RADIOCARBON AGE FOR THE CULTURAL LAYER OF THE NEOLITHIC-BRONZE AGE SETTLEMENT PESOCHNOE-1 (LAKE NERO, RUSSIA)

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ABSTRACT. Organic matter in the cultural layer of the ancient settlement Pesochnoe-1 near Lake Nero (NE of Moscow) yields reliable radiocarbon dates. The reason for this is the high concentrations of calcium and phosphorus in the cultural layer, especially in calcined bones. Several cultural epochs are distinguished in the cultural layer consisting of more or less homogeneous habitation deposits colored with humic susbstances. Artifacts of the Ljalovo culture are found in the lower part of the cultural layer; above these, artifacts of the Volosovo culture are present, and the upper part of the cultural layer corresponds to the Textile Ceramics culture. The ^{14}C dates for humic substances in the layers show a good chronological stratification and correspond to known ages of these cultural stages. The ^{14}C dates for the Ljalovo cultural layer cover 5600–5100 BP (4430–3900 cal BC), and dates for the Volosovo cultural layer span 4400–4200 BP (3000–2840 cal BC). Most dates from the upper part of the cultural layer correspond to the chronological interval of the Textile Ceramics culture and range from 3700 to 3200 BP (2100–1460 cal BC). More precise ^{14}C dates were obtained for humic substances from archaeological objects in the upper cultural layer (hearths, fillings of pottery vessels, etc.): 3900–3500 BP (2100–1800 cal BC).

INTRODUCTION

Humus is not the best material for radiocarbon dating of archaeological sites due to the soil humus developing *in vivo*. Under these conditions, the processes of humus mineralization and its accumulation due to the decomposition of root debris, perturbation, and alluvial processes lead to renewal of humic substances. Therefore, the ^{14}C dates are indicative of neither the time of the beginning of soil formation nor the time of the soil burying (in the case of buried paleosols); in fact, the dates characterize the mean residence time (MRT) of carbon in the soil (Paul et al. 1964).

A different situation is created at archaeological sites because of the input of large amounts of organic matter in a relatively short time. The age of humus developing from this matter corresponds to the time of existence of an archaeological site, especially if it is not "contaminated" with the soil humus. For example, we found good agreement between the ^{14}C dates of humus from filled wells of the first centuries AD at the Dyakov culture settlement in Tsaritsyno Park (Moscow) and the archaeological dates (Alexandrovskiy 2008). Similar results were obtained for the ^{14}C dates of humus from residential wells at the Mayatsky hill fort in the middle reaches of the Don River (Afanasyev et al. 1999). The high degree of preservation of humic substances is explained by the fact that the studied objects (wells, pits) are found below the root zone and are not "contaminated" with recent soil humus.

In relation to these findings, the first results of ^{14}C dating of humus from the cultural layer of the Bronze Age settlement Pesochnoe-1 on the shore of Lake Nero were rather surprising, because humic substances from this layer proved to be stable, and their ^{14}C age was not renewed (Alexandrovskiy et al. 2011a). It is important that the samples were taken from the entire cultural layer rather than from separate pits. It is also important that the cultural layer of this settlement is relatively thin and is surely affected by pedogenetic processes, such as the formation of recent humus and perturbation by animals. To study this phenomenon, we analyzed samples from different depths

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of this cultural layer and from separate archaeological objects found in the layer. Similar work is performed at other Bronze Age settlements on the shores of Lake Nero with somewhat different characteristics of their cultural layers.

MATERIALS AND METHODS

The settlement Pesochnoe-1 is located on the western shore of Lake Nero to the south of Rostov Veliky, about 200 km northeast of Moscow (Figure 1). It is located on a gentle slope of low terraces, and its lower part is under the present lake level. The cultural layer of this ancient settlement contains artifacts attributed to the Neolithic (Ljalovo and Volosovo cultures) and Bronze ages (Fatjanovo-Balanovo, Chirkovo, and Textile Ceramics cultures). The materials of the Textile Ceramics culture predominate. Archaeological material of the Ljalovo culture is present in the lower part of the cultural layer; the material of the Volosovo culture, in its middle part; and the material of the culture of Textile Ceramics, in the upper part. Specific archaeological objects—the remains of hearths—are present in the layer. These objects are of importance for ^{14}C dating.

