is measured in the number of NPP units per 1 gram of sample.

NPP zones were established from the NPP data by means of a cluster analysis based on square root transformation (Edwards and Cavalli-Sforza's chord distance) using TILIA software (Fig. 16).

To investigate interactions among the NPP taxa calculated in samples from different functional zones, Principal Component Analysis (PCA) was carried out in CANOCO 5 (Šmilauer and Lepš 2014). NPP concentrations were log-transformed ($Y' = \log(Y + 1)$) and centred. Rare taxa appearing ≤3 times in the sample dataset were removed from the analysis. In total, 26 NPP taxa that appeared more frequently in the samples were retained in the dataset for PCA.

A

B

Figure 7. *Plain view of other constructions: (a) 'Box' and (b) Object 5.*

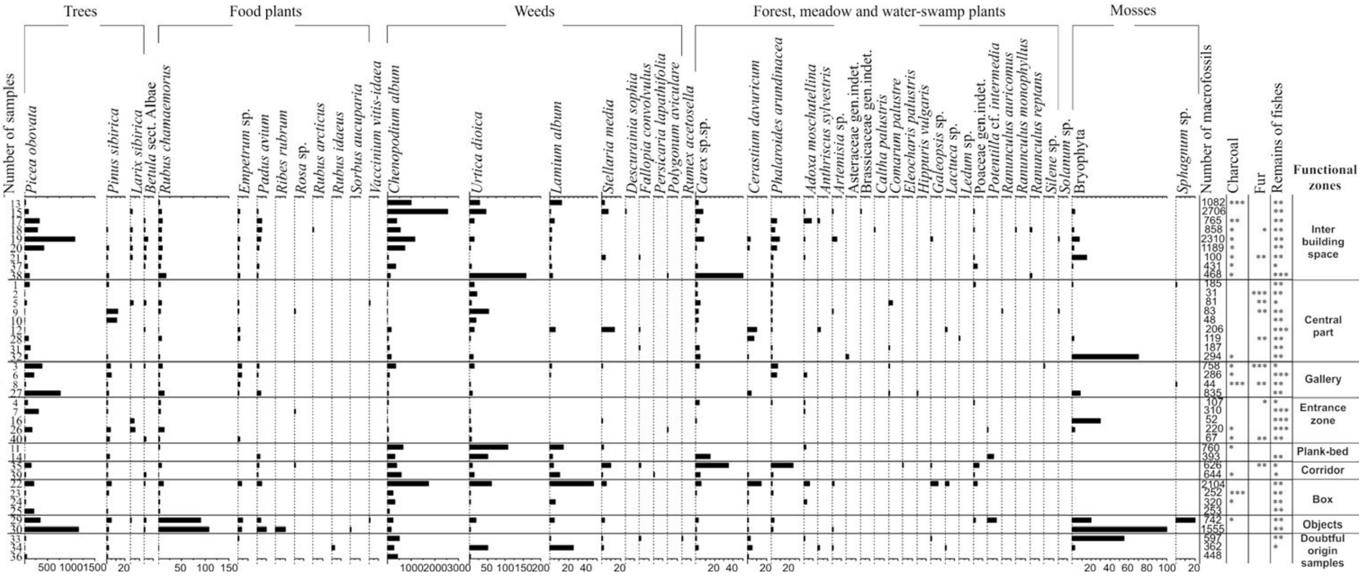

Figure 8. *Macrofossil diagram of the Ust-Voikar settlement.*

Results

Results of plant macroremain analysis

During the analysis of the composition of cultural layer samples, 22 878 macroremains of 46 plant taxa were selected and determined (Fig. 8). All plants whose macroremains were found in the samples have been found to grow on this territory (Goworukhin 1937).

The following groups of plants were identified to organise the variety of macroremains:

1) **Trees:** larch (*Larix sibirica*), spruce (*Picea obovata*) and birch (*Betula* sect. *Albae*). Macroremains from spruce, needles and small fragments of twigs, were most prevalent. Siberian pine (*Pinus sibirica*) would also have been included in this group, but only its seeds, which were used by people for food, were found, and their numbers were small compared to the remains of other trees. These remains did not significantly affect the group percentages. For this reason, this species was included in the food plants group instead.

2) **Food plants:** the fruits and seeds of wild plants that were eaten by people. These included Siberian pine, cloudberry (*Rubus chamaemorus* L.), Arctic raspberry (*Rubus arcticus* L.), raspberry (*Rubus idaeus* L.), crowberry (*Empetrum* sp.), bird cherry (*Padus avium* Mill.), cranberry (*Vaccinium vitis-idaea* L.), mountain ash (*Sorbus* sp.), currants (*Ribes rubrum* L.) and rosehip (*Rosa* sp.).

3) **Weeds:** plants from disturbed habitats, growing near dwellings. These included *Chenopodium album* L., *Descurainia sophia* (L.) Webb. ex Prantl., *Fallopia convolvulus* (L.) A. Love, *Lamium album* L., *Persicaria lapathifolia* (L.) Delarbre, *Polygonum aviculare* L., *Rumex acetosella* L., *Stellaria media* (L.) Cyr. and *Urtica dioica* L.

4) **Meadow, swamp and forest herbs:** this group of remains characterises the herbaceous vegetation in the vicinity of the settlement. Most of the plants in this group are distributed in meadows, in sparse forest and on their edges; many are confined to wet habitats. This group is composed of *Carex* sp., *Phalaroides arundinacea* (L.) Rausch., *Cerastium dahuricum* Fisch., *Adoxa moschatellina* L., *Ranunculus* sp., *Comarum palustre* L., *Caltha palustris* L., *Anthriscus*

sylvestris (L.) Hoffm. and others (22 taxa in total).

In accordance with the functional zones identified inside and outside the buildings, the samples were categorised in nine groups. For each group, the percentages of trees, food plants, weeds and meadow plants were calculated. The results of these calculations are shown in Table 1.

Results of pollen analysis

In all samples, the pollen concentration was not high (ranging from 6000 to 54000 grains per gram) and the pollen preservation was average, with a large number of crumpled and damaged grains. In total, 35 taxa were identified (Fig. 9). The samples in the pollen diagram are organised according to the division of functional zones.

In general, the pollen content of the different taxa varied in samples from different functional zones. Thus, the external samples (those from inter-building space) were characterised by a low content of pollen from arboreal plants (10–20%). Among these, the most frequently occurring were birch (*Betula* sect. *Albae*, 10– 15%) and Scots pine (*Pinus sylvestris*, 5–10%). A small amount of spruce pollen (*Picea*, 0–5%) was also present. Among herbaceous plants (80–90%), the highest pollen content was *Artemisia*, 40–70%, *Amaranthaceae*, 10–20% and pollen from *Poaceae*, 15–40%.

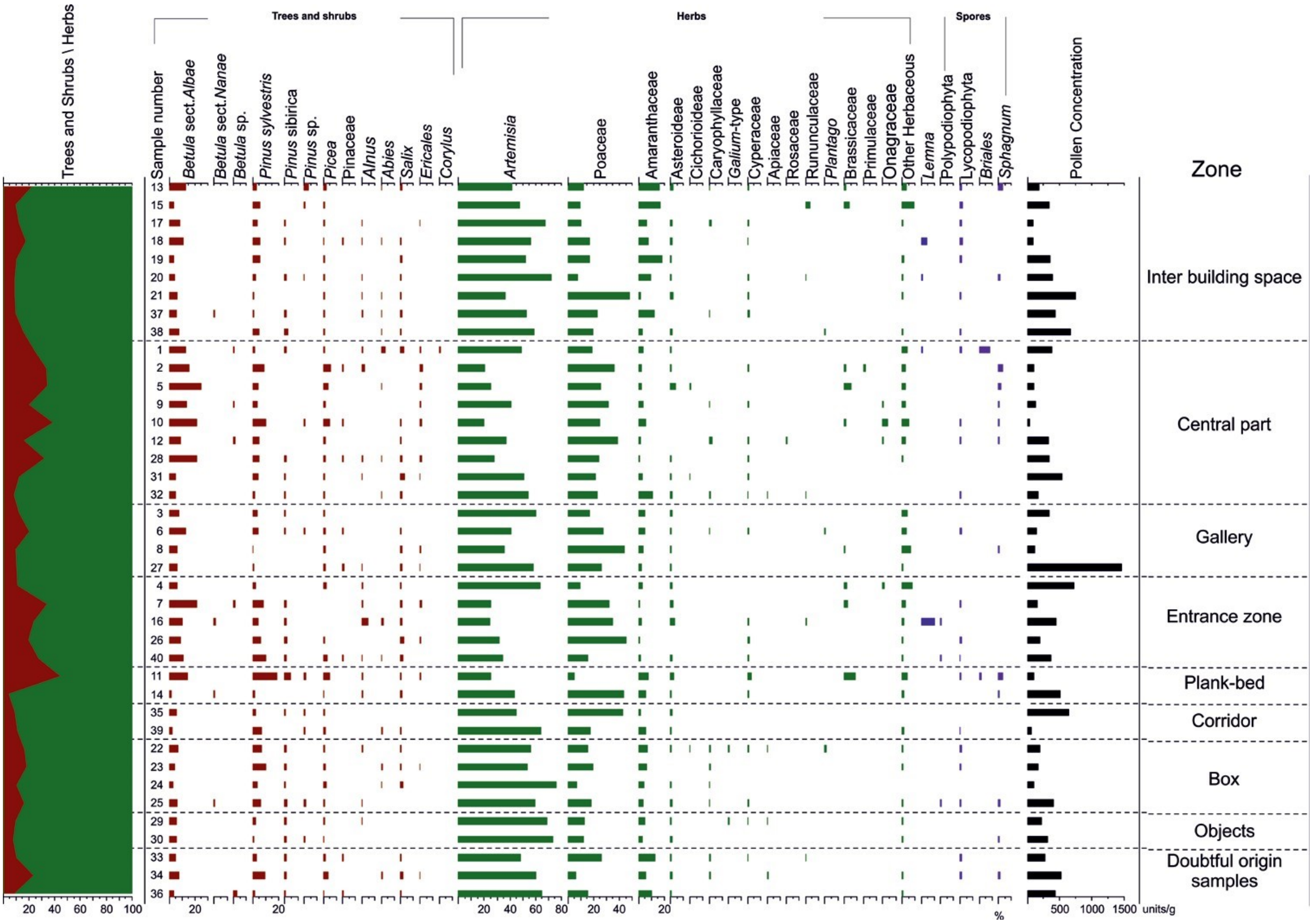

Figure 9. *Pollen diagram of the Ust-Voikar settlement.*

Functional zones	Trees, %	Food plants, %	Weeds, %	Meadow etc., %	Moss, %	Quantity of remains
Inter building space (no. 13,	24.7	1	72.5	1.5	0.3	9909

15, 17–21, 37, 38)						
Central part (no. 1, 2, 5, 9, 10, 12, 28,31, 32)	36.3	4.9	47.2	5.6	6	1234
Gallery (no. 3, 6, 8, 27)	71	3	24	1.5	0.5	1923
Entrance zone (no. 4, 7, 16, 26, 40)	76.2	4.6	13.5	1.3	4.4	756
Plank-beds (no. 11, 14)	1	1	96	2	–	1153
Corridor (no. 35, 39)	14	1	79	6	–	1270
Box (no. 22, 23, 24, 25)	15.5	1.2	81.5	1.8	–	2929
Objects 5 and 6 (no. 29, 30)	66	10	17	1	6	2297
Doubtful origin samples (no. 33, 34, 36)	6	0.7	88	1.3	4	1407

Table 1. *Percentages of plant groups in samples from different functional zones of the Ust-Voikar settlement, based on data from macroremain analysis*

NPP analysis result

A total of 50 types of NPP were found in the samples. Of these, 36 are defined and 14 are not (Figs 10, 11, 12). The undefined palynomorphs, which are not mentioned in the literature but were included in the analysis, are indicated by the abbreviation ‘NV’, for the city of Novosibirsk, where the laboratory is located. Palynomorphs found in more than three samples were included in the analysis. Some NPP types have been preliminarily identified; these are marked with the abbreviation ‘cf.’ (from Latin ‘confer’, meaning ‘compare’). This means that the object in question is similar and comparable to the one listed after the abbreviation.

