# COMPLEX PALEOECOLOGICAL RESEARCH OF BURIED SOILS AND RECONSTRUCTION OF THE BRONZE AGE CLIMATE IN THE EAST EUROPEAN PLAIN AND ADJACENT AREA

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## ABSTRACT

Climate reconstruction in the Holocene for the Russian Central Chernozemic region with use of palynological and soil research of deep cores in floodplain deposits and archaeological monuments are carried out. In the Preboreal period area was covered by meadow and grass steppes, pine and birch forests were locally spread. In the Boreal period they were dominated, broadleaved species were noted in small content at its beginning, in its middle span oak and hazel appeared, in the final phase ash and maple added. In the Atlantic period further warmth and humidity increase promoted to broadleaved forests domination, gradually their structure became multi-tiered, in Latter Atlantic oak groves with beech and hornbeam grown. In the Suboreal period forests area reduced and the herb-grass communities expanded. The increasing humidity and temperature in the Middle Subatlantic promoted to development of single-tiered oak forests with linden and elm, and spruce border migration to the south. In the Late Sub-Atlantic, the climate and population activities led to oak forests reduction and steppe vegetation expansion. The most sharp climate changes are timed in border of the Atlantic – Boreal, Boreal - Subatlantic and late Subatlantic early stages, and correspond to the main lines of the environment development in the Holocene.

**Keywords:** palynology, paleoclimate, paleochernozem, archaeological monument

## INTRODUCTION

A comprehensive study of buried soils in alluvial sediments and dated archaeological sites provides valuable information on the environment evolution, human activity and interaction of man and nature in different chronological periods of the ancient communities' existence [1, 7, 14, 12, 4, 11].

The studies were conducted in the Central-Chernozemic area. Palynological studies of ancient deposits and soils of this and adjacent regions were carried out [10, 9, 5]. The

climate reconstruction in the Holocene for was done on the base of palynological studies of cultural layers and soils of archaeological sites [13].

Recently, new extensive spore-pollen studies of deep columns of the Holocene material of floodplains deposits and layers of cores in the archaeological sites in this region were received. The aim of our work was to generalize these data to expand the information to the existing scheme for the evolution of landscapes of the Chernozemic region in accordance with the climate during the Holocene.

## MATERIALS AND METHODS

The study is carried out mainly in the forest-steppe zone of the Central-Chernozemic area within the Voronezh and neighboring regions. There are the Central Russian Upland and the Oka-Don Lowland, the feature of which is the shallow groundwater table on the depth from 2-3 to 3-10 m both in watersheds and in depressions, in the Central Russian Upland they occur in depth of 15-20 m. Following sites are studied: deep cores in alluvial deposits of high and low floodplains of the Upper Don and Seim Rivers (Kostenki and Semiluki, respectively) and small rivers: Gavrilo and Khroma, Shkurlat career, paleosols of archaeological sites: Plautino 2, 4, and soil horizons from ancient settlements: Gubarevo, Ksizovo, Rebound, Kamenka, Alexandrovka, Ryabinki. In the studied region the average temperature in January is -8-11°C, July - 19-22°C, annual temperature - 6.7 ° C. The average annual precipitation changes from 400 to 550 mm.

One of the most known paleobotanical method for the reconstruction of natural conditions existing in past epochs of soil formation is spore-pollen analysis. The method is based on the fact that plants during the flowering period produce a huge amount of pollen spores of an individual shape for each kind of vegetation. When deposited on the soil surface, they create a spore-pollen spectrum reflecting the vegetative composition of the region [15]. The preservation of these particles is hundreds of thousands and millions of years. As a result, it becomes possible to obtain data on the species composition of the vegetation cover for a certain historical period and also reconstruct the climatic conditions.

Both pedological and palynological investigations are used in order to paleoenvironment information. The pollen was received by following: disintegration in a solution of pyrophosphate (Na4P2O7), treatment with 10% HCl, fine fractions removal and separation in heavy liquid (CdI2, KI) of specific gravity 2.2.