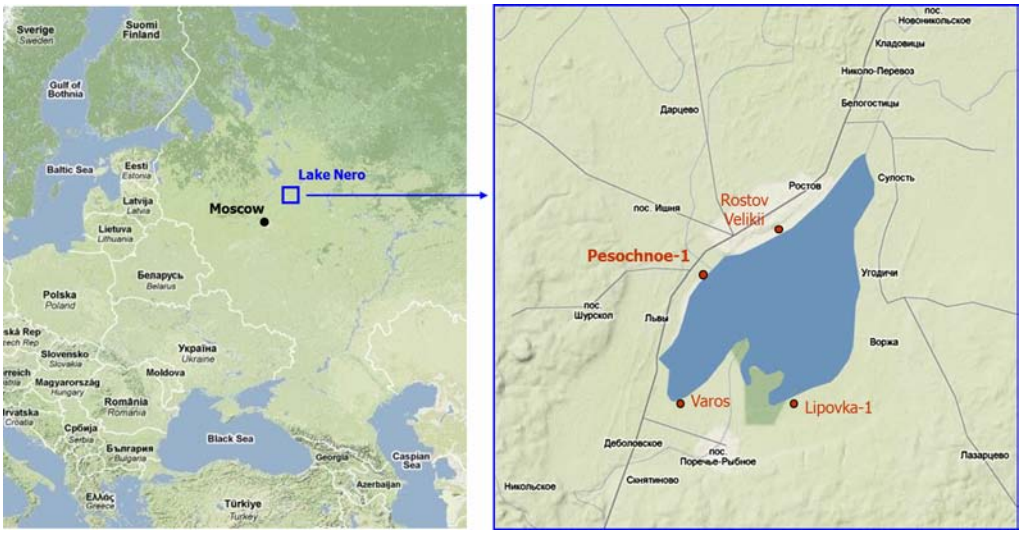

Figure 1 Location of the site within modern Russia

The duration of the Ljalovo culture (a local variety of the Pit-Comb Ware culture) in the Upper Volga region is 5000–3500 cal BC; of the Volosovo culture (Kama-Volga variety of Late Pit-Comb Ware), 3650–1800 cal BC; and the culture of Textile Ceramics (Netted Ceramics, Netter Ware, or Fabric Impressed Ware), 2500–1400 cal BC (Dolukhanov 1979; Thomas 1992; Emel'yanov 2001; Lavento 2001). The soils of background territories are classified as soddy gley soils and soddy Podzolic soils (Umbric Gleysols and Albeluvisols in the WRB system; IUSS Working Group WRB 2006).

The cultural layer of the Pesochnoe-1 settlement is relatively thin: from 25–30 cm on the upper slope to 50 cm on the lower part (Figure 2). It is characterized by a high content of humus, calcium, phosphorus, copper, and zinc (Alexandrovskiy et al. 2011b). It is densely penetrated by numerous pathways of soil animals, and it contains calcined bones. In the 3500 yr that have passed since the settlement was abandoned, the cultural layer has preserved its very dark color. At the same time, it has been homogenized considerably. The horizons corresponding to separate cultures cannot be eas-

ily distinguished by their morphology, though the stratification of the artifacts is generally preserved, and it is disturbed in some places. Up the slope, the base of the cultural layer contains artifacts (pottery, flint tools) of the Volosovo culture overlain by the artifacts of the Textile Ceramics (pottery, flint tools, metallurgical casts, building remains, disintegrated vessels), and a hearth. Within the lower part of the slope, the base of the cultural layer contains the material of the Ljalovo culture, which predominates in this part of the cultural layer near the lake. The cultural layer is underlain by the lower part of a thin dark-colored soil with numerous tunnels of rodents. The upper part of this paleosol was probably admixed with the cultural layer.