Among NPP units were identified: Charcoal particles 7–200 µ which are related to fires or fireplaces. Stomata of *Picea* and *Abies* which are the guard cells that facilitate gas exchange and are found in the epidermis of leaves and other plant organs. They indicate the presence of soft plant tissues at the site itself, because they cannot be transported by wind over long distances. Fungal hypha or other fungal remains without clear identification features (probably HdV-79, van Geel 1978).

HdV-342: zygospores of cosmopolitan widespread algae *Spirogyra* (Zygnemataceae) which produces spores in springtime, in shallow, stagnant, clean and oxygenrich warm water found near lake terraces; in flowing water; and in moist soils or bogs (Transeau 1938, 1951; Grenfell 1995; van Geel and Grenfell 1996; Cook et al. 2011). Their presence here can be interpreted as an indicator of wet conditions.

The parasitic trematode eggs are the NPP cf. *Opisthorchis* sp. (Slepchenko et al. 2015) or *Clonorchis* sp. and *Dicrocoelium* sp. which are associated with parasitic infections of the gold bladder in mammals. Eggs are passed in faeces. Humans (and dogs) can become infected with this trematode worm by eating undercooked freshwater fish or by other means.

HdV-55A ascospores of several mostly coprophilous *Sordaria* species, related to the presence of herbivores (van Geel et al. 1989; Yeloff et al. 2007; Dietre at al. 2012).

HdV-368 spores of the *Podospora*-type (coprophilous Sordariales) are of regular occurrence in samples from archaeological sites associated with the presence of man or cattle (Van Geel et al. 2003) and are abundant on sedge litter and open fen (Prager et al. 2012).

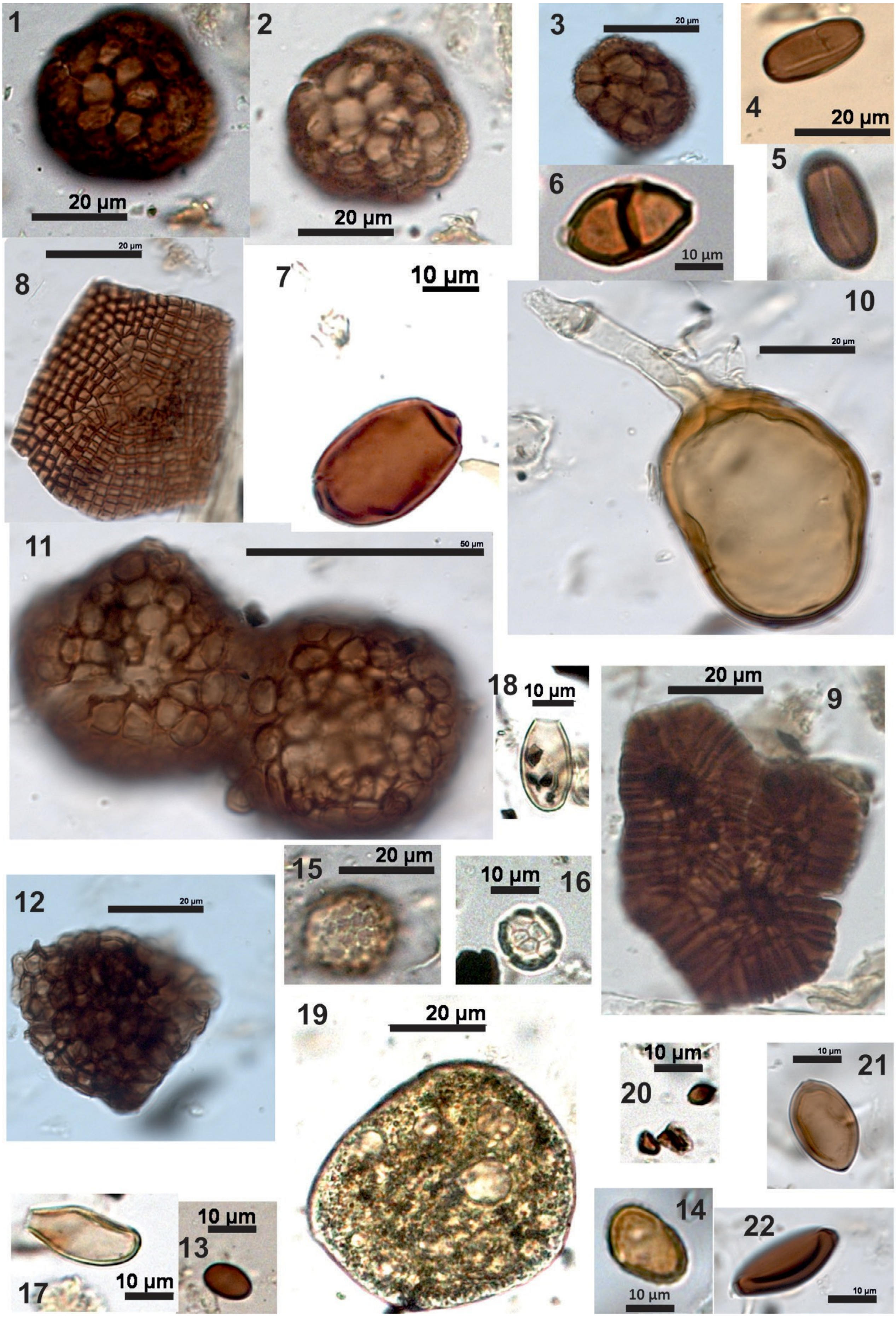
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Figure 10. *Non-pollen palynomorphs from the Ust-Voikar settlement included in analysis. 1, 2, 3: Thecaphora sp.; 4, 5: UG-1077; 6: Puccinia Type; 7: HdV-368.; 8, 9: cf. Mycrothyriacites sp.; 10: Glomus sp.; 11, 12: Type NV4; 13: Type 1173; 14: urediniospore; 15, 16: Tilletia; 17, 18: cf. Parasitic Trematoda egg.; 19: cf. Entamoeba; 20: Type NV2; 21, 22: HdV-55A.*

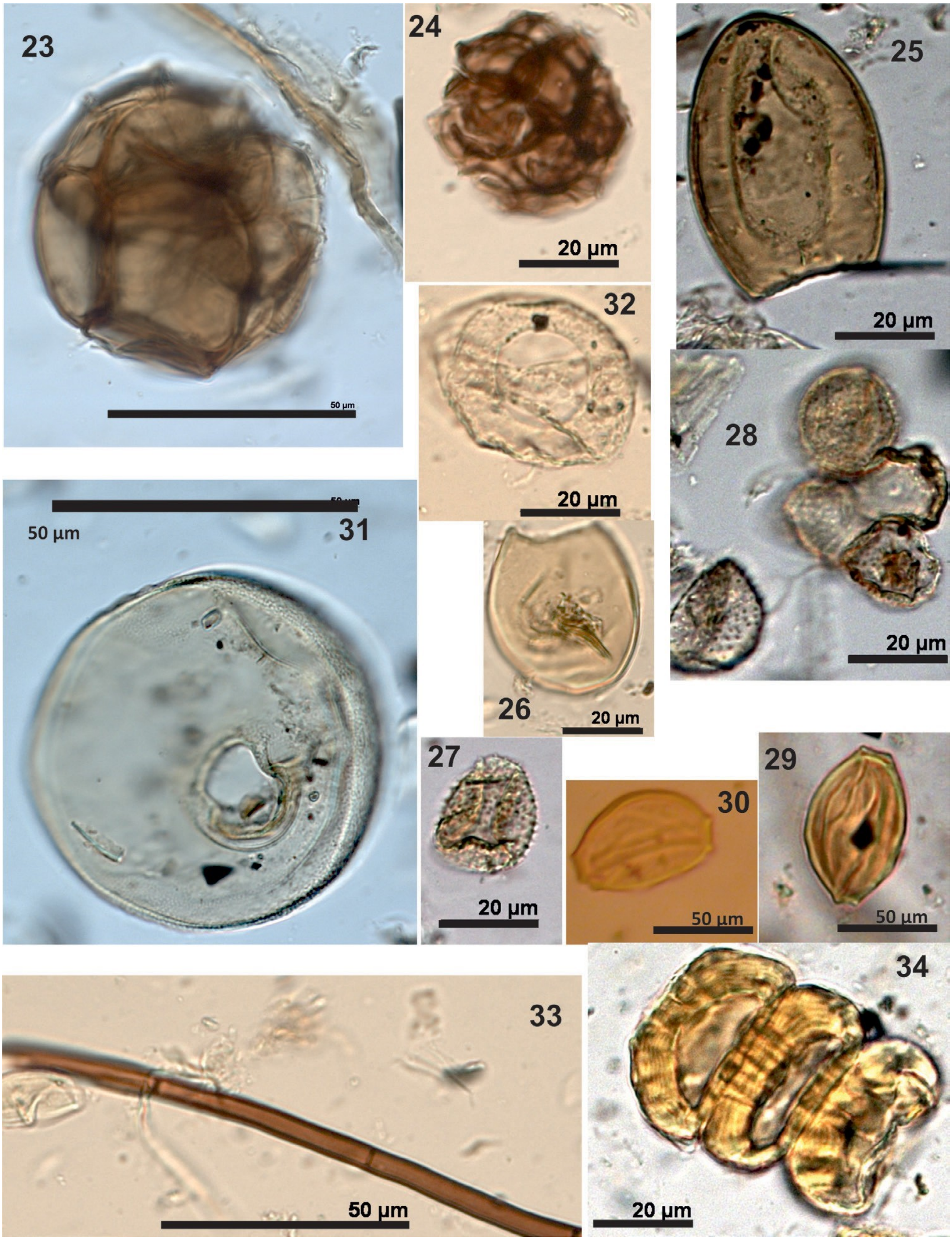

Figure 11. *Non-pollen palynomorphs from the Ust-Voikar settlement included in analysis. 23, 24: Urocystis; 25, 26:*

Neorhabdocoela oocyte; 27, 28: Type NV1; 29, 30: Trichuris sp.; 31: Arcella sp.; 32: Centropyxis aculeata 'discoides'; 33, 34: HdV-342; 35: Fungal hypha; 36: Type NV3.

