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ПРОБЛЕМЫ ПАЛЕОПОЧВОВЕДЕНИЯ И ГЕОАРХЕОЛОГИИ

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ДИНАМИКА ДРЕВЕСНОЙ РАСТИТЕЛЬНОСТИ И АНТРОПОГЕННАЯ АКТИВНОСТЬ ПО ДАННЫМ АНАЛИЗА ДРЕВЕСНЫХ УГЛЕЙ ИЗ ГОРОДИЩ РАННЕГО ЖЕЛЕЗНОГО ВЕКА И РАННЕГО СРЕДНЕВЕКОВЬЯ НА ВЕРХНЕЙ ВОЛГЕ

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Были исследованы угли в культурных слоях трех городищ, расположенных в верховьях р. Волги (Пеновский район Тверской области). Угли изучали в кернах и археологических шурфах. Характеристика культурных слоев городищ позволяет отнести их к палеоурбаноземам, "Archaeological Dark Earth" мощностью от 50 до 80 см. Возраст углей и археологические находки показали, что культурные слои городищ Заборовка-Лихуши и Ворошилово относятся к раннему железному веку (Дьяковская культура), а городища Руна-Заборовка – к раннему средневековью. Определены концентрация и таксономический состав углей в образцах, отобранных с разных глубин. Всего было определено 629 углей, относящихся к 13 родам древесных растений. На основе анализа углей из 12 датированных образцов дана оценка изменения таксономического состава деревьев во времени. Во все периоды доминировали древесные угли *Pinus*, за ними по числу следовала *Picea*; доли этих таксонов увеличивались от раннего железного века к позднему средневековью. Наибольшее число таксонов (9 родов) отмечено для раннего железного века, в том числе встречены *Quercus*, *Ulmus* и *Acer*. Информация, полученная в результате изучения древесного угля в почве, является ценным свидетельством присутствия таксонов деревьев на конкретной территории в определенные отрезки времени; позволяет воссоздать историю взаимодействия человека и древесной растительности в верховьях Волги.

Ключевые слова: педоантракология, палеоурбаноземы, Дьяковская культура, дровяная древесина, радиоуглеродное датирование

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1. INTRODUCTION

The Early Iron Age and subsequent centuries in the forest region of Eastern Europe is a crucial time of structural change in human–nature interactions. Therefore it is highly important to study the sites of the Dyakovo and neighboring cultures in terms of settlement, reconstruction of economy types, land use features, and anthropogenic impact on landscapes. In this regard, one of the most well-studied regions for the Early Iron Age is the Moskva River basin (Syrovatko, 2009; Krenke, 2011; Ershova et al., 2014, 2016; Syrovatko et al., 2016; Uspensky, Chaukin, 2016; Veksler, Gusakov, 2017; Islanova, 2017; Krenke, 2019; Lopatina, 2019). The monuments of the Dyakovo culture in the Upper Volga River and Valdai have been studied comparatively little (Islanova, 2012, 2013, 2014 a, b). This territory remains a "white spot" in the Early Iron Age, a poorly populated area in the middle to second half of the 1st millennium AD (Islanova, 2020). In terms of settlement and archaeological finds, the subsequent period (second half of the 1st millennium AD) in neighboring areas, such as Novgorod region (Eremeev, Dzyuba, 2016), ancient Smolensk and its surroundings, including the Gnezdovo archaeological complex (Ershova et al., 2020; Krenke et al., 2021), is much better studied.

The target of our study is the sites of fortifications (hillforts) in the upper Volga and the Western Dvina rivers, located in the contact zone of the Dyakovo and the Dnieper-Dvina cultures (northern part of the Peno district of the Tver region). Research of archival materials and reconnaissance in recent years allowed to judge the existence of hillforts of different size in the study area (Smirnov et al., 2021). Archaeological settlements mostly belong to the Early Iron Age, although some of them according to the few ceramic finds, could have appeared in the Early Middle Ages. The sparse networks of small hillforts identified in recent years raise questions about how the Early Iron Age people may have influenced the dynamics of ecosystems and how their lives were influenced by natural conditions.

In the last decade, pedoanthrocological studies have been actively developed to reconstruct the history of specific sites based on the analysis of charcoals in soil and sediments and their dating (Carcaillet, Talon, 1996; Carcaillet, Thinon, 1996; Talon et al., 2005; Nelle et al., 2013; Ohlson et al., 2017; Saulnier et al., 2019). These methods are widely used in the study of archaeological sites (Figueiral, 1996; O'Donnell, 2017; Masi et al., 2018; Moskal-del Hoyo et al., 2021; Novák et al., 2021; Ruiz-Giralt, 2021). They are often used together with other methods of paleoecological studies, primarily the study of different proxies in bog or lake sediments that provide information about the broader geographic and paleohistorical context. Applied to the region under the study, such work has been done for the Krivetsky Mokh bog (Mazei et al., 2020).

We focused on an anthracological study of areas of three hillforts of the Iron Age and the Early Middle Ages with the aim to identify the peculiarities of the interaction between humans and woody vegetation. The objectives of the research were to: (1) determine the thickness of the cultural layer and analyze the stratigraphy and concentration of charcoals in the hillfort; (2) analyze the taxonomic composition of charcoals with regard to their stratigraphy; and (3) determine the age of charcoals from different locations in the cultural layer and reconstruct changes in the taxonomic composition of charcoals in the hillfort areas during different historical periods.

2. STUDY AREA

Study area is located in the north of the Valdai Upland located in the central part of the East European Plain, in the Peno district of the Tver region (fig. 1).

The area is located in the hemiboreal forest region (European Russian Forests, 2017), in the southern subzone of the taiga forest. Landscapes are represented by a hilly plain (150–250 m a.s.l. with a maximum elevation of 275 m) moderately dissected by gullies, valleys of small streams and depressions. Quaternary deposits are formed by moraine materials and fluvioglacial sands. Moraine ridges and hills are mainly oriented from northwest to southeast, have a height of 6 to 20 and a length of 100 to 1500 m. The area is characterized by a large number of lakes and mires developed in depressions between moraine hills.

The climate is temperate and moderate continental with relatively cold winters (mean January temperature is −5.9°C) and warm summers (mean July temperature is 18.3°C) (the Toropets weather station, 80 km southwest from the study area, 1988–2019; http://www.meteo.ru). The mean annual temperature is +5.6°C. The mean annual precipitation is about 761 mm.

Forests are usually dominated by *Pinus sylvestris* (Scots pine) and *Picea abies* (European spruce) with the participation of *Betula* spp. (birch) and *Populus tremula* (common aspen). In the understorey, *Sorbus aucuparia* and *Frangula alnus* often occur. *Vaccinium myrtillus*, *V. vitis-idaea*, and green mosses prevail in the forest floor. Boreal and nemoral herbaceous species, such as *Hepatica nobilis, Calamagrostis arundinacea, Dryopteris filix-mas, Oxalis acetosella, Convallaria majalis, Galeobdolon luteum, Asarum europaeum,* and *Stellaria holostea* are common. *Anemone nemorosa* can often be found in spring. Broadleaf trees rarely occur in the vegetation. *Quesrcus robur* (pedunculate oak) is common in the understory of *Pinus sylvestris* forests while it rarely occurs in the overstory.

Small adult individuals of *Tilia cordata* (small-leaved lime) usually occurs in lowlands, near streams. *Acer platanoides* (Norway maple), *Ulmus glabra* (Scots elm), and *Fraxinus excelsior* (common ash) can be found in the north of the region where moraine hills prevail. We did not meet elm and ash in the study area; Norway maple was occasionally found. In wet depressions, often close to swamps, there are forests dominated by *Alnus incana* (grey alder); they also occur on moraine hills.

Sandy soils Albic and Entic Podzols prevail on watersheds and slopes; Stagnic Podzols and Histosols are common in depressions on the border with bogs (IUSS Working Group, 2015).

3. MATERIALS AND METHODS

We have studied soil charcoal in the area of three hillforts discovered in 2018–2019 (fig. 1, tabl. 1) (Smirnov et al., 2021), on which there were no large-scale archaeological excavations. The each hillfort is located on the edge of a moraine ridge (an oz ridge). Zaborovka-Likhusha and Runa-Zaborovka hillforts are located inside the forest tracts. Voroshilovo hillfort is located on a wooded hill surrounded by modern and

(a)

(b)