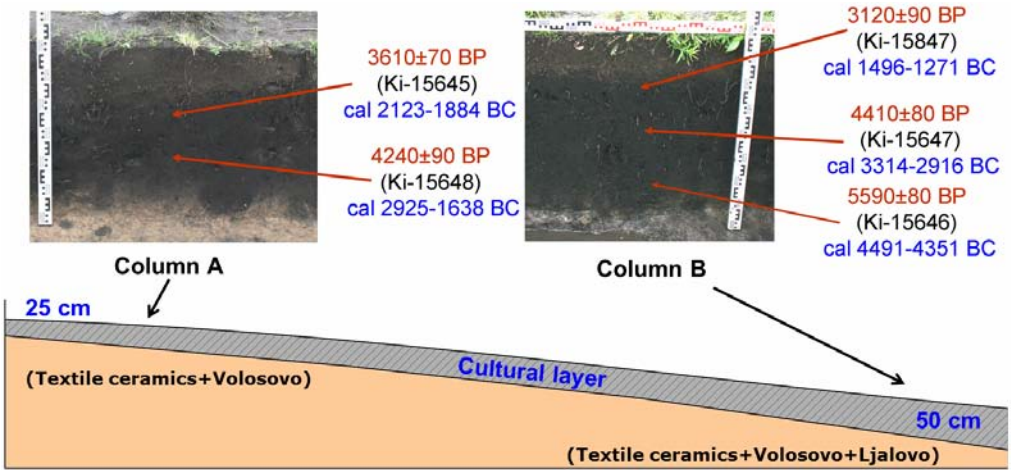

Figure 2 Position of cultural layer on a gentle slope near the shore of Lake Nero, and the location of samples dated

The age of the soils and cultural layer of ancient settlements was determined by using both ^{14}C and archaeological dating. Charcoal was not preserved in the cultural layer, and the fragments of bones were very small and show poor degree of preservation. Therefore, we could only use the humified material of the cultural layer, the soil humus, the dispersed charcoal particles, and the coal-like material (probably derived from calcined bones) for the ^{14}C dating. As the cultural layer was relatively homogenous in its appearance and could not be divided into subhorizons, all samples (including the samples for ^{14}C dating) were taken from certain depths. The samples taken from the lower part of the cultural layer near the shore of the lake corresponded to findings of the artifacts of the Neolithic (Ljalovo and Volosovo) cultures, while the samples taken from the upper part of this layer corresponded to findings of the artifacts of the Bronze Age culture of Textile Ceramics.

^{14}C dating was performed by the conventional method (liquid scintillation counting) in Kiev (Institute of Environmental Geochemistry of the National Academy of Sciences of Ukraine; lab code Ki). Dates were calibrated using the IntCal04 data set (Reimer et al. 2004) and OxCal v 4.1 software (Bronk Ramsey 2009). The contents of organic matter, carbonates, and phosphorus in the buried soils and cultural layers were determined in Moscow by standard methods. The humus content was determined by the wet combustion method (Tyurin's procedure). Analysis of the microelement composition of cultural layer was carried out by X-ray fluorescence whereby the object under study was kept intact.

RESULTS AND DISCUSSION

The cultural layer of the Pesochnoe-1 settlement has the following morphology. From the surface, it is covered by a thin (~15 cm) layer of recent (17th–18th centuries AD) lake deposits. Soil formation in the past 300 yr has transformed the upper part of this layer. Below, the actual cultural layer that existed at the surface for ~3500 ^{14}C yr (~4000 calendar yr) is found. This is a homogeneous layer of dark humic coloring with mole tunnels that are clearly visible near the lower boundary of the humus horizon (Figure 2). Archaeological artifacts in this layer are mainly represented by disintegrated pottery, hearths, and various flint tools (Figure 3). A thin horizon of the buried dark-humus soil is found immediately under the cultural layer. In turn, it is underlain by the layered lacustrine sediments.

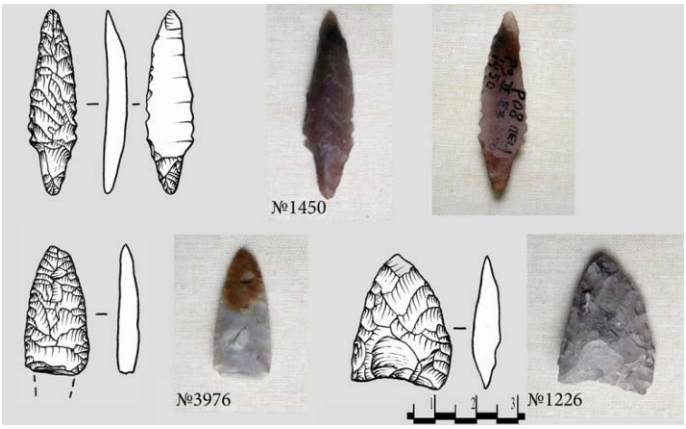

Figure 3 Arrowheads (Textile Ceramics culture)