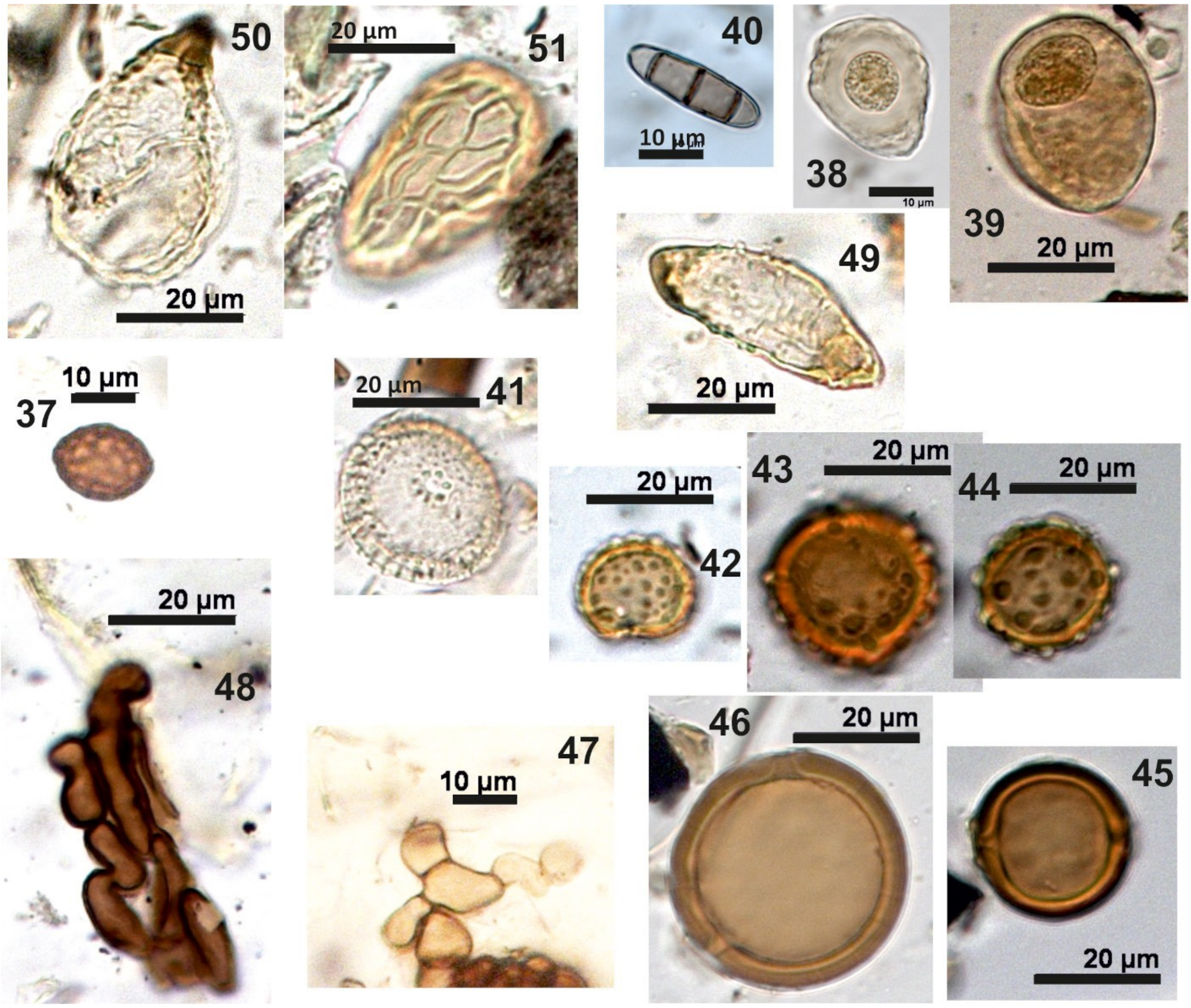

Figure 12. *Non-pollen palynomorphs from the Ust-Voikar settlement not included in analysis. 37: Gelasinospora; 41: HdV-187A; other unidentified NPP.*

Puccinia: spores of plant rust fungus (van Geel et al. 1983; Shumilovskikh et al. 2016), associated with Cyperaceae epidermis (van Geel et al. 2010).

UG-1077: cf. Xylariaceae/ Sordariaceae/ Coniochaetaceae. Ascospores possibly belong to the families Coniochaetaceae, Sordariaceae or Xylariaceae with various ecological characteristics (Gelorini et al. 2011). Correlates with *Glomus* sp. (Szymanski at al. 2017).

UG -1173: unidentified ascospores – ellipsoid, one-celled, yellow to brown, smooth and thick-walled, with dimensions of 15–24 × 6–12 µ (Gelorini et al. 2011); possibly similar to *Rosellinia* sp. fungi, which cause plant diseases.

Urediniospores: thin-walled vegetative spores that are produced by uredinial hyphae of plant parasite fungus, usually on the leaves or stems of grasses. Present in genera of *Puccinia*, *Uromyces*, etc. (Durrieu 1987).

Thecaphora sp.: teliospores of smut fungi (plant parasite causing plant decease) living only on herbs (van Geel et al. 1981; Vanky 1994; Miehe et al. 2009; Shumilovskikh et al. 2016). Peaks of *Thecaphora* could be indicative of unfavourable growth conditions, such as increased trampling (Miehe et al. 2009).

Tilletia & *Bryophytomyces*: spores of parasitic fungi associated with the genus *Sphagnum* were counted together due to difficulties in differentiating them (van Geel 1976; Kuhry 1985; Mudie and Lelievre 2013). Spores of parasitic fungus associated with the *Sphagnum* genus (van Geel 1976; Kuhry 1985; Mudie and Lelievre 2013).

cf. *Urocystis*: teliospores of smut fungus (plant parasite causing plant decease) living on several herbaceous families (Vanky 1994). Peaks of *Urocystis* are associated with increased trampling activity by animals or humans (Miehe et al. 2009) and correlated with grazing pressure (Ejarque et al. 2011).

cf. *Mycrothyriacites* sp.: flattened radial fruit bodies, similar in appearance to fungus of the genus *Microthyriacites* (Misra et al. 2014). Probably related to *Microthyriaceae* (Musotto et al. 2012, 2013). The family contains epiphytic fungi that characterize forest vegetation and are indicative of moist environments.

Glomus sp.: chlamydospores of endomycorhizal soil-inhabiting fungus. Increased concentrations of *Glomus* sp. are related to soil erosion (van Geel et al. 1989) or anthropogenic activity (López Sáez et al. 2000; Argant et al. 2006).

Arcella sp. (HdV-352). Hyaline, discoid theca of testate amoebae, 26–35 µ in diameter (van Geel et al. 1980). *Arcella* is a large genus that includes taxa living in different conditions (oligotrophic/eutrophic, nutrient-rich/poor, etc.). Here, its presence could be considered an indicator of wet conditions.

Centropyxis aculeata var. *discoides* Penard.: theca of testate amoebae indicating wet conditions, with characteristics of sediment-inhabiting taxa (van Geel et al. 1983; Glime 2012).

cf. *Entamoeba* sp.: parasitic amoeba living in intestines of all animals (Diamond and Clark 2001). Their cysts are passed in feces. These cysts are likely well preserving, as they have been found in sediments related to different periods of human history (Anastasiou 2015; Mitchell 2017) and even to dinosaur era (Poinar and Boucot 2006). Oval to round form from 15 to 40 µ in diameter with visible dark and transparent bubbles in it.

Trichuris sp.: eggs of the intestinal parasite whipworm. Whipworms live in the intestines of some mammals, including humans, and have been recorded at archaeological sites all over the world. Usually, the presence of *Trichuris* sp. eggs is interpreted in terms of the health and sanitary conditions of ancient humans (see for instance Jones 1985). In our case, however, precise taxonomical identification of these eggs as *Trichuris trichiura* (Linnaeus, 1771) (the whipworm affecting humans) is complicated by the influence of chemical treatment on the eggs' size (Buurman et al. 1995). In this study, *Trichuris* sp. is thus considered indicative of the presence of dung originating either from humans or domestic animals.

Neorhabdocoela oocyte: egg remains from flatworms (an aquatic invertebrate) associated with freshwater ponds (Haas 1996). At present, about 14 types of flat-worms are also known to infect people (Scholz 2009). In Eurasia and Western Siberia in particular, the main verified incidence of parasitic invasion is with *Diphyllobothrium latum* Linnaeus, 1758. Other species, such as *Diphyllobothrium dendriticum* Nitzsch, 1824 and *D. ditremum* Creplin, 1825, are common in northern Siberia, but have low epidemiological significance (Slepchenko and Adaev 2017; Yastrebov 2013; Scholz 2009).

Type NV1: unidentified unit of probable aquatic origin; possibly dinoflagellate cyst.

Type NV2: cf. Spaheropsidales. Small brown spores of different shapes, with thin linings less than 10 µ in diameter.

Type NV3: Attached globes with thick lining, probably wood remains.

Type NV4: cf. *Pycnidium* of Spaheropsidales. Spherical or elongated clusters of vesicles, arranged with no visible order. Vesicle walls are thin. Aggregate diameter 50–100 µ. Probably fungal remains.

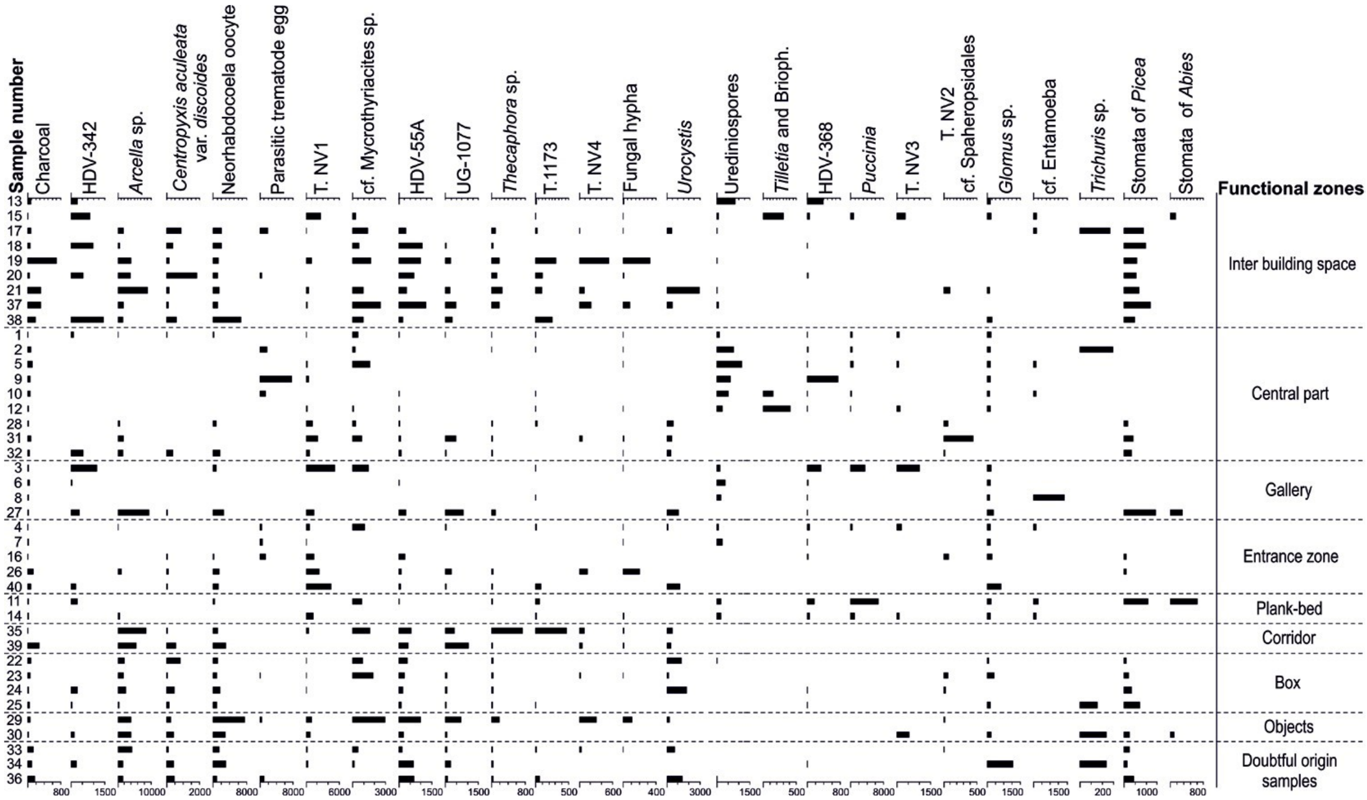

Figure 13. *NPP diagram; sample numbers are organised according to functional zones.*