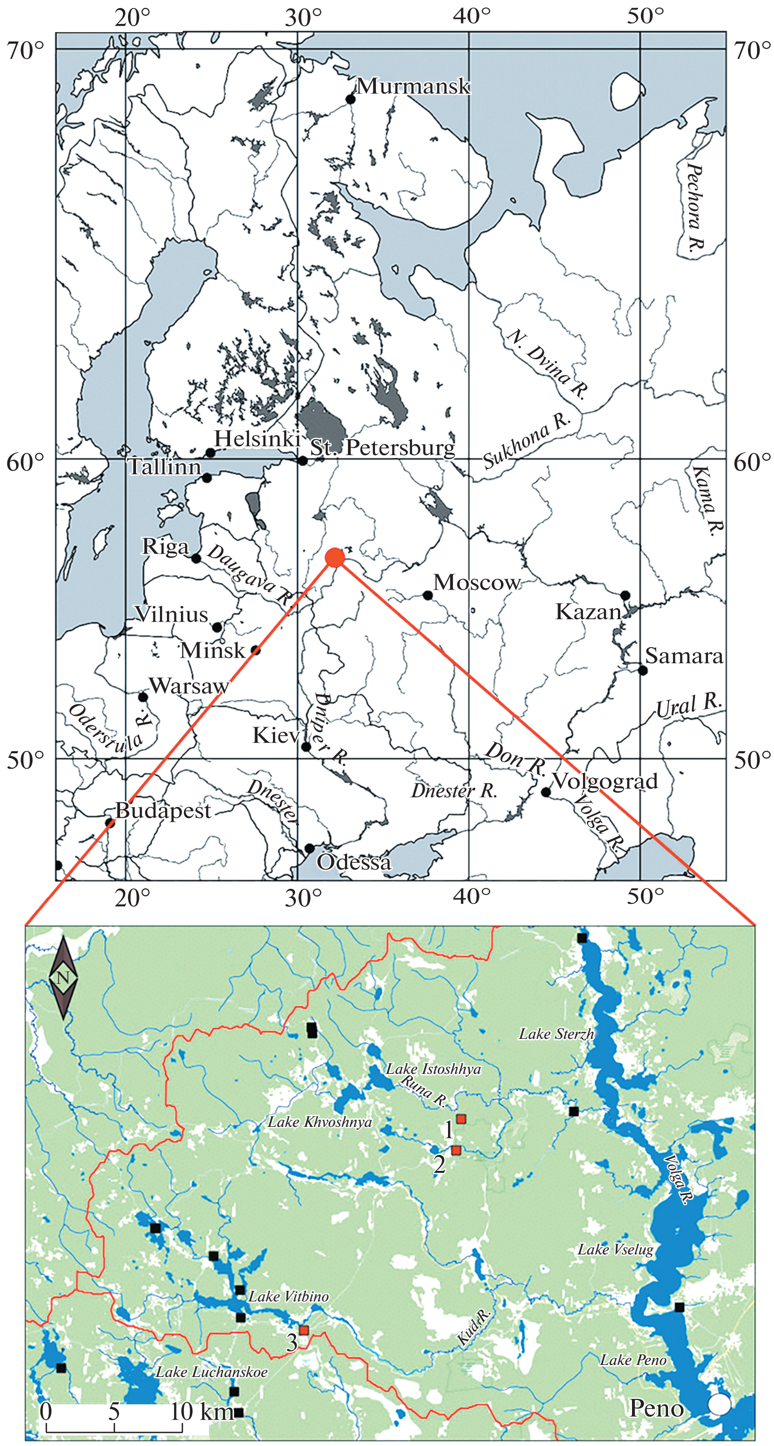

Fig. 1. Location (a) and map (b) of the study region with the hillforts (squares): 1 – Runa-Zaborovka, 2 – Zaborovka-Likhusha, 3 – Voroshilovo.

Рис. 1. Местонахождение (a) и карта (b) исследуемого района с городищами (квадраты): 1 – Руна-Заборовка, 2 – Заборовка-Лихуша, 3 – Ворошилово.

abandoned arable lands. *Pinus sylvestris* and *Picea abies* dominate in the forest canopy in all hillforts. According to the tree cores, *Pinus sylvestris* ranged from 80 to 110 years old in 2019. The brash *Lonicera xylosteum* and *Daphne mezereum* were common in the understory. Forest floor vegetation in the hillforts differed from the surrounding forests by low participation of boreal dwarf-shrubs and green mosses. Nemoral

Table 1. Points of soil sampling to define the concentration and taxonomic composition of charcoal
Таблица 1. Точки отбора проб почвы для определения концентрации и таксономического состава древесного угля

Hillfort	ID	Description	Number of samples used for charcoal concentration / taxonomical composition
Zaborovka-Likhusha	ZL-1	Soil core 1 in the inner site	8/8
	ZL-2	Soil core 2 in the inner site	8/8
	ZL-3	Soil core 3 in the inner site	8/8
	ZL-4	Soil core 4 in the inner site	3/3
	ZL-5	Archaeological excavation, depth 30–45 cm	0/1
	ZL-6	Archaeological excavation, depth 45–60 cm	0/1
	ZL-7	Archaeological excavation, depth 45–60 cm	0/1
	ZL-8	Archaeological excavation, depth 15–30 cm	0/1
	ZL-9	Ancient moat	0/3
Voroshilovo	V-1	Soil core 1 in the inner site	8/8
	V-2	Soil core 2 in the inner site	8/8
	V-3	Soil core 3 in the inner site	5/5
	V-4	Hillock of treefall with uprooting	0/1
	V-5	Archaeological excavation, depth 45–60 cm	0/1
	V-6	Archaeological excavation, depth 45–60 cm	0/1
Runa-Zaborovka	RZ-1	Soil core 1 in the inner site	6/6
	RZ-2	Soil core 2 in the inner site	6/6
	RZ-3	Soil core 3 in the inner site	6/6
	RZ-4	Archaeological excavation, depth 15–30 cm	0/1

herbs, such as *Galeobdolon luteum, Asarum europaeum, Stellaria holostea, Pulmonaria obscura, Aegopodium podagraria*, etc. were common together with *Hepatica nobilis* and *Urtica dioica*.

Hillforts are elevations surrounded by fortification structures. Zabarovka-Likhusha hillfort (fig. 2) is ringed by a creek to west and north and a bog to east. Size of the inner platform (inner site) is 35×21 m; height above the creek is 14 m. The fortification structure includes the rampart of the settlement itself, a moat in the south, and an additional cape rampart and moat in the north. Voroshilovo hillfort (fig. 3) has an oval inner area of 47×18 m; height of the site from the bottom is 5.5 m; traces of ramparts and moats can be seen from southwest and northeast. Runa-Zaborovka hillfort (fig. 4) has a rounded inner area with a diameter of 25 m; height of the site is 3.5 m.

Soil samples were taken at the inner site of each hillfort with a soil auger with a depth step of 15 cm to determine the concentration and taxonomic composition of charcoal. The diameter of soil auger was 5 cm; the volume of soil samples was about 235 cm^3. Soil samples were also taken from two archaeological excavations (1×1 m) both for the concentration /composition of charcoal and for radiocarbon dating with a soil sample volume of about 600 cm^3.

In Zaborovka-Likhusha hillfort, the following sampling was performed. Four soil cores were taken to a depth of 120 cm. Charcoals were also taken from an archaeological excavation: from a burnt wooden structure in a depth of 55 cm and from the depth of 35 cm (both for radiocarbon dating) and four samples at different depths for charcoal concentration and taxonomical composition (tabl. 1). Three soil samples were also taken from a pit dug on the western slope at the bottom of the hillfort, where an ancient moat was uncovered.

In Voroshilovo hillfort, the following sampling was done. Three soil cores to a depth of 120 cm were taken. Two charcoal samples were taken from an archaeological excavation located at the edge of the inner platform. Soil was also sampled from a hillock formed by a recent treefall with uprooting that was located in the inner platform and where a Dyakovo type spindle whorl was found.

In Runa-Zaborovka hillfort, three soil cores to a depth of 90 cm were selected and one soil sample was taken from a small archaeological excavation on the inner hillfort platform.

Fragments of textile ceramics, typical for the Dyakovo culture of the early Iron Age, were found at the Zaborovka-Likhusha and Voroshilovo hillforts. At Runa-Zaborovka hillfort, only stucco ceramics satu-

(a) (b) (c)

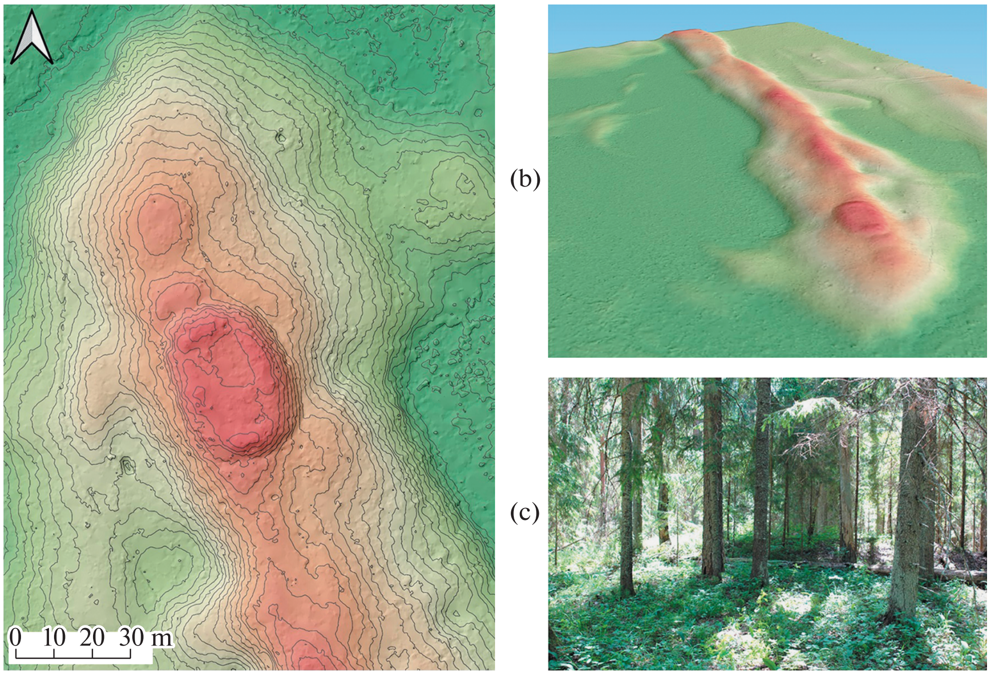

Fig. 2. Zaborovka-Likhusha hillfort: (a) – map of the hillfort with the LiDAR-derived local relief model; (b) – LiDAR-derived local relief model of the hillfort on the moraine ridge; (c) – forest vegetation in the area of the hillfort.