Specific features of the cultural layer of this settlement are the presence of numerous fragments of calcined bones, the dark color, and the presence of metal casts dating back to the Bronze Age. This cultural layer has been subjected to the impact of pedogenetic processes for ~4000 yr. Thus, it has become homogenized; wooden remains of buildings and various household tools have disappeared from it. Many microelements (including lead that is present in metal casts) have been leached off. Some restructuring of the soil mass has also taken place. At the same time, phosphorus and calcium, as well as copper and zinc, and ancient humus are well preserved in the cultural layer (Alexandrovskiy et al. 2011a). It is interesting that the natural soils of the background territory also contain relict humus horizons of the Middle Holocene; their ^{14}C age exceeds 5000 yr (Alexandrovskiy 2011). It is probable that stable humic substances of similar type have been forming in these soils throughout that time. However, in the cultural layer, the ancient humus is preserved much better, which can be due to the stabilizing effect of phosphorus and calcium.

As mentioned above, charcoal and bones are poorly preserved in the cultural layer of the settlement. Therefore, we used humic substances for the ^{14}C dating. The first results showed the ancient age of humus in this layer. This humus was much older than the humus of natural background soils at the same depths; its ^{14}C ages approximately corresponded to the ages of the archaeological artifacts found in the same parts of the cultural layer from which the samples for ^{14}C dating were taken. After these first findings, we performed ^{14}C dating for the samples taken from different parts of the cultural layer (layer by layer) and also for the samples collected from the specific archaeological objects (hearths and piles of disintegrated vessels) in the cultural layer. It was also interesting to identify the reasons for such a high stability of humus in the cultural layer. For this purpose, various chemical analyses of the soil and cultural layer samples were performed.

Table 1 ^{14}C dates of humus matter in samples from the cultural layers (CL) of the Pesochnoe-1 settlement.

Excavation, samples, depth	Lab code	^{14}C date (yr BP)	Calibrated ages
Ljalovo culture			
Column B, pit 1, CL 55–64 cm (lower part of the CL)	Ki-15646	5590 ± 80	4491–4351 BC (1σ) 4647–4264 BC (2σ)
Column C, excavation 3, plot D-3, CL 49–59 cm (lower part of the CL, Ljalovo layer)	Ki-15651	5310 ± 90	4229–4064 BC (1σ) 4231–4051 BC (2σ)
Column D, excavation 3, plot I-4 (lower part of the CL) 27–32 cm	Ki-15846	5120 ± 90	4035–3796 BC (1σ) 4226–3702 BC (2σ)
Excavation 3, plot I-3 (lower part of the CL), CL under vessel No. 2003	Ki-15855	5270 ± 90	4230–3990 BC (1σ) 4333–3848 BC (2σ)
Volosovo culture			
Column B, pit 1, CL 30–40 cm (middle part of the CL)	Ki-15647	4410 ± 80	3314–2916 BC (1σ) 3339–2902 BC (2σ)
Column A, excavation 3, plot N-4/5, CL 37–46 cm (middle-lower part of the CL)	Ki-15648	4240 ± 90	2925–2638 BC (1σ) 3090–2573 BC (2σ)
Excavation 3, plot B-3, layer 3 (middle part of the CL)	Ki-15862	4210 ± 90	2905–2638 BC (1σ) 3021–2498 BC (2σ)
Bronze Age			
Column E, Pit 1, CL 20–25 cm (upper part of the CL)	Ki-15847	3120 ± 90	1496–1271 BC (1σ) 1607–1128 BC (2σ)
Column A, Excavation 3, plot N-4/5, CL 27–37 cm (upper-middle part of the CL)	Ki-15645	3610 ± 70	2123–1884 BC (1σ) 2193–1768 BC (2σ)
Excavation 3, plot D-3, CL 31–41 cm (middle part of the CL, reticulate layer)	Ki-15650	3490 ± 80	1915–1694 BC (1σ) 2026–1620 BC (2σ)
Column G, excavation 3, plot P-10, CL 27–34 cm	Ki-15845	2990 ± 70	1370–1126 BC (1σ) 1407–1024 BC (2σ)
Column D, excavation 3, plot I-4, CL 17–22 cm (upper part of the CL)	Ki-15848	2760 ± 70	978–831 BC (1σ) 1112–800 BC (2σ)
Excavation 3, plot N-4/5, 28 cm (floor of the house, CTC layer)	Ki-15653	3390 ± 90	1867–1535 BC (1σ) 1917–1465 BC (2σ)
Excavation 3, plot N-1, 30 cm (upper-middle part of the CL)	Ki-15654	3720 ± 80	2275–1980 BC (1σ) 2430–1894 BC (2σ)
Excavation 3, plot N-6, 33 cm, CL with calcined bones	Ki-15652	3950 ± 80	2570–2309 BC (1σ) 2837–2155 BC (2σ)
Excavation 3, plot Z-3, layer 3, CL	Ki-15655	3220 ± 80	1607–1417 BC (1σ) 1688–1315 BC (2σ)
Excavation 3, plot O-3, 35 cm (under hearth stones)	Ki-15850	3330 ± 90	1657–1540 BC (1σ) 1668–1534 BC (2σ)
Excavation 3, plot O-3, layer 3, CL with dust	Ki-15857	3510 ± 90	1950–1695 BC (1σ) 2128–1614 BC (2σ)
Excavation 3, plot N-6, layer 1, CL within disintegrated pottery 4799	Ki-15859	2810 ± 60	1050–861 BC (1σ) 1129–822 BC (2σ)
Dates for the cultural layer within disintegrated pottery and stoves (see Figure 4)			
Excavation 3, plot N-6, layer 2, CL within disintegrated pottery 4798	Ki-15851	3660 ± 110	2199–1892 BC (1σ) 2431–1742 BC (2σ)
Excavation 3, plot N-6, layer 2, CL near disintegrated pottery 4798	Ki-15854	3320 ± 70	1684–1522 BC (1σ) 1755–1437 BC (2σ)