Distribution of NPPs in functional zones (Fig. 13)

1. Inter-building space: sample nos. 13, 15, 17–21, 37 and 38.

The samples contain maximum concentrations of charcoal particles and high concentrations of cf. *Mycrothyriacites* sp., HdV-55A, UG-1173, *Thecaphora* sp., HdV-342, *Arcella* sp., *Centropyxis aculeata* var. *discoides* and stomata of *Picea*.

2. Central part: sample nos. 1, 2, 5, 9, 10, 12, 28, 31 and 32.

In these samples, the majority of palynomorphs have very low concentrations.

However, all samples have high concentrations of urediniospores, and some have high concentrations of cf. *Mycrothyriacites* sp., Type NV2 and Parasitic Trematode egg. Sample no. 2 contains *Trichuris* sp.

3. Gallery: sample nos. 3, 6, 8 and 27.

All samples have low levels of urediniospores and *Glomus* sp.

Sample no. 3 contains high concentrations of the following NPPs: HdV-342, Type NV1, cf. *Mycrothyriacites* sp., HdV-368 sp., *Puccinia* Type and Type NV3. Sample no. 28 has high concentrations of *Arcella* sp., UG-1077 and stomata of *Picea*, and moderate concentrations of cf. *Urocystis* and stomata of *Abies*. Sample no. 8 contains cf. *Entamoeba*.

4. Entrance zone: sample nos. 4, 7, 16, 26 and 40.

Most of these samples have high or moderate concentrations of fungal hypha and low concentrations of *Glomus* sp., *Neorhabdocoela* oocyte and HdV-55A. However, individual sample spectra differ in NPP content.

5. Plank-beds: sample nos. 11 and 14.

Both samples contain small amounts of Type 1173, urediniospores, HdV-368 sp., *Glomus* sp. and cf. *Entamoeba*. However, the two samples' spectra also differ: sample no. 11 contains HdV-342, cf. *Mycrothyriacites* sp., *Puccinia* Type, stomata of *Picea* and stomata of *Abies*; sample no. 14 contains Type NV1.

6. Corridor: sample nos. 35 and 39.

In both samples, the following NPPs are present in significant concentrations: *Arcella* sp., *Neorhabdocoela* oocyte, HdV-55A and UG-1077. Also present are low concentrations of Type NV4, cf. *Urocystis* and fungal hypha.

Again, however, there are differences in the two NPP spectra. Sample no. 35 has cf. *Mycrothyriacites* sp., *Thecaphora* sp. and UG-1173, while sample no. 39 has significant levels of charcoal particles, *Centropyxis aculeata* var. *discoides* and *Neorhabdocoela* oocyte.

7. Box: sample nos. 22–25.

All samples have high levels of *Arcella* sp., *Neorhabdocoela* oocyte and HdV- 55A, and low levels of charcoal particles, UG-1077, *Thecaphora* sp. and stomata of *Picea*.

8. Objects 5 and 6: sample nos. 29 and 30.

The NPP spectra of these samples differ: sample no. 29 contains significant levels of *Arcella* sp., *Neorhabdocoela* oocyte, cf. *Mycrothyriacites* sp., HdV-55A, UG- 1077, *Thecaphora* sp., Type NV4, fungal hypha and *Puccinia*.

Sample no. 30 contains *Arcella* sp., *Centropyxis aculeata* var. *discoides*, *Neorhabdocoela* oocyte, Type NV3, *Glomus* sp., *Trichuris* sp., stomata of *Picea* and stomata of *Abies*.

9. Samples of doubtful origin: sample nos. 33, 34 and 36.

The spectra of these samples vary, but all three contain significant concentrations of charcoal particles, *Arcella* sp., *Centropyxis aculeata* var. *discoides*, *Neorhabdocoela* oocyte, HdV-55A and stomata of *Picea*. Sample no. 34 also contains HdV- 342, *Glomus* sp. and *Trichuris* sp.

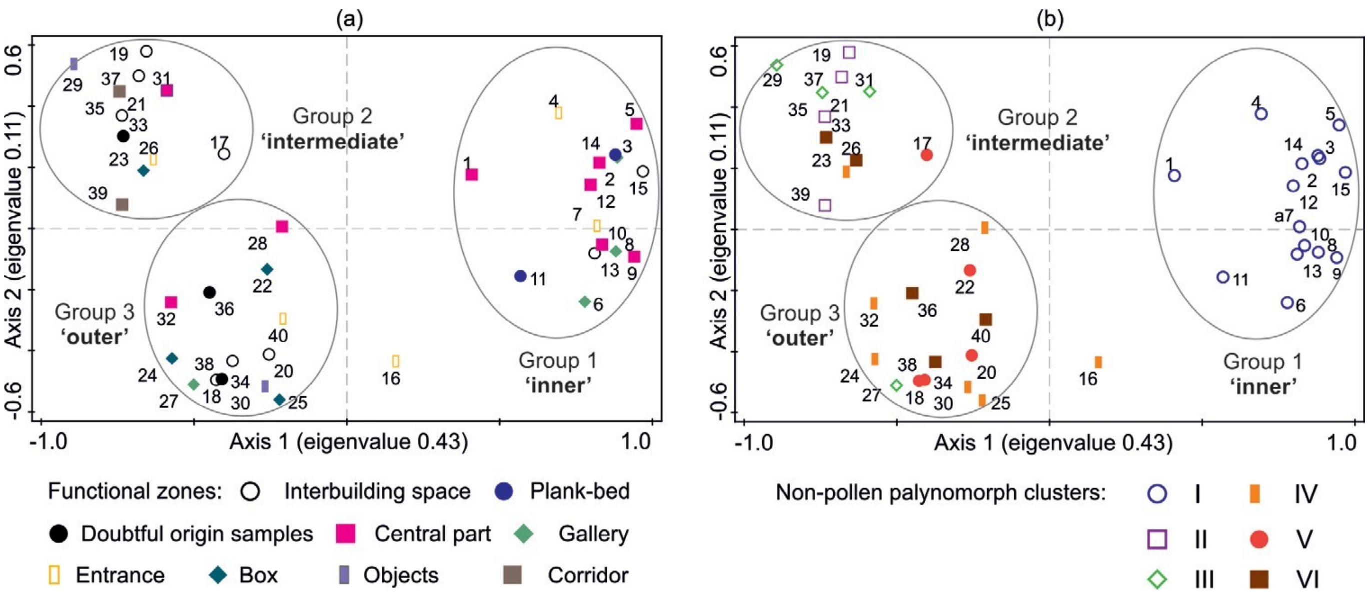

Figure 14. *Principle Component Analysis sample score biplots for the NPP results. Functional zones (a) and NPP clusters (b) are represented with different symbols. Numbers represent sample ID. Ellipses indicate groups of samples that can be associated with 'inner', 'outer' and 'intermediate' spaces according to archaeological data. For PCA species score biplots, see Suppl. material 2.*

Result of NPPs numerical analysis

Fig. 15 shows the results of the PCA performed on the NPP assemblages to evaluate the role of functional zones in the NPP's distribution. The first two PC axes explain 54% of the total variance. The first PC axis (eigenvalue 0.43) is oriented between positive species score values of HdV-368 (0.82), urediniospores (0.81), *Puccinia* Type (0.66), *Glomus* sp. (0.61), *Entamoeba* (0.5) and NV3 (0.49), and negative species score values of HdV-55A (−0.91), *Arcella* sp. (−0.87), *Centropyxis aculeata* var. discoides (−0.83), *Neorhabdocoela* oocyte (−0.83), *Thecaphora* sp. (−0.83), UG-1077 (−0.82), stomata of *Picea* (−0.67), cf. *Urocystis* (−0.64), charcoal particles (−0.44) and Type NV2 (−0.43) (see Suppl. material 2). The second PC axis (eigenvalue 0.11) is oriented between positive species score values of fungal hypha (0.73), cf. *Mycrothyriacites* sp. (0.59), NV4 (0.67) and Type NV1 (0.35), and negative species score values of HdV-342 (−0.61) (see Suppl. material 2).

Plotted PCA sample scores divide the dwelling samples into three clearly recognisable groups (Fig. 14). Group 1 (n = 15) is located on the positive side of the first axis and includes mostly samples from the zones 'Central part' (six of nine samples), 'Gallery' (three of four samples) and 'Plank-beds' (two of two samples), and to a lesser degree, 'Entrance zone' (two of five samples) and 'Inter-building space' (two of nine samples). Group 1 can thus be considered to include samples from 'inner' locations.

Groups 2 (n = 11) and 3 (n = 14) are located on the negative side of the first PC axis and on the positive and negative sides of the second PC axis, respectively (Fig. 14a). Group 2 includes samples from 'Inter-building space' (four of nine samples) and 'Corridor' (two of two samples), and to a lesser degree, 'Entrance zone' (one of five samples), 'Box' (one of four samples), 'Objects 5 and 6' (one of two samples), 'Samples of doubtful origin' (one of three samples) and 'Central part' (one of nine samples). In terms of archaeological functional differentiation, we attribute these samples to an 'intermediate' location that is between 'inner' and 'outer' (Fig. 14a).

Group 3 includes mostly samples from 'Box' (three of four samples), 'Samples of doubtful origin' (two of three samples), 'Entrance zone' (two of five samples), 'Objects 5 and 6' (one of two samples) and 'Inter-building space' (three of nine samples), and to a lesser degree, 'Central part' (two of nine samples) and 'Gallery' (one of four samples). Group 3 can therefore be considered to include samples from 'outer' locations.