Рис. 2. Городище Заборовка-Лихуша: (a) – цифровая модель рельефа городища по данным лидарной съемки; (b) – цифровая модель рельефа моренной гряды с городищем по данным лидарной съемки; (c) – лесная растительность в районе городища.

(a) (b)

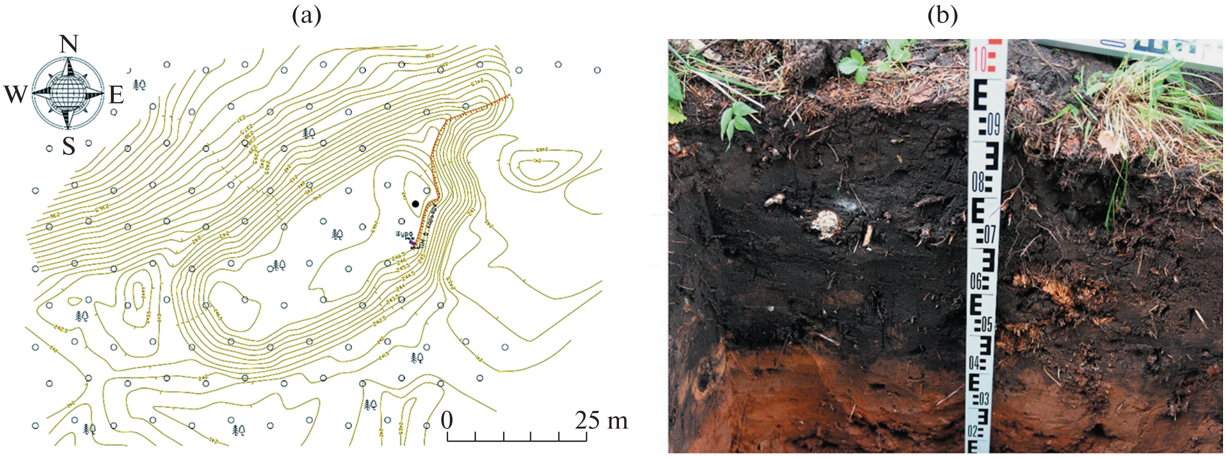

Fig. 3. Voroshilovo hillfort: (a) – map of the hillfort; (b) – soil (cultural layer) profile in an archaeological excavation.

Рис. 3. Городище Ворошилово: (a) – схема городища с горизонталями; (b) – профиль почвы (культурного слоя) в археологическом шурфе.

rated with gruss has been found so far. The latter is typical both for the early Iron Age and for the early Middle Ages, so small fragments of this pottery cannot be used as chronological indicators.

Soil samples were dried on air and gently sieved dry through 2 mm mesh size (Carcaillet, Talon, 1996). Charcoal fragments were extracted by hand from the sieved samples and then weighed to calculate charcoal concentration (or anthracomass, g of charcoal per kg of dry soil).

Taxonomic identification of charcoals was performed using a reflected light microscope (40–400×) using wood anatomy atlas (Benkova, Schweingruber, 2004). The transverse, radial and tangential anatomic planes of each charcoal were observed to identify charcoals at the genus taxonomic level. When calculating

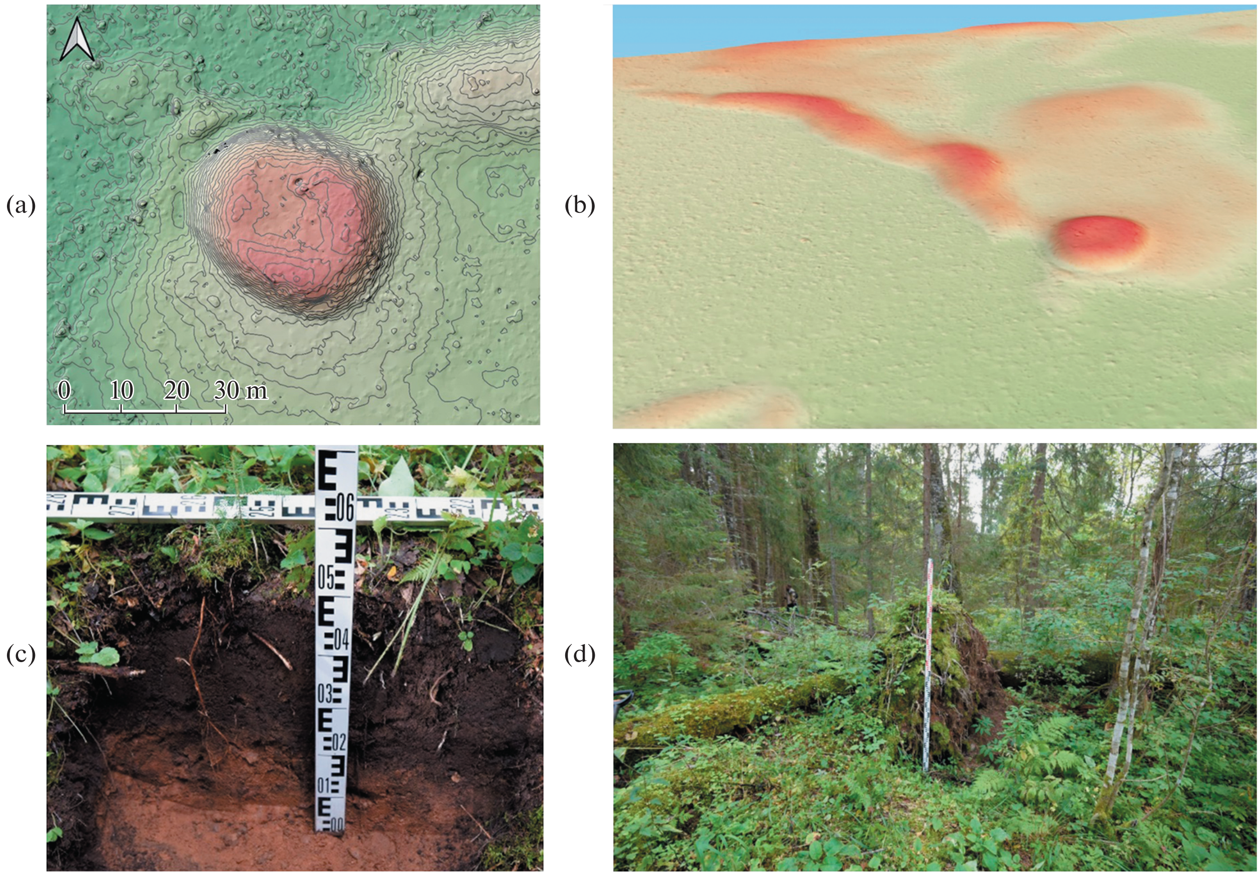

Fig. 4. Runa-Zaborovka hillfort: (a) – map of the hillfort with the LiDAR-derived local relief model; (b) – LiDAR-derived local relief model of the hillfort on the moraine ridge; (c) – soil (cultural layer) profile in an archaeological excavation; (d) – forest vegetation in the area of the hillfort.

Рис. 4. Городище Руна-Заборовка: (a) – цифровая модель рельефа городища по данным лидарной съемки; (b) – цифровая модель рельефа моренной гряды с городищем по данным лидарной съемки; (c) – профиль почвы (культурного слоя) в археологическом шурфе; (d) – лесная растительность в районе городища.

the percentage composition of taxa, all identified charcoals larger than 2 mm were counted.

Fourteen charcoal samples were radiocarbon dated by accelerator mass spectrometer – AMS in the Laboratory of Radiocarbon Dating and Electron Microscopy in the Institute of Geography of the Russian Academy of Sciences (IG RAS). The radiocarbon dates were calibrated with the IntCal20 (Reimer et al., 2013) using OxCal (Ramsey, 2009). For the reconstruction of historical dynamics of woody taxa in the area of hillforts studied, we assumed that the degree of mixing of the cultural layer material is not very high and the age of the dated charcoal corresponds to the age of the remaining charcoals in the sample. Thus, data on 12 radiocarbon samples were extrapolated to 209 charcoals.

For each hillfort, taxa diversity was estimated by taxa richness calculated as (i) the total number of taxa in all samples studied within the hillfort, (ii) taxa density estimated as the mean number of taxa per a sample, and (iii) Shannon's and Simpson's diversity indices calculated by standard formulas and accounting for the taxa abundance (Magurran, 2004).

4. RESULTS

Cultural layer, soil charcoal stratigraphy and concentration. The cultural layer (topsoil) of all the studied hillforts had a dark coloring due to the abundance of fine charcoal. In some places, cultural layer had inclusions of stones destroyed by incideration. The thickness of the cultural layer varied from 50 to 75 cm and from 50 to 80 cm in Zaborovka-Likhusha and Voroshilovo hillforts, respectively, and it was about 50 cm in Runa-Zaborovka. In archaeological excavations, the cultural layer looked relatively homogeneous in structure and color to a depth of 50 cm in Zaborovka-Likhusha and Voroshilovo inner sites, and to 30–40 cm in Runa-Zaborovka. Deeper, lighter and darker spots and interlayers alternated, and traces of pedoturbations were visible.