Table 1 ^{14}C dates of humus matter in samples from the cultural layers (CL) of the Pesochnoe-1 settlement. *(Continued)*

Excavation, samples, depth	Lab code	^{14}C date (yr BP)	Calibrated ages
Excavation 3, plot O-3, layer 2, CL inside the hearth stones	Ki-15858	3410 ± 90	1877–1612 BC (1σ) 1935–1501 BC (2σ)
Excavation 3, plot O-5, layer 1, burnt earth, hearth (upper part of the CL)	Ki-15649	3610 ± 80	2131–1880 BC (1σ) 2198–1750 BC (2σ)
Excavation 3, plot N-6m layer 1; CL underlying disintegrated pottery 4799	Ki-15864	3510 ± 90	1950–1695 BC (1σ) 2128–1614 BC (2σ)
Excavation 3, plot N-6, CL near disintegrated pottery 4799	Ki-15861	3330 ± 60	1683–1531 BC (1σ) 1750–1458 BC (2σ)
Lipovka-1, cultural layer			
Column 1, A1, 20 cm	Ki-16186	850 ± 90	AD 1049–1264 (1σ) AD 1016–1292 (2σ)
Column 2, Ahh, 40 cm	Ki-16187	1890 ± 70	AD 54–218 (1σ) AD 45–322 (2σ)

These analyses showed that the chemical composition of the cultural layer from Pesochnoe-1 is rather unusual. It is characterized by extremely high concentrations of calcium, phosphorus, copper, and zinc (Table 2). The highest concentrations are found in the zones containing burnt bones. During gradual degradation of the bones, calcium phosphate (apatite) forming the basis of bone tissues was admixed with the soil, so that the concentrations of these elements increased in the entire cultural layer. Calcium phosphate is resistant to weathering in soils, including the cultural layer. Its presence in the soil (cultural layer) decreases the mobility of 2 elements: copper and zinc. It is interesting that high contents of a number of elements, including copper, are found in the uppermost part of the cultural layer; at the same time, the copper content in overlying lake deposits is low. Hence, the stability of copper in the cultural layer that remained exposed to the surface (and in the root zone) for ~4000 yr, may be explained by the stabilizing effect of the calcium phosphates. This cultural layer is also characterized by the high stability of humus, which in particular is observed in the increased content of organic carbon in this layer (C_{org} 3–3.5% versus 1.3% in background soil at the same depth, Table 2).