Fig. 15 presents the results of the NPP analysis, with clustering performed in TILIA. It is visually determined that all six clusters (I–VI) differ in the distribution of NPPs (Fig. 15). Clustering shows results that are very similar to the PCA grouping (Figs. 14a, b; 16). Cluster I has exactly the same sample composition as Group 1 (the 'inner' locations): (I) 'Central part' (1, 2, 5, 9, 10, 12), 'Gallery' (3, 6, 8), 'Plank-beds' (11, 14), 'Entrance zone' (4, 7) and 'Inter-building space' (13, 15) (Fig. 14b). Clusters II and III mainly correspond with Group 2 (the 'intermediate' location): (II) 'Inter-building space' (19, 21, 37) and 'Corridor' (39); (III) 'Gallery' (27), 'Objects 5 and 6' (29), 'Central part' (31), 'Corridor' (35) and 'Box' (22). Clusters IV and V mainly correspond with Group 3 (the 'outer' locations): (IV) 'Central part' (28, 32), 'Box' (23, 24, 25), 'Objects 5 and 6' (30) and 'Entrance zone' (16); (V) 'Samples of doubtful origin' (34) and 'Inter-building space' (17, 18, 20) Finally, Cluster VI overlaps with Groups 2 and 3: (VI) 'Inter-building space' (38), 'Entrance zone' (26, 40) and 'Samples of doubtful origin' (33, 36) (Fig. 14b).

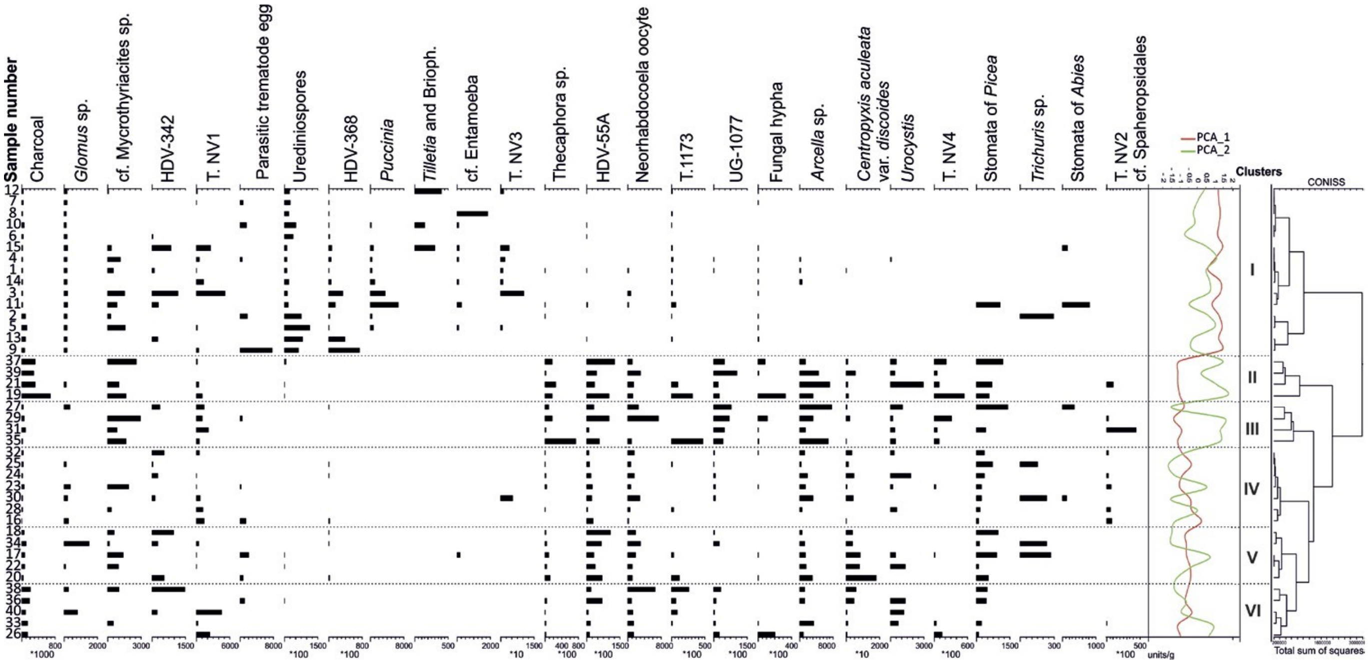

Figure 15. *NPP diagram; sample numbers are organised according to Clusters I–VI.*

Interpretation of results

Pollen provides data on local and regional vegetation. In the modern pollen spectra from the contact zone between the northern taiga and the forest tundra (Grichuk 1967), there are percentages of about 40% arboreal pollen and 40% herbaceous pollen; the latter contains only about 5% of *Artemisia* and *Amaranthaceae* in total. In comparison, the samples from the settlement area contain much more wormwood and chenopod pollen, but much less arboreal pollen. Based on pollen spectra from the inter-building space, the plant cover within the settlement can be reconstructed. In general, the settlement's plant communities corresponded to those of the northern taiga zone, but with *Artemisia* – *Poaceae* associations prevailed on the settlement territory. *Artemisia* and *Amaranthaceae* are often referred to as ruderal vegetation, and can be considered pollen indicators of anthropogenic activity.

In the samples from inter-building space, the main sources of pollen were plants growing in and around the settlement; this includes pollen from trees, which can be transported for many kilometres (Davis and Goodlett 1960; Erdtman 1943). In the indoor samples, pollen, spores and plant macroremains could have been brought in by the flow of air, on people's clothes and shoes, on animal hair, on household items and possibly on plants that were used indoors. NPPs are mainly produced in situ or brought in on footwear, animal hair and household items from the immediate environment. According to the indicator properties of different groups of NPPs, their distribution in groups of samples from different functional zones can be used for additional characterisation of the usage patterns of each zone. Factors assumed to affect the formation of the NPP spectra are substrate moisture, animal presence, and human plant use and economic activity.

1. **Inter-building space.** These samples contain the largest number of macroremains from weeds, and many fewer from trees; food plants and meadow plants occur just singly. This composition indicates the presence of sites that were overgrown with weed plants (mainly Amaranthaceae and *Urtica*) on the settlement territory. Most samples contain fragments of wood and bark in addition to fruit and seed remains. The inter-building space was thus also covered with woodworking waste (chips and shavings). According to palynological data, wormwood and cereals mainly grew on the settlement's territory. The paleobotanical study of the other site, Tiutey-Sale 1, also located in the tundra zone, shows that the vegetation on the territory of this settlement corresponded to a zone type of vegetation with signs of anthropogenic impact (Panova 1998). Plant macroremain studies have also been carried out at Nadym Fort (Korona 2015) and Zeleny Yar burial ground (Korona 2005). The vegetation at these archaeological sites was also found to be zonal, with ruderal complexes around the sites. A small number of food-plant fruits were found, and no remains of cultivated plants were found at all.

It was also noted that in the samples from inter-building space, charcoal particles exist in much higher concentrations than in samples from the interior space. This may indicate the spread of combustion waste through the settlement's territory due to the probable periodic cleaning of fireplaces. The majority of samples from the inter-building space are also characterised by high concentrations of spores and fungi remains. These fungi are coprophilous (HdV-55A) and are associated with the decomposition and rotting of plants (cf. *Mycrothyriacites* sp., UG-1173, *Thecaphora* sp.). Testate amoeba shells (*Arcella* sp., *Centropyxis aculeata* var. *discoides*) and algae (HdV-342) living on wet substrates and spruce stomata are also abundant. The presence of spruce stomata is indicative of direct use of spruce at the sampling site; the residents most likely used the spruce branches as a 'decking' in wet areas of the settlement. The presence of coprophilous fungi and *Thecaphora* sp., associated with herbs rotting after trampling, suggests the presence of herbivorous animals in the settlement area. The planning characteristics of sample nos. 13 and 15 can be clarified according to the NPP analysis; in terms of NPP distribution these samples are from 'inner' locations instead.

2. **Central part.** The samples from this zone contain relatively low levels of plant remains. Predominant among them are the seeds of weed plants; there are slightly fewer macroremains of wood and a significant percentage of meadow, coastal wetland and forest herbs compared to other groups. There are also quite a few foodplant remains. It should also be noted that this group of samples is the most heterogeneous in its composition. There are significant differences in the numbers of macrorests and the species composition, ranging from 31 residues and five taxa to 206 remains and 14 taxa. This indicates the existence of different functional zones within this part of the dwelling. Plant fruits and seeds could only be brought into the room by people, either accidentally or intentionally. It is possible to assume that residents used plants for food, medicine and household needs. In sample nos. 1, 5, 28 and 31, remains of conifers are predominant, while in sample nos. 2, 9, 10, 12 and 32, weed remains are more abundant. We can thus see that herbaceous plants were used indoors, probably to cover sleeping places or the floor. Weeds growing on the settlement's territory, as well as meadow and coastal marsh plants growing nearby (such as sedges, ribbon grass and other grains) were probably used for this purpose. Logically, it is not surprising that samples from the central part of the dwellings contain high numbers of food-plant macroremains. Significant levels of tree bark was also found in samples from this group; these are obviously the remains of decking or plank-beds, which were made of tree branches with unpeeled bark.

These samples also contained numerous remains of reindeer wool, in fragments similar to felt. It follows that the inhabitants of the settlement covered their sleeping places mainly with animal skins, which is natural in such a harsh climate; plants played a secondary role. Quite a few bones and fish scales were also found in the samples, suggesting that meals were eaten here. It is interesting that only one sample from this group contained charcoal, in small amounts. This may indicate that the settlement's inhabitants were very careful with fire inside their dwellings and did not use ash indoor.

This group of samples was characterised by low NPP content. The presence of spores and fungal remains associated with the decomposition of plants (urediniospores, cf. *Mycrothyriacites* sp.) is probably due to the use of herbs as bedding indoors. Sadges may have been used for this purpose, as spores of the urediniospore type are associated with the *Puccinia* spores of fungi that grow on the epidermis of sadges (van Geel et al. 2010). The presence of Type NV2 and parasitic Trematoda eggs without coprophilous spores which associated with herbivore dung could be related to the presence of carnivorous mammals inside the dwelling. Dogs could become infected with trematodes by ingesting fresh fish. Human faeces could also be the source of parasitic Trematoda eggs.

3. **Gallery and Entrance zone.** Table 1 shows that these groups were dominated by woody plant remains (mainly conifers). Macroremains of weed plants were significantly less common, and among these, chenopod seeds were predominant. There were even fewer food plants in these zones; fruits and seeds from meadow, swamp and forest herbs occurred only singly. We can assume that people used spruce branches in these areas, as not only needles but also fragments of twigs were found in the samples. Spruce branches may have been used to make fishing equipment, to cover wet areas or to provide heat. Quite a large percentage of the weed seeds in the gallery may be related to the use of these plants for household needs.

The samples from the gallery were characterised by the presence of spores of coprophilous fungi (HdV-368) and potentially coprophilous fungi (UG-1077), which in combination with parasitic amoeba (cf. *Entamoeba*) suggest the presence of animals indoors, and perhaps not just herbivores. The spores of fungi associated with the herb's decease (urediniospores, cf. *Urocystis*, *Puccinia* Type) and the stomata of spruce and fir indicate the indoor use of plant bedding made of herbs and spruce and fir branches.

The spectra of NPPs from the entrance zone differed from one another; this can be explained by the mixed nature of this zone, which is located between the outdoor and indoor areas.

4. **Plank-beds.** The samples were characterised by the absolute dominance (96%) of weed macroremains (mostly chenopod and, in significantly lesser quantities, nettle). Other plant macroremains were found only singly. It is likely that pigweed and nettle seeds came here as part of a green mass. Nettles could be used as medicinal or textile materials: for example, such use of nettles by the Khanty in the early eighteenth century is reported by G. Novitskii (1941) in one of the first works on historical ethnography in Siberia.