Table 2. Mean charcoal concentrations in the soil cores in the study sites, g × kg^{-1} of dry soil
Таблица 2. Средние концентрации древесного угля в образцах почвы на исследуемых участках, г × $кг^{-1}$ сухой почвы

Depth, cm	Zaborovka-Likhusha		Voroshilovo		Runa-Zaborovka	
	Mean	SE	Mean	SE	Mean	SE
0–15	3.59	2.19	0.34	0.21	0.42	0.27
15–30	0.95	0.21	0.59	0.05	0.51	0.29
30–45	0.37	0.13	0.43	0.10	0.36	0.19
45–60	0.90	0.76	0.30	0.22	0.29	0.18
60–75	0.02	0.02	0.70	0.58	0.21	0.18
75–90	0.03	0.01	0.16	0.16	0.00	0.00
90–105	0.02	0.01	0.22	0.22	NA	
105–120	0.06	0.04	0.23	0.23	NA	

The highest values of both maximum (10 g kg^{-1} of dry soil) and average (1.24 ± 0.55 g kg^{-1}) concentrations of charcoals in the cultural layer were observed in Zaborovka-Likhusha hillfort. These values were 1.84 and 0.47 ± 0.12 g kg^{-1} in Voroshilovo and 1.06 and 0.40 ± 0.10 g kg^{-1} in Runa-Zaborovka hillforts.

In all sites, charcoal concentration strong varied both spatially and by depth (fig. 5, tabl. 2). In Zaborovka-Likhusha, it varied in different columns at depth up to 60 cm and then decreased sharply. In Voroshilovo, in two columns (V-1 and V-3) charcoal occurred only within the cultural layer; in the third column (V2), the maximum concentration of charcoal was in the lower part of the cultural layer, but even deeper, up to 120 cm, charcoals were found in abundance. In Runa-Zaborovka, charcoal concentrations varied between columns to the greatest extent among all hillforts, but charcoal was not found deeper than 75 cm.

The soil pit at the bottom of Zaborovka-Likhusha hillfort (across the ancient moat) comprised three layers of sediments with boundaries at a depth of 16, 35, and 49 cm. The layers contained charcoals and consisted of brown sand, lighter in color than the material of the cultural layer.

Soil charcoal taxonomy: distribution and diversity. We extracted 932 charcoal fragments from 64 soil samples; 5 soil samples were without charcoal. A total of 629 charcoal fragments belonging to 13 woody genera were taxonomically identified: 304 in Zaborovka-Likhusha, 173 in Voroshilovo, and 119 in Runa-Zaborovka hillforts.

In taxa composition of charcoals (fig. 6), *Pinus* dominated (66 and 40%, respectively) in Zaborovka-Likhusha and Voroshilovo hillforts, followed by *Picea* (16 and 20%). Charcoals of four hardwood trees were also found in these sites: *Quercus*, *Ulmus*, *Acer*, and *Tilia* (11% from all charcoals) were identified in Zaborovka-Likhusha and *Quercus*, *Ulmus*, *Acer*, and *Corylus* (16%) in Voroshilovo. Runa-Zaborovka hillfort differed notably in the composition of charcoals from the other two sites. *Picea* charcoals prevailed (50%) and only few *Pinus* charcoals occurred (6%). *Quercus* charcoals were second in number (26%), but this was the contribution of one soil sample from the archaeological excavation; charcoals of *Ulmus, Acer,* and *Tilia* were absent, while the proportion of *Alnus* (6%) was greater than in the other sites.

In the inner site of Zaborovka-Likhusha hillfort (ZL-1 – ZL-8), *Pinus* charcoals were found throughout the depths; charcoals of *Picea* prevailed in the upper part while *Populus, Betula*, and *Alnus* dominated in the bottom part of the cultural layer (fig. 7). Charcoals of hardwoods, such as *Ulmus, Acer,* and *Tilia,* occurred at depth from 15 to 60 cm; it means they were neither in the upper part, nor under the cultural layer. In soil pit across the ancient moat (ZL-9), only *Pinus* charcoals were found throughout the depths, whereas *Picea* and *Betula* occurred only in the upper sediment layer.

In Voroshilovo hillfort, charcoals of the hardwood species *Quercus, Ulmus*, and *Acer* were found within the cultural layer, except for the upper 15 cm (fig. 8). Charcoals of *Corylus,* on the contrary, was found only to a depth of 15 cm. The taxonomic composition was richest in the lower part of the cultural layer at the level of 45–60 cm (up to 5 taxa in the sample). Thus, in the sample V-6 from the archaeological excavation we found charcoals of *Picea, Populus, Ulmus, Acer,* and *Salix;* in the sample from treefall hillock (V-4) charcoals of *Pinus, Picea,* and *Alnus* were found together with the Dyakovo spindle whorl.

In Runa-Zaborovka hillfort, almost all charcoals were found within the cultural layer, except for a few in the column RZ-2 (fig. 9). *Picea* charcoals dominated in most samples. *Pinus* and *Alnus* were found at different depths. Charcoals of *Quercus* occurred mainly at a depth of 15–30 cm; *Corylus* and *Salix* only in the upper 15 cm.

All taxa diversity indices were highest in Voroshilovo (tabl. 3). They were followed by Runa-Zaborovka

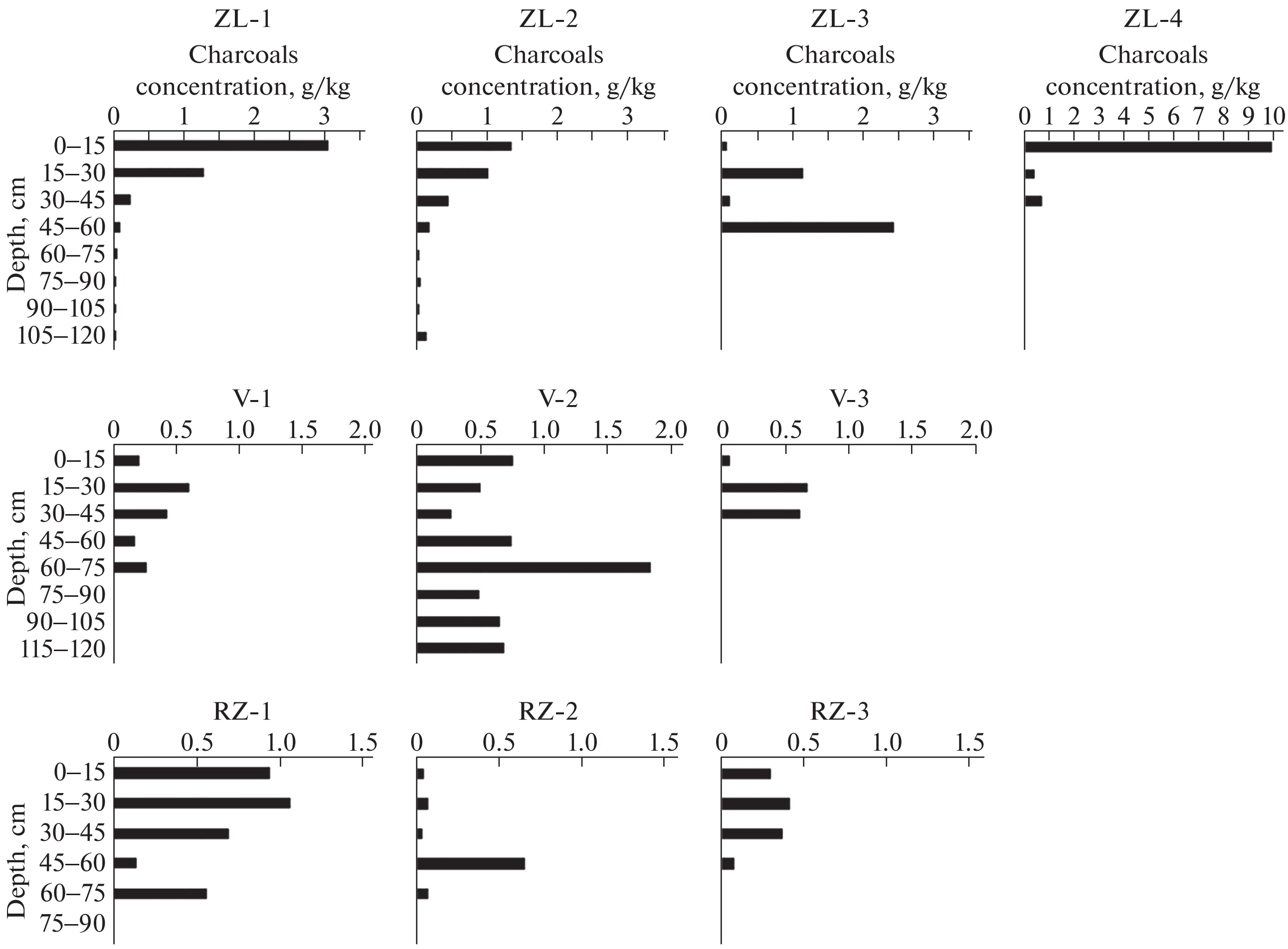

Fig. 5. Charcoal concentration in the soil cores taken in the inner sites of hillforts.

Рис. 5. Концентрация древесного угля в образцах, взятых на внутренних площадках городищ (обозначения в тексте).