## RESULTS AND DISCUSSION

In the Late Pleistocene, 14000-10000 BP throughout all interval pine forests were dominated, on Middle Driass they added a spruce (up to 20%) to the Dryas, an appearance of lime and oak was noted in the second half of the allied, and burs with a rare inclusion of birch remained in the late Dryas.

In the Preboreal period (10000-9500 BP, site Gavrilo-86) birch-pine forests began to spread to local areas, among them heat-loving broad-leaved forest, mostly elm, were sporadic. In this period *Herbaceous* associations were dominated and represented by mixed herbs, meadow and cereal loci. However, among them, a lot of the

Chenopodiaceae and Artemisia pollen was found. According to T. Tregub [15] this was determined not by a climate aridization, but depended on local conditions, such as plant development on proluvial, predominantly weakly fixed deposits, which initially overgrow mainly with ruderal and psammophyte species, which contain many species of Chenopodiaceae and Artemisia.

Based on the above data, it can be assumed that at the end of the Pleistocene and the ancient Holocene, periglacial landscapes were widespread in the region and cryogenic soil formation was developing (Table 1).

**Boreal period** (9000-8500) BP, Plautino 2, Gavrilo, Gavrilo-86). At its beginning, as a result of climate warming, pine and birch-pine forests with a small amount of spruce (up to 6%) dominated in the landscape. Later, the palynospectra composition was enriched by the pollen of alder, elm, aspen. In the Middle Boreal period, the pollen of heat-loving forest constituents gradually increased: the first area of oak forests with hazel trees enlarged, their composition gradually filled out, ash and maple appeared in the final stages [15].

In the Boreal period among grass vegetation, herbaceous-motley biocenoses replaced by the herbage-grass associations, then became enriched in the components of wet and floodplain meadows according the natural conditions improvement. In the late Boreal stages, a large amount of halophytic Salsola soda L. pollen appeared. The area of its growth is saline meadows or carbonate rocks. Their appearance may be due to a sharp but short climate aridization.

A cold episode about 8200 BP in the Northern Europe, widely discussed in the literature, caused a decrease in air temperature of 1-2°C and lasted for 160 years almost did not occur in Eastern Europe south of 70° N. w. (according to the analysis of 500 pollen diagrams) [3].

According NA. Khotinskii' data this stage is manifested in the 8300 – 8000 BP span. In the Atlantic period due to the Holocene climatic optimum, the soil development is directed towards the formation of meadow chernozemic soils. In the Atlantic third rhythm, their development often consists of two phases: first - a meadow, then - a forest one [14].

In the soil cover on poorly drained plains in the boreal period, probably hydromorphic meadow complexes with forest-meadow gley, meadow and bog soils continued to develop, and the process of salinization of their profile occurred in arid phases. On the watersheds, forest soils were formed [1].

**Atlantic period** (8000-4500 BP, high floodplain of the Don, Gavrilo, Seym and Kroma Rivers). At its beginning, the increase in warmth and moisture continued, which contributed to the expansion of the oak forests areas, distribution of alder, aspen, elm and linden in their composition, gradually oak forests developed into multi-tiered structures.

The Middle Atlantic period characterized **by an optimum ratio of warmth** and **moisture**, as indicated by the spreading oak forests of a complex composition to the south of the Voronezh region and the maximum abundance of pollen of thermophilic *Tilia* of the studied forest-steppe palynospectra. Oak complex structure forests also spread from the Belarus to Volga region in the area of 50-52° N [5, 6, 15]. The area of the pine forest complexes, in which there were a lot of birch and juniper, obviously

decreased due to their disappearance at the watersheds. While burs remained in lowered relief forms, mainly on low sandy river terraces.