However, what the residents of the settlement used chenopod for is unclear. It is too juicy and tender to be used in bedding, while in its dried form it is fragile and quickly turns to dust. Nevertheless, the vast geographical spread of archaeological finds of pigweed seeds testifies to the widespread tradition of their use in different cultures. One possible application is as a raw material for medicine (Alkin and Sergusheva 2013).

Chenopodium album L. is an annual herbaceous ruderal plant – a typical weed. It is one of the most common human satellites. It grows abundantly near human habitation, in places with disturbed soil cover. According to various estimates, one pigweed plant can produce between 100 000 and 600 000 seeds (Buch et al. 1981). Due to the good germinating ability of its seeds in a relatively short period, pigweed may occupy a large area. Pigweed seeds mature in late July–August; thus, if the seeds got into a dwelling with a green mass of plants, they could spread in the second half of summer. *Ch. album* is an edible plant and is used by practitioners of the traditional system of medicine. The leaves and tender shoots are consumed in raw form or cooked into vegetables; seeds represent the high protein content (Singh et al. 2023).

According to the NPP analysis, both samples here were characterised by low concentrations of coprophilous fungi and parasitic intestinal amoebas, possibly originating from animals or their skins. However, the samples differed significantly in the composition of their NPP spectra, which may indicate the occurrence of different human activities in these parts of the dwelling. Thus, in sample no. 11, the stomata of spruce and fir, together with fungal remains, testify to the use of plant bedding, while in sample no. 14, the shells of amoebas (*Arcella* sp.) and Type NV1 indicate that this part of the room was used in conditions of constant wetness.

5. **Corridor and Box.** This group of samples was also dominated by the remains of weeds. In contrast to the plank-bed samples, the number of macroremains of wood (spruce needles), fruits and meadow grass seeds increased. Perhaps spruce branches and grass were used in the corridor to cover the floor. The box may have been used for sanitary purposes; it may therefore have contained the remains of this covering.

In terms of the NPP spectra of the corridor, the presence of animals, wet conditions and herbal bedding is also indicated.

The presence of coprophilous fungi spores (HdV-55A, UG-1077), plant disease fungi (*Thecaphora* sp.) and spruce stomata suggests that the box could contain the remains of indoor bedding. The remains of testate amoebas (*Arcella* sp.) and flatworm oocyte (*Neorhabdocoela* oocyte) indicate that conditions were wet, but not with the intended use of clean water.

The NPP analysis allowed us to clarify the planning characteristics of the samples from the box. We can see that the box was opened or closed at different times, or that different parts of the box were used in different ways - one opened and another closed. This is because sample nos. 23–25 are more likely to be ‘outer’ samples, while no. 22 is more likely to be an ‘intermediate’ sample.

6. **Objects 5 and 6.** These samples contained mainly spruce remains. The remains of other plants appeared at much lower levels. Weeds were dominated by *Chenopodium alba*. Interestingly, though, these samples contained the largest number of macroremains from various food plants out of all groups of samples: seven species of food plants were identified, with cloudberries dominating. There were also quite a few moss twigs. The large number of coniferous remains can be explained either by the fact that these constructions were covered from above with spruce branches, or that on the contrary, the floor was formed by them. The large number of food-plant remains in these samples suggests that these structures may have been used as toilets. The significant number of moss residues compared to other groups may also be related to their uses for hygiene.

Both samples indicate wet conditions (due to the presence of *Arcella* sp., *Centropyxis aculeata* var. *discoides* and *Neorhabdocoela* oocyte). Sample no. 29 is characterised by the presence of coprophilous fungi spores (HdV-55A, UG-1077) and plant parasite and decomposition fungi (cf. *Mycrothyriacites* sp., *Thecaphora* sp., Type NV4, fungal hypha). Sample no. 30 contains whipworm eggs (*Trichuris* sp.) and spruce and fir stomata. These respective compositions indicate the different uses of Objects 5 and 6. Although the purpose of these objects cannot be precisely determined, sample nos. 29 and 30 fall into the ‘intermediate’ group according to the NPP analysis.

An indirect argument for the interpretation of Objects 5 and 6 as toilets is the identification of *Trichuris* sp. eggs in one of the samples (no. 30). The presence of these eggs in different parts of the dwellings, as well as in the inter-building space, indicates certain unhygienic living conditions in the settlement. Such peculiarities of daily life are often mentioned in travelers’ notes (Vizgalov et al. 2013: 49).

7. **Samples of doubtful origin.** Fruits and seeds from weeds predominated in these samples, and macroremains from other groups of plants were found only singly. These samples are most similar to those from the plank-beds, but in contrast to the latter, they contained moss remains. It is possible that the composition of these samples reflects the mixed nature of layer formation in these areas. They are probably more closely related to the filling of the 'zavalinka', for which this woody plant substrate may have been brought from the inter-building space.

Interestingly, the composition of macroremains in samples from 'outer' spaces was similar to that from those in 'inner' spaces, where seeds and fruits were not easily accessible. It is possible that the large number of weed seeds (such as chenopod and nettle) are associated not only with these plants' distribution within the site, but also with their probable use by people for various purposes (such as medicine, food and other household uses). It is also possible that there were interruptions in the settlement's inhabitation, resulting in periods when weeds were widespread in the open sites.

As has been shown above, the number of food-plant macroremains found was limited, and it is likely that the inhabitants of the settlement did not collect berries and nuts systematically. However, the diversity of food plants (10 taxa) indicates that the inhabitants nevertheless made extensive use of local plant resources. Along with their nutritional value, the fruits of these plants have medicinal properties, and were therefore part of people's diets, especially during the harvest years.

According to the NPP analysis, the category 'Samples of doubtful origin' also overlaps with that of 'outer' samples. These samples' NPP spectra are similar to those of the inter-building space samples.

There was no evidence of cultivated plant remains in any of the samples. They are also absent from the late medieval-New Age layers of other large aboriginal settlements in the region (Nadym Fort and Polui Cape Town) (Korona 2013, Korona 2015). The results obtained are consistent with ethnographic data on the absence of agriculture among the population of North West Siberia due to the harsh climatic conditions for agriculture and the traditional way of life and occupations of the indigenous population, which are poorly combined with agriculture (Fedorova 2000: 130). Written sources about the Russian settlements established in the course of the colonisation of northern Siberia also testify that the extreme natural conditions were the main reason for the underdevelopment of agriculture. Products from cultivated plants were imported (Vizgalov, Parkhimovich 2008: 115). For that region, some local agricultural experiments conducted by settlers from the European part of Russia are known, mainly from the middle of the 19th century (Fedorova 2000: 131).

The data from archaeobiological studies of the investigated settlements correspond with later ethnographic material. They testify that fishing, reindeer husbandry, hunting and gathering were the main economic activities of the indigenous inhabitants of the Lower Ob region. (Vizgalov et al. 2013; Fedorova 2000: 24–79, Sokolova 2009: 115–134). This is consistent with the archaeozoological data from the Ust-Voykar settlement (Vizgalov 2013: 314–322) and our new archaeobotanical data that Siberian pine seeds, bird cherry and mountain-ash fruits, and various berries were used for medicinal and food purposes. Since many ethnographers have noted the conservative nature of the culture of the aborigines of northern Western Siberia, it can be assumed that their diet was determined by fishing and hunting activities. Taking into account the ethnographic material, this conclusion allows us to make a retrospective analysis of the dietary system. According to it all Ob Ugrian groups (Khanty and Mansy) had fish as the basis of their diet (Fedorova 2000: 159). The inhabitants of the settlement may have dealt with domestic form of the reindeer, as the presence of a significant amount of reindeer bone suggests (Vizgalov et al. 2013: 318). Grain products were supplied to the natives only in processed form (flour), and its sufficient supply to the Lower Ob region began in the middle of the nineteenth century (Fedorova 2000: 165, 167).

Conclusion

Both the plant macroremains and pollen analyses showed that the plant communities in the area adjacent to the Ust-Voikar settlement generally corresponded to the modern plant communities characteristic of the northern taiga subzone as it borders the forest tundra. On the territory of the settlement itself, some areas were overgrown with weed vegetation (*Chenopodium alba*, *Urtica dioica*). As no remains of cultivated plants were found, it can be concluded that the local people did not engage in agriculture. From the species composition of the plant macroremains, we can conclude that residents used local plant resources for construction (spruce, larch, birch) and for medicinal and food purposes (Siberian pine, bird cherry, cloudberry, Arctic raspberry, crowberry, cranberry, raspberry, rosehip, currant, mountain ash).

The macroremains and the data from the NPP analyses also allow for the reconstruction of (1) the use of spruce branches and grass bedding indoors and outdoors on wet sites; (2) the careful use of fire indoors; and (3) the presence of animals indoors. They also clarify the planning characteristics of the ‘Samples of doubtful origin’ and their classification as samples from ‘outer’ spaces.

Notably, the appearance of coprophilous fungi spores (mainly associated with herbivores) and whipworm eggs (*Trichuris* sp.) in the spectra did not correlate with each other. This leads to the suggestion that, although it is not possible to accurately identify the species belonging to *Trichuris* sp., it may have been a parasite species that fed on humans, not animals.

This study has also shown that the use of cluster analysis and PCA in the study of NPPs resulted in consistent conclusions and allowed us to divide the samples into groups conditionally marked by the type of territory in which they occurred, and by their use as ‘internal’ or ‘external’. This made it possible to clarify the planning affiliations of several samples, and to suggest ways in which the ‘box’ and the ‘objects’ were used by the inhabitants. Thus, it can be said that planning studies of archaeological sites appear fruitful, alongside traditional studies of vertical sections.

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References

Alkin SV, Sergusheva EA (2013) Semena mari beloj (*Cenopodium album*) v kulturnyh otlozheniyah Ust-Cherninskogo gorodisha. Problems of Archaeology, Ethnography and Anthropology of Siberia and Neighboring Territories 20: 251–254. [In Russian]

Anastasiou E (2015) Parasites in European populations from prehistory to the industrial revolution. In: Sanitation, Latrines and Intestinal Parasites in Past Populations. Ashgate, Farnham, UK, 203 pp.

Argant J, López-Sáez JA, Bintz P (2006) Exploring the ancient occupation of a high altitude site (Lake Lauzon, France): comparison between pollen and non-pollen palynomorphs. Review of Palaeobotany and Palynology 141: 151–163. https://doi.org/10.1016/j.revpalbo.2006.01.010

Bachura OP, Kosintsev PA, Gimranov DO, Korona OM, Nekrasov AE, Panteleev AP (2017) Ust-Poluj: hozyajstvennaya deyatelnost naseleniya i prirodnoe okruzhenie. In: Arheologiya Arktiki. Ust-Poluj: materialy i issledovaniya, T. 1. Delovaya pressa, Yekaterinburg, 82–101 p. [In Russian]

Brinkkemper O, van Haaster H (2012) Eggs of intestinal parasites whipworm (*Trichuris*) and mawworm (*Ascaris*): Non-pollen palynomorphs in archaeological samples. Review of Palaeobotany and Palynology 186: 16–21. https://doi.org/10.1016/j.revpalbo.2012.07.003

Buch TG, Kachura NN, Shvydkaya VD, Andreeva ER (1981) Sornye rasteniya Primorskogo kraya i mery borby s nimi. Dal'nevostochnoe knizhnoe izdatel'stvo, Vladivostok, 243 pp. [In Russian]

Buurrnan J, van Geel B, van Reenen GBA (1995) Palaeoecological investigations of a Late Bronze Age watering-place at Bovenkarspel, the Netherlands. Mededelingen Rijks Geologische Dienst 52: 249–270.