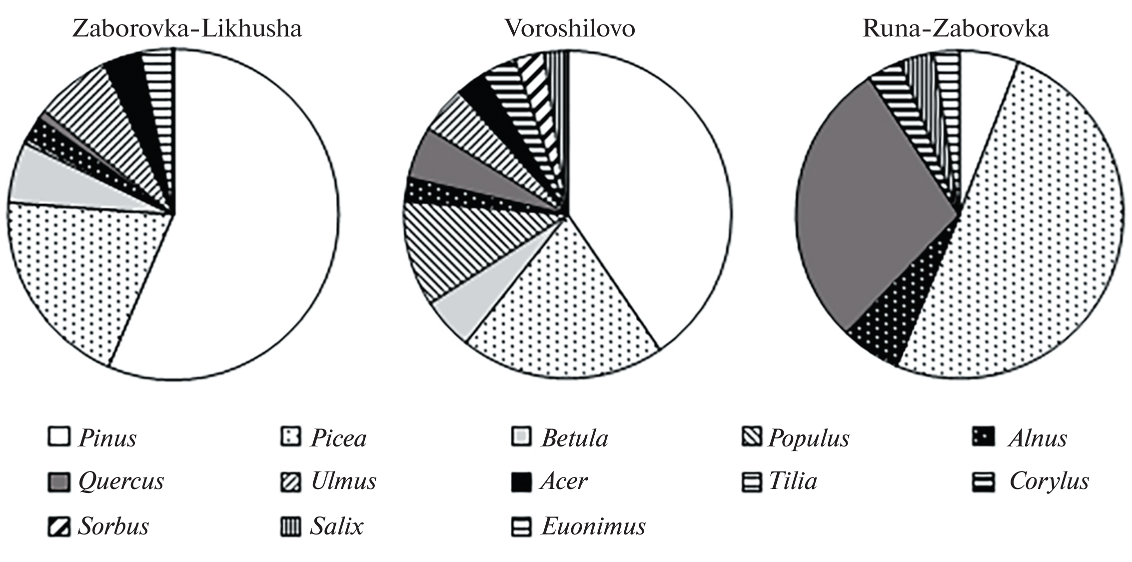

Fig. 6. Taxonomical composition of soil charcoals from the hillforts.

Рис. 6. Таксономический состав углей из культурного слоя городищ.

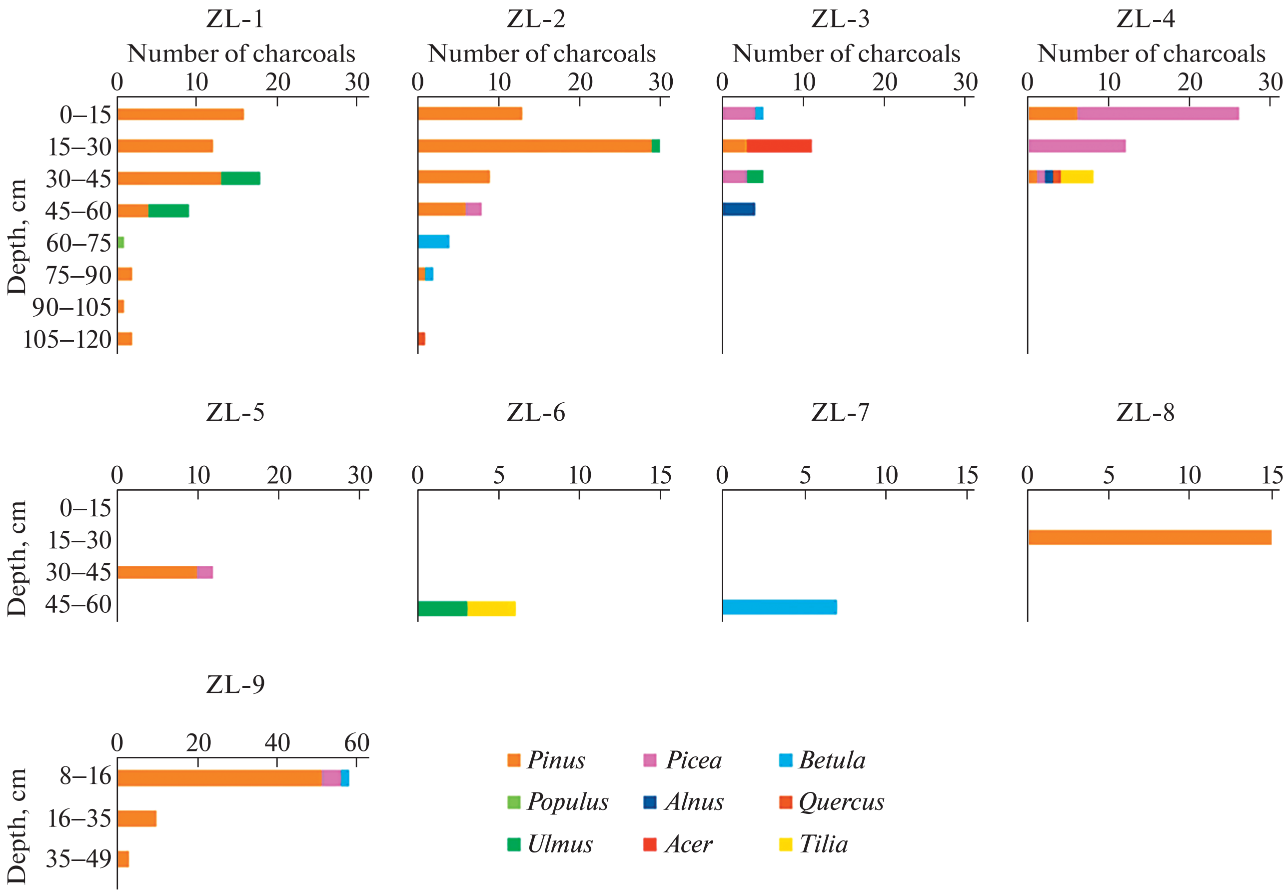

Fig. 7. The number of charcoals of different taxa in Zaborovka-Likhusha hillfort.
Рис. 7. Число углей разных таксонов в культурном слое городища Заборовка-Лихуша.

indices with the exception of the taxa richness, which was lower in Runa-Zaborovka (7 taxa) than in Zaborovka-Likhusha (9 taxa), probably due to twice as many samples in the latter. Simpson's index shows that dominance was the highest in Zaborovka-Likhusha.

Radiocarbon dating of soil charcoal samples. In Zaborovka-Likhusha hillfort the oldest date was obtained for charcoal from the burnt wooden structure from the lower part of the cultural layer (from a depth of 55 cm), about 296 cal. BC (IGANAMS-7118, tabl. 4, fig. 10). A relatively close date was obtained from the sediment at the bottom of the moat (IGANAMS-7297). The third date belonging to the Early Iron Age was obtained for charcoal from the soil core from the depth of 15–30 cm (IGANAMS-8075). Thus, for Zaborovka-Likhusha hillfort, the dates within the Early Iron Age were in the interval from 3rd c. BC to 1st c. AD. Three more dates fell on the early Middle Ages, 7th–8th cc. AD. There were two samples from the cultural layer: charcoal from the archaeological excavation from 35 cm depth (IGANAMS-7119) and from the soil core at 45–60 cm depth (IGANAMS-8075). Also charcoal from the second (16–35 cm) sediment layer in the moat under the hillfort (IGANAMS-7298) belong to this period. The calibrated age of charcoal from the

Table 3. Taxa diversity of charcoals from the cultural layers of hillforts
Таблица 3. Таксономическое разнообразие древесных углей из культурных слоев городищ

Hillfort	Taxa richness	Taxa density	Shannon's diversity index	Simpson's diversity index	Number of samples with charcoals
Zaborovka-Likhusha	9	1.6	0.27	0.83	29
Voroshilovo	11	2.9	0.84	0.51	17
Runa-Zaborovka	7	2.1	0.44	0.75	13