The samples of humified material for ^{14}C dating were taken from the upper, middle, and lower parts of the cultural layer in different places of the settlement. The results of ^{14}C dating attest to the high stability of organic matter and to a clear stratification of the dates by separate layers. Most of the dates for the upper part of the layer (i.e. Textile Ceramics culture) are in the range of 3700–3200 BP (2100–1460 cal BC). Dates for the Volosovo cultural layer are 4400–4200 BP (3000–2840 cal BC), and 5600–5100 BP (4430–3900 cal BC) for the Ljalovo layer. A significant rejuvenation of the dates is only seen for the uppermost (5–8 cm) part of the cultural layer. Though this layer contains high amounts of Cu, the formation of young humus influenced by roots during the 4000 yr of its existence at the surface is clearly seen. Below, in the main part of the cultural layer, the addition of young humus is insignificant.

Different results have been obtained for the cultural layer from the nearby Bronze Age settlement of Lipovka-1 (Voronin 2000). At this site, the humus content in the cultural layer is much smaller. At the surface, typical Albeluvisols are formed. They contain relatively small amounts of humus, calcium, and phosphorus. The humus age in the upper part of the cultural layer is significantly younger: 850 ± 90 BP (Ki-16186).

Table 2 Results of soil analyses and concentrations of macroelements (oxides, %) and microelements (mg/kg) in soil samples from the Pesochnoe-1 settlement.[a]

Horizon, depth (cm)	pH_{water}	Loss on ignition (%)	C_{org} (%)	P_2O_5 (%)	CaO (%)	Fe_2O_3 (%)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Cr (ppm)
Pit 7, background soil										
Ad, 0–5 cm	5.25	—	13.46	0.54	2.09	6.51	46	102	**57**	81
AB, 5–16 cm	5.15	—	6.55	0.36	0.83	4.94	26	46	28	103
A1, 16–37 cm	6.05	5.1	1.33	0.48	0.8	2.5	8	13	18	56
ABg, 37–48 cm	6.3	1.94	0.37	0.29	0.62	1.62	3	2	10	42
B_1g, 48–57 cm	6.65	—	0.12	0.16	0.67	1.16	4	4	6	61
B_2, 57–63 cm	6.4	—	0.25	0.2	1.05	5.03	21	43	27	120
Excavation 3, plot N-4/5, column A										
Ad, 0–12 cm	5.7	17.6	5.19	**3.88**	**5.25**	5.17	**64**	**298**	16	82
AB, 12–17 cm	6	14.96	3.9	**3.20**	4.79	4.20	**74**	**244**	15	77
CL_1, 17–37 cm	6.5	12.78	3.18	**8.32**	**11.06**	3.24	**104**	**447**	8	53
CL_2, 37–46 cm	6.55	8.26	1.95	**6.11**	**8.42**	3.15	**60**	**326**	13	66
A1cl, 46–55 cm	6.4	5.4	0.72	**1.34**	2.06	3.36	23	75	13	92
B, 55–65 cm	6.5	—	0.31	0.73	1.37	5.06	16	88	18	122
Pit 1, column B										
Ad, 0–8 cm	5.25	26.71	8.47	**1.51**	2.64	6.07	53	**220**	**41**	102
AB, 8–26 cm	5.6	20.18	4.47	**2.09**	3.26	5.56	**69**	**224**	21	102
CL_1, 26–40 cm	6.3	11.76	5.57	**6.70**	**9.32**	3.19	**85**	**384**	12	59
CL_2, 40–64 cm	6.5	6.99	1.41	**2.97**	4.63	3.13	**38**	**132**	16	75
A1cl, 64–74 cm	6.6	4.84	0.72	**1.16**	2.05	3.03	25	62	13	79
B, 74–(84)	6.6	—	0.3	1.25	1.80	4.68	27	58	20	104
Excavation 3, plot D-3, column C										
Ad, 0–8 cm	5.4	—	7.94	**2.17**	3.51	5.30	55	**228**	31	89
AB, 8–12 cm	5.4	—	4.95	**2.76**	3.69	5.49	**61**	**213**	21	87
CL_1, 12–41 cm	6.45	12.3	3.05	**8.80**	**11.20**	3.56	**140**	**417**	12	53
CL_2, 41–59 cm	6.5	6.65	1.39	**5.09**	**6.89**	2.53	**45**	**232**	11	50
A1cl, 59–68 cm	6.55	4.18	0.76	**1.31**	1.97	3.11	18	65	20	92
B, 68–75 cm	6.5	—	0.31	1.07	1.55	4.03	15	57	17	95

[a]Note: CL – cultural layer; A1cl – humus horizon with presence of cultural layer material. Maximum concentrations are given in bold numbers.