Chichinadze M, Kvavadze E (2013) Pollen and non-pollen palynomorphs in organic residue from the hoard of ancient Vani (western Georgia). Journal of archaeological science 40: 2237–2253. http://dx.doi.org/10.1016/j.jas.2012.12.036

Cook EJ, van Geel B, van der Kaars S, van Arkel J (2011) A review of the use of non-pollen palynomorphs in palaeoecology with examples from Australia. Palynology 35: 155–178. https://doi.org/10.1080/gspalynol.35.2.155

Davis MB, Goodlett JC (1960) Comparison of the present vegetation with pollen-spectra in surface samples from Brownington Pond, Vermont. Ecology 41: 346–357.

Diamond LS, Clark CG (2001) Entamoeba and Entamoeba histolytica. Encyclopedia of life sciences. https://doi.org/10.1038/npg.els.0001963

Dietre B, Gauthier É, Gillet F (2012) Modern pollen rain and fungal spore assemblages from pasture woodlands around Lake Saint-Point (France). Review of Palaeobotany and Palynology 186: 69–89. https://doi.org/10.1016/j.revpalbo.2012.07.002

Dobrokhotov VN (1961) Semena sornyh rastenij. Selhozizdat, Moscow, 414 pp. [In Russian]

Dunin-Gorkavich AA (1910) Tobolskij Sever. T. 2: Geograficheskoe i statistiko-ekonomicheskoe opisanie strany po otdelnym geograficheskim rajonam. Tipographiya Kirshbauma, Saint-Petersburg, 357 pp. [In Russian]

Durrieu G (1987) Uredinales from Nepal. Mycologia 79(1): 90–96.

Ejarque A, Miras Y, Riera S (2011) Pollen and non-pollen palynomorph indicators of vegetation and highland grazing activities obtained from modern surface and dung datasets in the eastern Pyrenees. Review of Palaeobotany and Palynology 167: 123–139. https://doi.org/10.1016/j.revpalbo.2011.08.001

Erdtman G (1943) An introduction to pollen analysis. Chronica Botanica Company, Waltham, 239 pp.

Faegri K, Iversen J (1989) Textbook of Pollen Analysis. 4 Ed. Wiley, Chichester, 328 pp.

Fedorova NV (2006) Voikarskij gorodok: Itogi raskopok 2003–2005 gg. Scientific Bulletin of the Yamalo-Nenets Autonomous District 4: 11–17. [In Russian]

Fedorova EG (2000) Rybolovy i okhotniki basseina Obi: problemy formirovaniya kul'tury khantov i mansi [Fishermen and hunters of the Ob basin: problems of the formation of the culture of the Khanty and Mansi]. Evropeiskii dom, St. Petersburg, 365 pp. [In Russian]

Feeser I, O'Connell M (2010) Late Holocene land-use and vegetation dynamics in an upland karst region based on pollen and coprophilous fungal spore analyses: an example from the Burren, western Ireland. Vegetation History and Archaeobotany 19: 409–426.

Gavrilov DA, Shumilovskih LS, Amirov ESH, Kamaldinov IR (2016) Mikrobiomorfnoe issledovanie kul'turnogo sloya gorodishcha Zhankent (X-XIII vv.), yuzhnyj Kazahstan. Dinamika okruzhayushchej sredy i global'nye izmeneniya klimata 7(1): 54–62. https://doi.org/10.17816/edgcc7154-62

Garkusha YuN (2022) Log Cabins of Ust-Voikary, a Fortified Settlement in Northwestern Siberia: Dendrochronological Analysis. Archaeology, Ethnology and Anthropology of Eurasia 50(4): 99–110. https://doi.org/10.17746/1563-0110.2022.50.4.099-110

Garkusha YuN (2020) K istorii arheologo-arhitekturnogo izucheniya gorodishcha Ust'-Vojkarskogo (Sever Zapadnoj Sibiri). Balandinskie chteniya 15: 133–143. https://doi.org/10.24411/9999-001A-2020-10017[In Russian]

Gauthier E, Bichet V, Massa C, Petit C, Vannière B, Richard H (2010) Pollen and non-pollen palynomorph evidence of medieval farming activities in southwestern Greenland. Vegetation History and Archaeobotany 19: 427–438.

Gelorini V, Verbeken A, van Geel B, Cocquyt C, Verschuren D (2011) Modern non-pollen palynomorphs from East African lake sediments. Review of Palaeobotany and Palynology 164: 143–173.

Ghosh R, Paruya DK, Acharya K, Ghorai N, Bera S (2017) How reliable are non-pollen palynomorphs in tracing vegetation changes and grazing activities? Study from the Darjeeling Himalaya, India. Palaeogeography, Palaeoclimatology, Palaeoecology 475: 23–40. https://doi.org/10.1016/j.palaeo.2017.03.006

Glime JM (2012) Protozoa: Peatland Rhizopods. Chapter 2–5. In: Glime JM (Ed.) Bryophyte Ecology. Volume 2. Bryological Interaction, 251 pp.

Goworukhin WS (1937) Flora Urala. Obl. Izd-vo, Sverdlovsk, 536 pp. [In Russian]

Graham LK, Wilcox LW (2000) The origin of alternation of generations in land plants: a focus on matrotrophy and hexose transport. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences 355: 757–767.

Grenfell HR (1995) Probable fossil zygnematacean algal spore genera. Review of Palaeobotany and Palynology 84: 201–220.

Grichuk MP (1967) The study of pollen spectra from recent and ancient alluvium. Review of Palaeobotany and Palynology 4: 107–112.

Grimm E (2015) Tilia and TGView 19 version 2.0.41. software. Illinois State Museum Research and Collection Center, Springfield.

Gurskaya MA (2006) Preliminary tree-ring dating of historical wood from Ust-Voykar settlement (15th–20th Centuries), Northwestern Siberia. Tree-rings in archaeology, climatology and ecology 54: 236–243.

Gurskaya MA (2007) A 900-years larch chronology for north-western Siberia on the bases of archaeological wood of the Ust-Voykar settlement. Geochronometria 8: 67–72.

Gurskaya MA (2008) Dendrochronological dating of archaeological wood of Ust-Voykar settlement (north-western Siberia). In: Kosintsev PA (Ed.) Faunae and Florae of the Northern Eurasia in the Late Cenozoic. Rifei Publ., Yekaterinburg, Chelyabinsk, 212– 231 p. [In Russian]

Haas JN (1996) Neorhabdocoela oocytes – Palaeoecological indicators found in pollen preparations from Holocene freshwater lake sediments. Review of Palaeobotany and Palynology 91: 371–382. http://dx.doi.org/10.1016/0034-6667(95)00074-7

Jankovská V, Pokorný J (2002) Palaeoecology of a medieval fishpond system (Vajgar, Czech Republic). Folia Geobotanica 37: 253–273.

Jones AK (1985) Trichurid ova in archaeological deposits: their value as indicators of ancient faeces. In: Fieller NRJ, Gilbertson DD, Ralph NG (Eds) A Palaeobiological Investigations. Reseach Design, Methods and Data Analysis, Symposia of the Association for Environmental Archaeology B, Vol. 5. B.A.R., Oxford, 105–115 p.

Jones GJ (1994) Bloom-forming bluegreen algae (Cyanobacteria). In: Sainty GR, Jacobs SWL (Eds) Water Plants in Australia. Sainty and Associates, Sydney, 266–285 p.

Kardash OV (2009) Nadymskij gorodok v konce XVI – pervoj treti XVIII vv. Istoriya i materialnaya kultura. Magellan Publ., Yekaterinburg, Nefteyugansk, 360 pp. [In Russian]

Kardash OV (2013) Poluysk settlement under Tayshin Princes. Magellan Publ., Yekaterinburg, Nefteyugansk, 380 pp. [In Russian]

Katz NJ, Katz SV, Kipiani MG (1965) Atlas and the identification keys of the fruits and seeds occurring in the Quaternary deposits of the USSR. Nauka, Moscow, 365 pp. [In Russian]

Korona O (2015) Archaeobotanical finds from the Nadymsky Gorodok medieval settlement in the forest-tundra of Western Siberia, Russia. Vegetation History and Archaeobotany 24: 187–196. http://dx.doi.org/10.1007/s00334-014-0496-5

Korona OM (2005) Rezultaty paleokarpologichesko analiza. In: Fedorova NV (Ed.) Zelenyj Yar: arheologicheskij kompleks epohi srednevekovya v Severnom Priobe. UB RAS Publ., Yekaterinburg, Salekhard, 320 pp. [In Russian]

Korona OM (2013) Results of carpological analysis of samples of the cultural layer from the excavations of the Poluy Cape town (2004) In: Kardash OV (Ed.) Poluysk settlement under Tayshin Princes. Magellan Publ., Yekaterinburg, Nefteyugansk, 366–369. [In Russian]

Kuhry P (1985) Transgression of a raised bog across a coversand ridge originally covered with an oak – lime forest: palaeoecological study of a middle holocene local vegetational succession in the Amtsven (Northwest Germany). Review of palaeobotany and palynology 44: 303–353.

Larin SI (2004) Atlas Yamalo-Neneckogo avtonomnogo okruga. Omskaya kartograficheskaya fabrika, Omsk, 303 pp. [In Russian]

López Sáez JA, van Geel B, Martín Sánchez M (2000) Aplicaciónde los microfósiles no polínicos en

Palinología Arqueológica. In: Actas III Congreso de Arqueología Peninsular, Vila-Real (Portugal), vol. IX. UTAD, Vila Real, 11–20 p.

Martynova EP (1998) Ocherki istorii i kultury hantov. IEA RAS Publ., Moscow, 235 pp. [In Russian]

Mazier F, Galop D, Gaillard MJ, Rendu C, Cugny C, Legaz A, Peyron O, Buttler A (2009) Multidisciplinary approach to reconstructing local pastoral activities: an example from the Pyrenean Mountains (Pays Basque). The Holocene 19: 171–188.

Miehe G, Miehe S, Kaiser K, Reudenbach C, Behrendes L, Duo L, Schlütz F (2009) How old is pastoralism in Tibet? An ecological approach to the making of a Tibetan landscape. Palaeogeography, Palaeoclimatology, Palaeoecology 276: 130–147. https://doi.org/10.1016/j.palaeo.2009.03.005

Miola A (2012) Tools for Non-Pollen Palynomorphs (NPPs) analysis: A list of Quaternary NPP types and reference literature in English language (1972–2011). Review of Palaeobotany and Palynology 186: 142–161. https://doi.org/10.1016/j.revpalbo.2012.06.010

Misra JK, Tewari JP, Deshmukh SK, Vágvölgyi C (2014) Fungi from different substrates. CRC Press, Boca Raton, 74 pp.