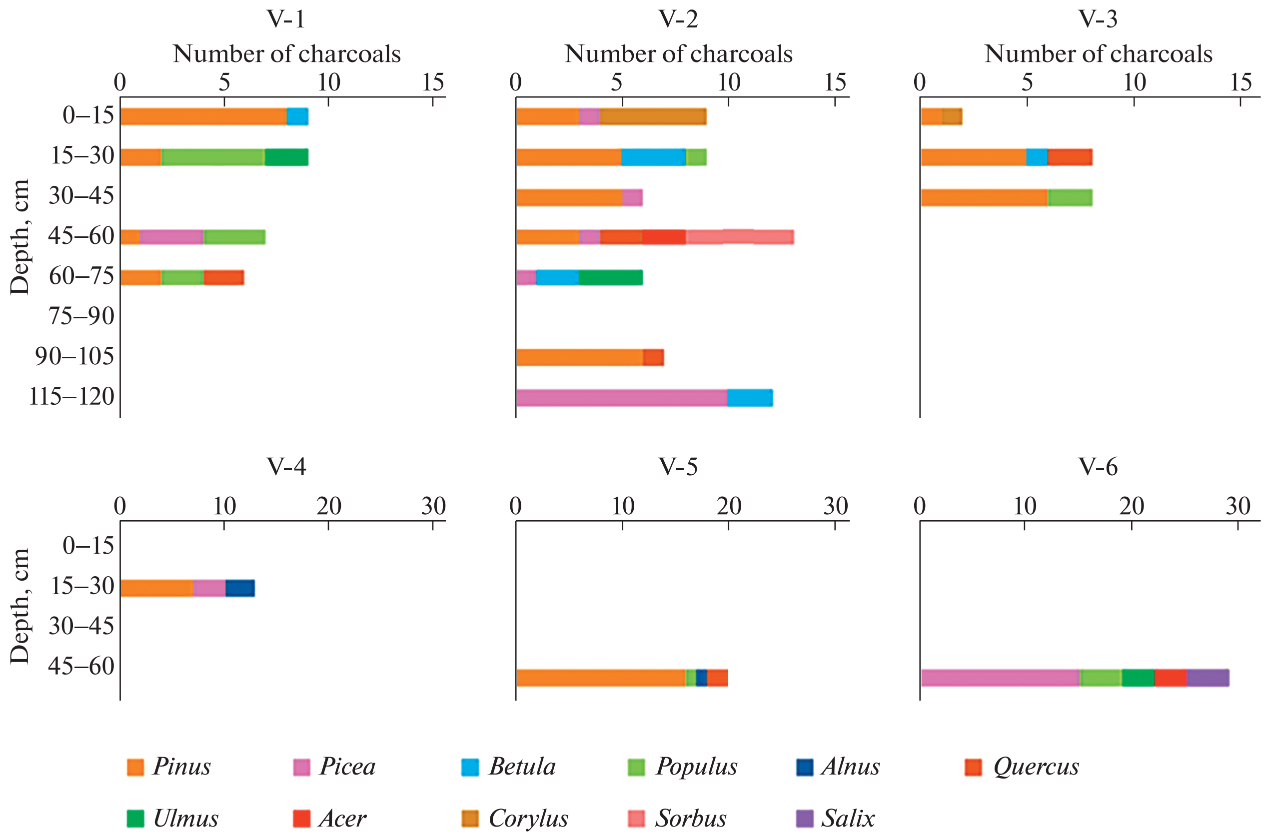

Fig. 8. The number of charcoals of different taxa in Voroshilovo hillfort.
Рис. 8. Число углей разных таксонов в культурном слое городища Ворошилово.

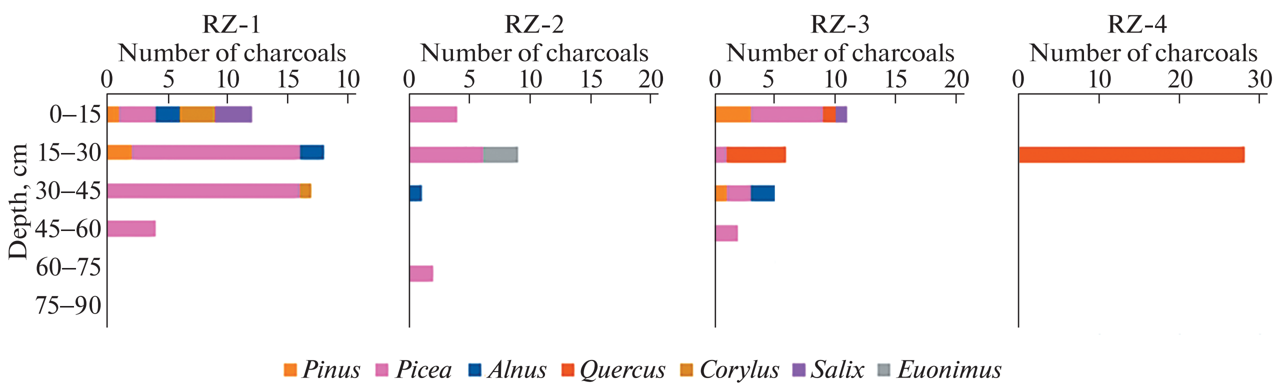

Fig. 9. The number of charcoals of different taxa in Runa-Zaborovka hillfort.
Рис. 9. Число углей разных таксонов в культурном слое городища Руна-Заборовка.

upper sediment layer in the moat (IGANAMS-7299) corresponded to 16th–17th cc. AD.

For Voroshilovo hillfort, all 4 radiocarbon dates fell within the interval of the Early Iron Age (tabl. 4, fig. 10). The oldest date for all samples was obtained from charcoal from a soil core at the depth of 105–120 cm (IGANAMS-8084) and corresponded to ca. 4th–3rd cc. BC. Since the charcoals were located deeper than the cultural layer, it is unknown whether their origin is related to the existence of the hillfort. Charcoals from the lower part of the cultural layer dated from 1st c. BC up to 1st c. AD: charcoals were from the archaeological excavation at 45–60 cm depth (IGANAMS-7293) and from the soil core at 70–75 cm depth (IGANAMS-8083). The earliest date of charcoal from the core at 15–30 cm depth (IGANAMS-8082) corresponded to ca. 4th c. AD.

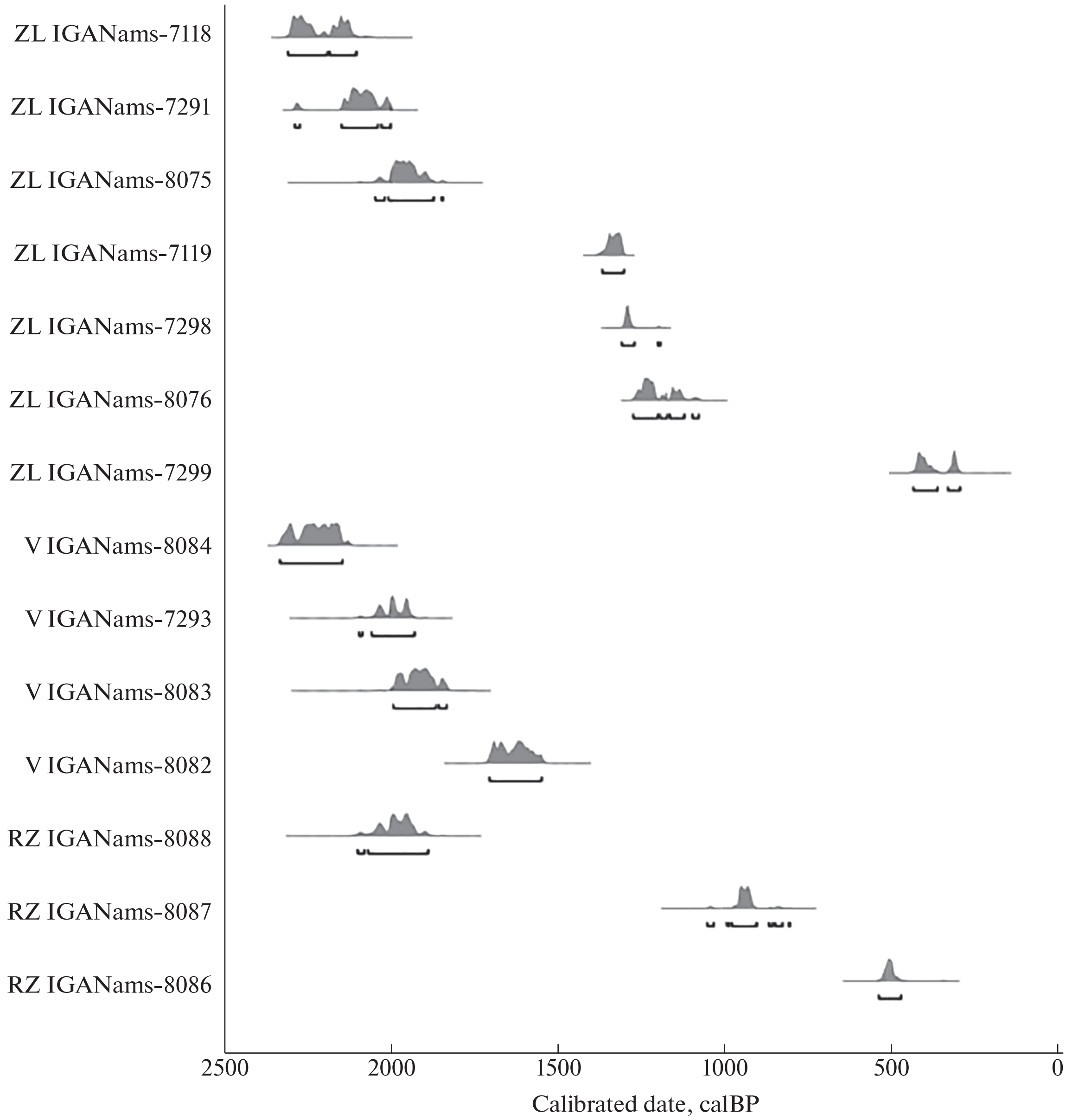

Fig. 10. Probability curves of calibrated radiocarbon dates for soil charcoals from the hillforts: ZL – Zaborovka-Likhusha, V – Voroshilovo, RZ – Runa-Zaborovka.

Рис. 10. Вероятностные кривые калиброванных радиоуглеродных дат для углей из культурного слоя городищ: ZL – Заборовка-Лихуша, V – Ворошилово, RZ – Руна-Заборовка.

For Runa-Zaborovka hillfort, all dated charcoals were taken from soil cores (tabl. 4, fig. 10). The sample from 60–75 cm depth (IGANAMS-8088) was located below the cultural layer and contained a significant number of charcoal fragments. Its calibrated age corresponded to the interval from 1st c. BC up to 1st c. AD. The calibrated dates of charcoals from the cultural layer from a depth of 15–30 cm corresponded to ca. 11th c. AD, from a depth of 0–15 cm to 15th–16th cc. AD.

On the whole, the burning activities in the studied sites can be represented as three main clusters: about 2000, 1300, and 500 cal. BP (fig. 11).