Most dates for the Pesochnoe-1 settlement have been obtained for the Textile Ceramics culture layer. Dates from the interval 3700–3200 BP (2100–1460 cal BC) predominate, though there are also dates (3000–2800 BP) which are rejuvenated, probably resulting from soil mixing by rodents.

The dates obtained for the hearths, fillings of vessels, and the material immediately under the vessels in the layer of the Textile Ceramics culture (3610 ± 80, 3510 ± 90, and 3660 ± 110 BP; 2100–1800 cal BC) are of particular interest. They are older than dates from the same layer beyond these fillings (Table 1; Figures 4, 5). Hence, inside the fillings that are "closed" for humus rejuvenation processes, humus matter is well preserved, whereas outside the fillings it is subjected to rejuvenation due to the activity of rodents, roots, and other factors. At the same time, the degree of this rejuvenation is relatively small. We assume that the hearths and the fillings of vessels contained charred organic materials resistant to the processes of humus renewal. Though the vessels are broken, and the stones of the hearths are scattered, this charred organic material is preserved in sufficient amounts and ensures more ancient ^{14}C dates in comparison with the material of the adjacent cultural layer near the hearths and disintegrated vessels.

Figure 4 Disintegrated vessels no. 4798 (left) and 4799 (right) of the Textile Ceramics culture

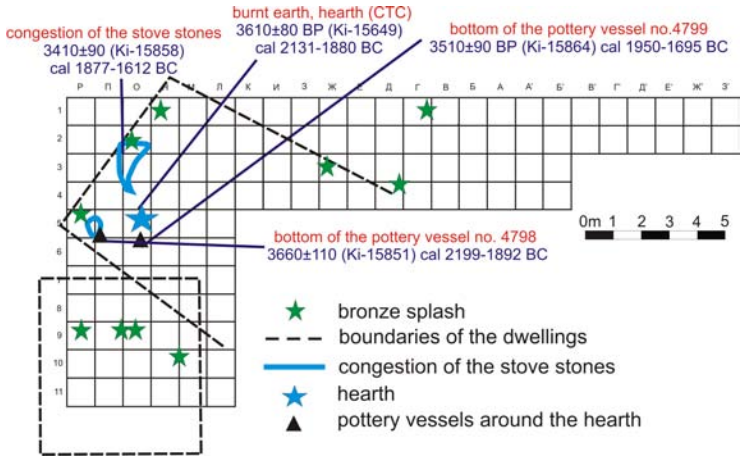

Figure 5 ^{14}C dates of archaeological complexes (Textile Ceramics culture)

CONCLUSION

The ^{14}C dating results of organic matter (humus) from the cultural layer of the Pesochnoe-1 settlement at Lake Nero show a high stability of organic matter and a clear stratification of the dates in agreement with the stratification of the layers of the Neolithic and Bronze Age cultures. Most dates from the upper part of the cultural layer correspond to the layer of the Textile Ceramics culture. The dates for the Volosovo layer are in the range 4400–4200 BP (3000–2800 cal BC), and dates for the Ljalovo layer span 5600–5100 BP (4430–3900 cal BC). Rejuvenation of the ^{14}C dates of humus is only observed in the uppermost 5–8 cm of the habitation deposits and can be explained by the activity of roots and rodents. Within the major part of the deposits, the rejuvenation of dates is insignificant. This can be assessed from the differences in the dates of the fillings of archaeological objects

(hearths, vessels, etc.) ranging from 3700–3500 BP (2100–1800 cal BC) and dates from the background mass of the layer of the Textile Ceramics culture, 3700–3200 BP (2100–1460 cal BC). Thus, the ^{14}C contained in the humified organic matter filling the archaeological objects (hearths, pottery vessels, etc.) can be used to reliably date these objects.

The cultural layer of the Pesochnoe-1 settlement is characterized by an unusually high stability of organic matter. Therefore, our conclusions on the dating results cannot easily be extrapolated to other sites of the Bronze Age. In this context, it is important to study other settlements in the area of Lake Nero with the dark-colored habitation deposits enriched in burnt bones. ^{14}C dates for these deposits should be compared with the dates obtained for the Pesochnoe-1 settlement.

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