Mitchell PD, Anastasiou E, Syon D (2011) Human intestinal parasites in crusader Acre: evidence for migration with disease in the medieval period. International Journal of Paleopathology 11: 132–137. https://doi.org/10.1016/j.ijpp.2011.10.005

Mitchell PD (2017) Human parasites in the Roman world: health consequences of conquering an empire. Parasitology 144: 48–58. https://doi.org/10.1017/s0031182015001651

Mudie PJ, Lelièvre MA (2013) Palynological study of a Mi'kmaw shell midden, Northeast Nova Scotia, Canada. Journal of archaeological science 40: 2161–2175. https://doi.org/10.1016/j.jas.2012.10.004

Musotto LL, Bianchinotti MV, Borromei AM (2012) Pollen and fungal remains as environmental indicators in surface sediments of Isla Grande de Tierra del Fuego, southernmost Patagonia. Palynology 36: 162–179. https://doi.org/10.1080/01916122.2012.662919

Musotto LL, Bianchinotti MV, Borromei AM (2013) Inferencias paleoecológicas a partir del análisis de microfósiles fúngicos en una turbera pleistoceno-holocena de Tierra del Fuego, Argentina. Revista del Museo Argentino de Ciencias Naturales nueva serie 15: 89–98.

Novikov AV, Garkusha YuN (2017) Preliminary results of studies of the Ust-Voikarskoe-1 settlement (Subpolar zone of Western Siberia) in 2012–2016. Bulletin of the Russian Foundation for Basic Research. Humanities and social sciences 3: 141–149. [In Russian]

Novitskii G (1941) Kratkoe opisanie o narode ostyackom. Novosibgiz, Novosibirsk, 105 pp. [In Russian]

Panova NK (1998) Paleoekologiya poseleniya Tiutej-Sale-1 po rezultatam sporo-pylcevogo analiz. In: Fedorova NV, Kosintsev PA, Fitskh'yu VV (Eds) «Ushedshie v holmy». Kultura naseleniya poberezhij severo-zapadnogo Yamala v zheleznom veke. Yekaterinburg Publ., Yekaterinburg, 91–98 p. [In Russian]

Panova NK (2008) Paleovegetation reconstruction of Yarte-VI site of ancient settlement on the Yamal peninsula based on pollen records. In: Kosintsev PA (Ed.) Faunae and Florae of the Northern Eurasia in the Late Cenozoic. Rifei Publ., Yekaterinburg, Chelyabinsk, 244–249 p. [In Russian]

Panova NK, Yankovska V (2008) Results of spore-pollen analysis of the Ust-Poluy site and sediments in the vicinity of Salekhard. Scientific Bulletin of the Yamalo-Nenets Autonomous District 9: 55–64. [In Russian]

Perevalova EV (2004) Severnye hanty: etnicheskaya istoriya. UrO RAN, Yekaterinburg, 404 pp. [In Russian]

Poinar G, Boucot AJ (2006) Evidence of intestinal parasites of dinosaurs. Parasitology 133: 245–249. https://doi.org/10.1017/S0031182006000138

Prager A, Theuerkauf M, Couwenberg J, Barthelmes A, Aptroot A, Joosten H (2012) Pollen and non-pollen palynomorphs as tools for identifying alder carr deposits: A surface sample study from NE-Germany. Review of Palaeobotany and Palynology 186: 38–57. https://doi.org/10.1016/j.revpalbo.2012.07.006

Reille M (1992) Pollen et spores d’Europe et d’Afrique du nord: Laboratoire de botanique historique et palynologie. URA CNRS, Marseille, 520 pp.

Reille M (1995) Pollen et spores d'Europe et d'Afrique du Nord (Vol. 2). Laboratoire de Botanique historique et Palynologie. URA CNRS, Marseille.

Reille M (1998) Pollen et spores d'Europe et d'Afrique duNord: Supplement 2. Laboratoire de Botanique Historique et Palynologie. URA CNRS, Marseille.

Riera S, López-Sáez JA, Julià R (2006) Lake responses to historical land use changes in northern Spain: the contribution of non-pollen palynomorphs in a multiproxy study. Review of palaeobotany and Palynology 141: 127–137. https://doi.org/10.1016/j.revpalbo.2006.03.014

Scagel RF, Bandoni RJ, Rouse GE, Schofield WB, Stein JR, Taylor TMC (1965) An Evolutionary Survey of the Plant Kingdom. Wadsworth, Belmont, 638 pp.

Schofield JE, Edwards KJ (2011) Grazing impacts and woodland management in Eriksfjord: Betula, coprophilous fungi and the Norse settlement of Greenland. Vegetation History and Archaeobotany 20: 181–197. https://doi.org/10.1007/s00334-011-0281-7

Scholz T, Garcia HH, Kuchta R, Wicht B (2009) Update on the human broad tapeworm (genus *Diphyllobothrium*), including clinical relevance. Clinical Microbiology Reviews 22: 146–160. https://doi.org/10.1128/CMR.00033-08

Shumilovskikh LS, Seeliger M, Feuser S, Novenko E, Schlütz F, Pint A, Pirson F, Brückner H (2016) The harbour of Elaia: A palynological archive for human environmental interactions during the last 7500 years. Quaternary Science Reviews 149: 167–187. https://doi.org/10.1016/j.quascirev.2016.07.014

Singh S, Singh A, Hallan SS, Brangule A, Kumar B, Bhatia R (2023) A Compiled Update on Nutrition, Phytochemicals, Processing Effects, Analytical Testing and Health Effects of *Chenopodium album*: A Non-Conventional Edible Plant (NCEP). Molecules 28(13): 4902. https://doi.org/10.3390/molecules28134902

Slepchenko S M, Gusev AV, Ivanov SN, Svyatova EO (2015) Opisthorchiasis in infant remains from the medieval Zeleniy Yar burial ground of XII-XIII centuries AD. Memórias do Instituto Oswaldo Cruz 110: 974–980.

Slepchenko SM, Adaev VN (2017) On archaeological reconstruction of dietary traditions among native peoples of Siberia: arhaeoparasitological analysis of materials dated to 17-th – beginning of

20-th centuries. Moscow University Anthropology Bulletin 1: 103–114.

Šmilauer P, Lepš J (2014) Multivariate analysis of ecological data using CANOCO 5. Cambridge university press, Cambridge

Sokolova ZP (2009) Khanty and Mansy. A View from the 21st Century. Nauka, Moscow, 756 pp. [In Russian]

Transeau EN (1938) Notes on Zygnemataceae. American Journal of Botany 25: 524–528. Transeau EN (1951) The Zygnemataceae. Ohio State University Press, Columbus.

van Geel B (1976) Fossil spores of Zygnemataceae in ditches of a pre-historic settlement in Hoogkarspel (The Netherlands). Review of Palaeobotany and Palynology 22: 337–344.

van Geel B (1978) A palaeoecological study of Holocene peat bog sections in Germanyand The Netherlands, based on the analysis of pollen, spores and macro- and microscopic remains of fungi, algae, cormophytes and animals. Review of Palaeobotanyand Palynology 25: 1–120.

van Geel B (1986) Application of fungal and algal remains and other microfossils in palynological analyses. Handbook of Holocene palaeoecology and palaeohydrology 24: 497–505.

van Geel B (2002) Non-Pollen Palynomorphs. In: Smol JP, Birks HJB, Last WM, Bradley RS, Alverson K (Eds) Tracking Environmental Change Using Lake Sediments. Developments in Paleoenvironmental Research. Vol 3. Springer, Dordrecht, 99–119. https://doi.org/10.1007/0-306-47668-1_6

van Geel B, Aptroot A (2006) Fossil ascomycetes in Quaternary deposits. Nova Hedwigia 82: 313–329.

van Geel B, Bohncke SJP, Dee H (1980) A palaeoecological study of an upper Late Glacial and Holocene sequence from “De Borchert”, The Netherlands. Review of palaeobotany and palynology 31: 367–448.

van Geel B, Bos JM, Pals JP (1983) Archaeological and palaeoecological aspects of a medieval house terp in a reclaimed raised bog area in North Holland. Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek 33: 419–444.

van Geel B, Buurman J, Brinkkemper O, Schelvis J, Aptroot A, van Reenen G, Hakbijl T (2003) Environmental reconstruction of a Roman Period settlement site in Uitgeest (The Netherlands), with special reference to coprophilous fungi. Journal of Archaeological Science 30: 873–883.

van Geel B, Coope GR, van Der Hammen T (1989) Palaeoecology and stratigraphy of the Lateglacial type section at Usselo (The Netherlands). Review of palaeobotany and palynology 60: 25–129.

van Geel B, Grenfell HR (1996) Green and blue-green algae. 7A – Spores of Zygnemataceae. In: Jansonius J, McGregor DC (Eds) Palynology: principles and applications. American Association of Stratigraphic Palynologists Foundation 1, Salt Lake City, 173–179.

van Geel B, Guthrie RD, Altmann JG, Broekens P, Bull ID, Gill FL, Jansen B Nieman AM, Gravendeel B (2011) Mycological evidence of coprophagy from the feces of an Alaskan Late Glacial mammoth. Quaternary Science Reviews 30: 2289–2303. https://doi.org/10.1016/j.quascirev.2010.03.008

van Geel B, Guthrie RD, Fisher DC, Altmann JG, Broekens P, Bull ID, Gill FL, Gravendeel B, Jansen B, Nieman AM, Rountrey AN, van Reenen GBA (2010) Paleoecological studies of mammoth and mastodon feces and the evidence for coprophagy. Quaternaire, Hors Série 3: 98–99.

van Geel B, Mur LR, Ralska-Jasiewiczowa M, Goslar T (1994) Fossil akinetes of Aphanizomenon and Anabaena as indicators for medieval phosphate-eutrophication of Lake Gosciaz (Central Poland). Review of palaeobotany and Palynology 83: 97–105.

van Geel B, Pals JP, van Reenen GBA, van Huissteden J (1995) The indicator value of fossil fungal remains, illustrated by a palaeoecological record of a Late Eemian/Early Weichselian deposit in the Netherlands. Neogene and Quaternary Geology of North-West Europe. Mededelingen Rijks Geologische Dienst 52: 297–315.

Vánky K (1994) European smut fungi. Gustav Fischer Verlag, Stuttgart.

Vizgalov GP, Kardash OV, Kosintsev PA, Lobanova TV (2013) Istoricheskaya ecologiya naseleniya severa Zapadnoi Sibiri [Historical ecology of the population of the north of Western Siberia]. AMB Publ., Yekaterinburg.

Yastrebov KV (2013) Ecology, epidemiology and prevalence Diphyllobothriasis in Siberia and the Far East. In: Actual Aspects of Parasitic Diseases in the Modern Period: Abstracts of All-Russian Conference. FBUN Tyumen Research Institute of Regional Infectious Pathology, Tyumen, 205–207.

Yeloff D, Charman D, van Geel B, Mauquoy D (2007) Reconstruction of hydrology, vegetation and past climate change in bogs using fungal microfossils. Review of Palaeobotany and Palynology 146: 102–145.

Supplementary material 1

Table 1. Pollen percents. Table 2. NPP Concentrations.

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Data type: Excel tables

Explanation note: The tables present the pollen percents and non-pollen palynomorphs (NPP) concentrations.

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Supplementary material 2

Principle Component Analysis species score biplots

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Data type: scheme

Explanation note: The scheme presents the species score biplots.

Link: http://journal.asu.ru/biol/article/view/13909/11728