Due to a small number of dated charcoal samples, we can perform only a preliminary reconstruction of historical dynamics of woody taxa in the area of hillforts studied (fig. 12). Based on 12 radiocarbon samples of 209 charcoals belonging to 11 taxa, it can be concluded that *Pinus* charcoal dominated all the time, followed by *Picea* which increased from Early Iron Age to High-Late Middle Ages. For the Early Iron Age, there was the greatest number of taxa: 9 woody species including *Quercus, Ulmus*, and *Acer*. For Early Middle Ages, four taxa, including *Ulmus*, were registered. For

Table 4. Radiocarbon dates for charcoals from the hillforts calibrated according (to Reimer et al., 2013)
Таблица 4. Радиоуглеродные даты древесных углей из городищ, калиброванные (по Reimer et al., 2013)

Identificator	Sampling	Horizon	Depth, cm	Material	Lab. Code	Lab. radiocarbon age (BP)	Cal. radiocarbon age (BP)
Zaborovka-Likhusha hillfort							
ZL-1	Auger sampling	Axp	45–60	Charcoal	$IGAN_{AMS}$-8076	1250 ± 20	2310–2104
ZL-2	Auger sampling	Axp	15–30	Charcoal	$IGAN_{AMS}$-8075	2020 ± 30	2289–2002
	Archaeological excavation	Axp	55	Charcoal (burnt construction)	$IGAN_{AMS}$-7118	2180 ± 25	2047–1844
	Archaeological excavation	Axp	35	Charcoal	$IGAN_{AMS}$-7119	1450 ± 20	1367–1302
ZL-9	Soil pit	M1(AxpB)	8–16	Charcoal	$IGAN_{AMS}$-7299	290 ± 20	1308–1192
ZL-9	Soil pit	M2(AxpB)	16–35	Charcoal	$IGAN_{AMS}$-7298	1360 ± 20	1274–1078
ZL-9	Soil pit	M3(AxpB)	35–49	Charcoal	$IGAN_{AMS}$-7297	2125 ± 20	433–294
Voroshilovo hillfort							
V-1	Auger sampling	Axp	15–30	Charcoal	$IGAN_{AMS}$-8082	1740 ± 30	2334–2146
V-2	Auger sampling	Axp	60–75	Charcoal	$IGAN_{AMS}$-8083	1985 ± 30	2097–1930
V-2	Auger sampling	BC	105–120	Charcoal	$IGAN_{AMS}$-8084	2220 ± 30	1993–1833
V-5	Archaeological excavation	Axp	45–60	Charcoal	$IGAN_{AMS}$-7293	2050 ± 20	1705–1549
Runa-Zaborovka hillfort							
RZ-1	Auger sampling	Axp	0–15	Charcoal	$IGAN_{AMS}$-8086	450 ± 30	2100–1889
RZ-2	Auger sampling	Axp	15–30	Charcoal	$IGAN_{AMS}$-8087	1030 ± 30	1051–804
RZ-2	Auger sampling	BC	60–75	Charcoal	$IGAN_{AMS}$-8088	2040 ± 30	537–470

High and Late Middle Ages, there were 6 taxa: apart from *Pinus* and *Picea* these were *Betula, Alnus, Corylus*, and *Salix*.

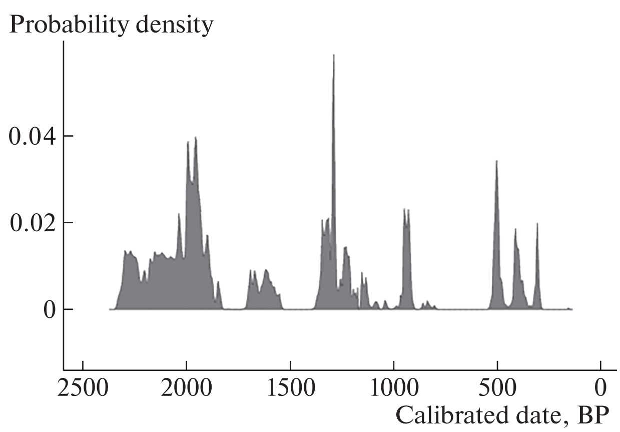

Fig. 11. Cumulative probability curve of calibrated radiocarbon dates for soil charcoal from the hillforts.

Рис. 11. Кумулятивная кривая вероятности калиброванных радиоуглеродных дат для углей из культурных слоев исследованных городищ.

5. DISCUSSION

There are several common features of the studied hillforts. The geomorphological basis for the fortified settlements was a cape of moraine hill, at the foot of which there was at least one water stream. The shape of the hillfort when viewed from above was closest to an oval. The cultural layer was from 50 to 80 cm thick, dark-colored and filled with fine charcoal particles. Quality characteristics of the cultural layers of the hillforts allow us to refer them to the category of archaeological Dark Earths (Anthropogenic Dark Earths, ADE), which are poorly stratified dark-colored soils, usually rich in charcoal and other anthropogenic inclusions.

As at many sites of the Dyakovo culture (Krenke, 2011) and at later archaeological sites with similar soils (Sedov et al., 1999; Ershova et al., 2020), the Early Iron Age layer is often overlapped by later cultural layers. The thickness of the cultural layer varies greatly. For example, in Gnezdovo the thickness of ADE soil ranges from 20 to 150 cm (Sedov et al., 1999; Trofimov et al., 2004).

In recent years, ADEs have been investigated across Europe (Devos et al., 2009, 2019; Ackcel et al.,

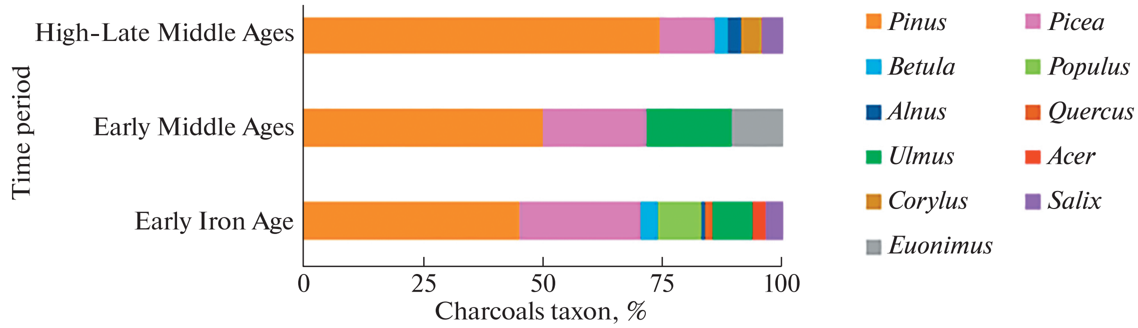

Fig. 12. Proportions of charcoals of different taxa from the studied hillforts by the historical periods: Early Iron Age from 5th c. BC to 5th c. AD, Early Middle Ages from 6th to 10th cc. AD, and High and Late Middle Ages from 11th to 16th cc. AD.

Рис. 12. Соотношение углей разных таксонов из исследованных городищ по историческим периодам: ранний железный век (5 в. до н. э. – 5 в. н. э.), раннее средневековье (6–10 вв. н. э.), высокое и позднее средневековье (11–16 вв. н. э.).

2017; Dotterweich, Schreg, 2019; Negassa et al., 2019; Asare et al., 2021). Dark Earths are common in settlement areas throughout much of Europe, but predominate in northern Europe, where they are sometimes referred to as “Baltic black earths”. The formation of these soils began between 3800 and 2000 BC (Acksel et al., 2017), but the formation of most Dark Earths is attributed to the Viking and Northern Slavic economy in the 1st millennium CE (Wiedner et al., 2015). The properties of these soils have been attributed to the long-term application of organic waste, charcoal, and fecal matter (Acksel et al., 2016). The existence of Dark Earths demonstrates the ability of sandy soils in the European climate to retain a high content of organic matter for hundreds of years when economic use is discontinued. Although the origin of Dark Earths is closely related to settlements, there is speculation that it was used for plant cultivation (gardening) (Wiedner et al., 2015). In this case, such soils may have been an important component of the economy.

The peculiarities of ADE in the investigated sites are their location on the modern surface, absence of obvious signs of late anthropogenic influences, and the existence of forest at the sites for at least the last centuries. Both the age of charcoals in the cultural layer and the archaeological findings (primarily textile pottery) show that the main thickness of the ADE at the hillforts of Zaborovka-Likhusha and Voroshilovo was formed in the Early Iron Age.

For Zaborovka-Likhusha hillfort, the interval of ADE formation was ca. 300 cal. BC – 10 cal. AD, corresponding to Early Iron Age (500 BC – 500 AD). However, in Zaborovka hillfort, we can also assume human activity in the Early Middle Ages, accompanied by possible reconstruction of the hillfort and its use. This is indicated both by an episode of erosion of material with charcoals (sediment in the moat) around 610 cal. AD, and charcoals in the cultural layer around 730 cal. AD. The sediment in the moat with charcoals of about 1580 cal. AD may be related both to the fire and more likely to local human activity on the hillfort (no archaeological findings later than Early Iron Age were found). The cultural layer of Zaborovka-Likhusha had the most obvious (among all three sites) signs of soil mixing, which can include reversion of dates (occurrence of charcoals of the same period at different depths and younger charcoals deeper than the older ones) and variability of the charcoal concentration by depth.

For Voroshilovo hillfort, the time of ADE formation can be attributed to 70 cal. BC – 320 cal. AD. Charcoal of about 300 cal. BC were also encountered at the Voroshilovo site, for which no connection with the cultural layer was established. There were no significant visible signs of soil mixing within the main ADE thickness.

For Runa-Zaborovka hillfort, it is most difficult to attribute the time of ADE formation. The charcoals of about 30 cal. BC were located deeper than the cultural layer. The findings of smooth-walled (Smirnov et al., 2021) date the time of the formation of the hillfort to the Early Medieval period, and the date of about 1010 cal. AD from the middle of the depth of the cultural layer refers to the end of this period. The charcoals on the surface date to about 1440 cal. AD, it is difficult to associate them with a specific activity because no archaeological findings from this time have been found.

Thick Anthropogenic Dark Earths are the result of complex interactions of anthropogenic and natural factors lasting at least several centuries. It is impossible to identify these factors without detailed archaeological excavations, which are so far the task of future research.

The diversity of tree taxa described at the hillforts seems to be high for the southern taiga region, in the area of modern pine forest dominance with a relatively poor species composition. According to the stratigraphy of charcoals and the taxonomic composition of dated samples, the greatest species richness was peculiar to the Early Iron Age. The greatest diversity of hardwood tree species was also detected for this time.

Often for Europe, a decrease in species diversity or even a complete change of species complexes is noted based on the results of studies of charcoals in soils and archaeological sites (Bobek et al., 2019). This is especially the case in mountainous areas (Benatti et al., 2019; Saulnier et al., 2020; Tolksdorf et al., 2020).

For the loess areas of southern Poland, a comparison was made of charcoal complexes from archaeological sites between the Neolithic period, the Early and Middle Bronze Age (Moskal-del Hoyo, 2021). There was no change in species, only a change in their participation, but there was probably a change in plant communities. The species composition depended to a greater extent on the landscape: important regional differences between, on one hand, the loessic uplands and the forelands, and, on the other, the foothills were shown. A large-scale study was carried out by Novák et al. (2021) for lowlands in the Czech Republic, analyzing charcoal records from 474 localities. A significant differentiation in the dynamics of taxa between different landscapes there was shown. The smallest changes were noted for landscapes with the predominance of *Quercus* and high abundance of *Pinus*. The Late Holocene woodland transformation was related to the migration trends of *Carpinus, Fagus,* and *Abies*; the activity of changes decreases from west to east.

There were no changes in the species composition and migration of woody species in the Late Holocene in our study area, either from charcoal records or from pollen data (Mazei et al., 2020). All our charcoal findings of species are within their current distribution areas, but as noted in the study area section, some tree species are rare in the region (*Acer* and *Ulmus*), especially as mature trees. At the same time, almost all genera of trees whose ranges cover the study area, except for ash (*Fraxinus*), were found as charcoal.

The reasons for the presence of certain species in the form of charcoal in the cultural layer are always the result of several factors, such as the availability of the tree species, its economic function, and the features of wood burning and charcoal preservation (Novenko et al., 2009).

The principle of least effort, assuming that charcoal frequency direct reflects the prevalence of woody taxa, has usually been used to interpret the results of charcoal findings. However, as Rubiales et al. (2011) noted, charred remains are the final result of diverse human activities; consequently, archaeological charcoals are not haphazardly distributed by the sole effect of climatic and environmental conditions. In our study, it is likely that most of the charcoals are firewood; some (probably small) portion may belong to burnt buildings. As far as can be judged from the soil cores and archaeological excavations, there were no obvious areas of confined charcoal concentration, although the thickness of the cultural layer and charcoal concentrations varied. The charcoals were found in the cultural layer throughout the studied area. It is probably the result of long-term burning of wood, horizontal movement of charcoals, and vertical pedoturbations. In general, these are the mechanisms of the formation of all ADEs, but the elucidation of specific factors requires detailed study.

We can talk about a significant and likely dominant participation of *Pinus* in the area of the studied hillforts. In the areas of Zaborovka-Likhusha and Voroshilovo, the occurrence of *Pinus* and its probably significant participation in the stands was recorded already at the time of the first burning in the sites in 3rd–1st cc. BC. The presence of a prominent proportion of hardwood charcoals probably indicates their availability and common presence in the vegetation near the hillforts. For *Tilia,* we can assume rather an occasional presence in the composition of firewood. *Quercus* had a very diverse and wide range of uses, including as firewood. However, the use of *Acer* and *Ulmus*, especially the latter, as firewood is not straightforward or cost-effective. The intended use of wood of these species (on a par with *Quercus*) is not excluded when it is necessary to obtain high flame temperatures, for example, in smelting of metals. The significant predominance of *Picea* charcoals in different layers of Runa-Zaborovka hillfort, including in the Early Iron Age, may be evidence of its predominance in the surrounding forests with little participation of other tree species. The use of spruce wood can hardly be considered intentional, as it is not the optimal species for firewood.

The results correlated well with the palynological data obtained from the study of the nearby Krivetsky Mokh bog (Mazei et al., 2020). Hardwood trees have dominated the region since about 9000 cal. BP. Around 4300 cal. BP, the relative abundance of *Picea* and *Pinus* increased. The most notable changes in vegetation occurred at the turn of the Early Iron Age, ca. 2600 cal. BP. From that time, the proportion of *Betula* and *Alnus* increased, while most other deciduous trees (*Tilia, Quercus*, and *Ulmus*) decreased in abundance. *Quercus* further increasing participation, the decrease of *Tilia* and *Ulmus* was irreversible. There is insufficient data to judge the participation and dynamics of *Acer* and *Fraxinus* in the vegetation. The abundance of *Picea* and *Pinus* varied greatly. This time was marked by an increased proportion of *Artemisia* and *Plantago,* as well as other grasses (*Poaceae, Chenopodiaceae*). During this period there was a slight (not strong) increase in charcoal input, but also an increase in the frequency of local fires, which became more regular (about one episode per 250 years) after a large period of their rarity (more than one episode per 1000 years).

The results of a study of another complex of bogs located on Valday Upland to southeast of the region we studied (Central Forest Nature Reserve) showed that significant changes in the vegetation composition occurred there somewhat later, ca. 2000 cal. BP. At this time, the content of *Picea* pollen decreased, the content of pollen of hardwood trees noticeably decreased, and the proportion of *Betula* pollen increased (Novenko et al., 2009).

The information we obtained from the soil charcoal composition is a valuable evidence of the presence of a tree taxon at a particular site at a particular point in time, detailing the reconstruction of the vegetation history in the upper reaches of the Volga River.

6. CONCLUSION

Cultural layer of all studied hillforts was presented by Archaeological Dark Earth saturated with charcoal and 50 to 80 cm thick. At Zaborovka-Likhusha hillfort on the basis of charcoal dating, three periods of human activity were identified: (i) from 3rd to 1st c. BC, (ii) from 7th to 8th c. AD, and (iii) 16th c. AD. At Voroshilovo hillfort, two periods were marked: (i) from 3rd c. BC to 1st c. AD and (ii) 4th c. AD. At Runa-Zaborovka hillfort, human activities were in 11th and 15th c. AD while charcoal of 1st c. BC also occurred. Thus the duration of the cultural layer formation was probably hundreds of years; Zaborovka-Likhusha and Voroshilovo hillforts belong to the Early Iron Age (the Dyakovo culture) whereas Runa-Zaborovka hillfort belongs to the Early Middle Ages.

A significant number of woody species taxa (13 genera) were identified in the cultural layer of the hillforts. There were no drastic changes in the composition of the regional species pool, such as the species disappearance. Among the three periods: Early Iron Age (from 5th c. BC to 5th c. AD), Early Middle Ages (from 6th to 10th cc. AD), and High and Late Middle Ages (from 11th to 16th cc. AD), the greatest diversity of woody species genera was recorded for Early Iron Age, where charcoals of *Quercus*, *Ulmus*, *Acer*, and *Populus* were found. Runa-Zaborovka hillfort noticeably differed in the taxonomic composition of charcoals, and there were no archaeological Early Dyakovo finds here.

The sparse network of small hillforts identified in recent years in the Valdai Upland in the northern part of the Peno District of the Tver Region raises questions about how Early Iron Age peoples may have influenced the dynamics of ecosystems and how their life depended on natural conditions. The study of charcoal in other hillforts and in the surrounding soils in the region will make it possible both to estimate the activity of the population in the areas of hillforts and to reveal the peculiarities of the anthropogenic transformation of the adjacent areas.

WOODLAND DYNAMICS AND HUMAN ACTIVITY BASED ON CHARCOAL ANALYSIS FROM HILLFORTS OF THE IRON AGE AND EARLY MIDDLE AGES IN THE UPPER VOLGA RIVER

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Soil charcoals in cultural layers of three hillforts located in the upper Volga River (Peno District, Tver Region) were studied in soil cores and archaeological excavations. The characteristics of the cultural layers of the hillforts allow us to refer it to the category of Archaeological Dark Earth with a thickness from 50 to 80 cm. The age of charcoals and archaeological findings showed that the cultural layers of Zaborovka-Likhusha and Voroshilovo hillforts belong to the Early Iron Age (the Dyakovo culture) and Runa-Zaborovka hillfort belongs to the Early Middle Ages. A total of 629 charcoal fragments belonging to 13 woody genera were taxonomically identified. The charcoals of the 12 dated samples were evaluated for changes in the taxonomic composition over time. In all periods, *Pinus* charcoals dominated, followed by *Picea*; their proportions increased from the Early Iron Age to the High-Late Middle Ages. For the Early Iron Age, the largest number of taxa, 9 woody species, including *Quercus, Ulmus,* and *Acer,* was observed. The information obtained from the soil charcoal composition is a valuable evidence of the presence of tree taxa in a particular area at a particular time; it details the reconstruction of the history of vegetation in the upper Volga River.

Keywords: pedoanthracology, Archaeological Dark Earth, Dyakovo culture, firewood, radiocarbon dating

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