In the short spans of the Atlantic, the climate was most favorable, as evidenced by the appearance of pollen (*Carpinus betulus* L., up to 15%, % from tree pollen amount), beech (*Fagus silvatica* L., up to 1.5%) and the presence of forests with the following complex composition: with two oak species (*Quercus robur* L., *Q. pubescens* Willd – 30 - 40%) and linden (*Tilia cordata* Mill., *T. cordifolia* Bess., 20 - 30%), maple (*Acer tataricum* L.), elm and hazel. Within the Voronezh region layer with the presence of pollen hornbeam and beech is rarely detected, it is found only in Kostenki site is the high floodplain of the Don River [15]. The palinological column of the Holocene sediments of the Central Russian Upland (the floodplain of the Kroma River) and the data from the territory. Confirmation of this span presence is provided by palynological data for the Ukrainian regions adjacent to the Voronezh area [6].

In the grassy cover in the Atlantic, mixed herbs with a large number of meadow species were predominantly distributed, they replaced the grass-and-motley groupings that prevailed at the end of the Boreal stage. In a phase with a favorable ratio of warmth and moisture conditions in the Don River basin increase in average annual temperature and precipitation indicators reached 1°C and 50-100 mm compared to modern ones [9].

In the final stage of the Atlantic period (4600 BP), the Pontian-Mediterranean species *Salsola soda* L. is introduced into vegetation. The abundance of this plant species indicates about arid conditions that were more contrasting and prolonged than at the end of the Boreal stage, when these plants were also detected in the pollen spectra. This arid and cool stage is established according to the pollen composition of the floodplain deposits of the Kroma and Don River (the Gavrilo site) of the Voronezh region [15] and also recorded in the Belarus. Palynological data are in good agreement with the appearance of brackish-water species of diatom algae in the sediment layer of this climatic stage in the sections of the upper part of the high floodplain of the Don River (Gavrilo-86 and Shkurlat-6 sites).

According to Spiridonova [13] during the chronoperiod of 7000 – 5000 BP there were three phases of desiccation, which alternated with more humid conditions. Consequently, the processes of soil formation and their intensity were transformed in accordance with these changes. So the stages with increased moisture were characterized by a rise of groundwater table, the accumulation of carbonates and salts in the soil profile. In the wet phases lowering of groundwater table occurred and it was accompanied by soil leaching processes [1]. These processes were more pronounced in the Oka-Don lowland plains.

Based on the generalization of the soil study of accumulative landscapes (80 objects, 180 - $^{14}C$ dates), seven stages of soil formation were identified in the Central Chernozemic area of the East European Plain in the Holocene: 0.15-0.45, 1.5-2.3, 2.8-4.2, 4.7-6.2, 6.6-7.7 , 8.3-9.5 and 10.2-10.4 BP, when the climate favored soil formation, they are separated by stages of intensive erosion and accumulation of sediments, the rate of their development did not contribute to soil formation [14].

Detailed changes of the climate during 5000-2000 BP based on the palynological study of the Saki Lake sediments in the steppe Crimea are shown in the table. A cyclic alternation of warm and cool climatic phases with a duration of 300-600 years was revealed [6]. These phases roughly correlate with high and low levels of the Black Sea

[2]. A progressive cooling trend - from the Late Atlantic to the Late Subatlantic took place. The most humid span was 4200-4100 and 3200-3000 years and the driest - 3600-3300 BP [6].

Based on the reconstruction of palynological data, NA. Khotynsky [8] identified three main thermal maximums of the Holocene in the territory of Northern Eurasia: Boreal (8900-8300 $^{14}$C BP), Atlantic (6000-4700 $^{14}$C BP) and Subboreal (4200-3200 $^{14}$C BP), of which the Boreal maximum was most pronounced in Siberia and the Far East, and Atlantic and Subboreal span - on the Russian Plain. Note that, on these regional differences, N.A. Khotynsky concluded that thermal changes in the Holocene in the Northern Eurasia were unidirectional and more or less synchronous, albeit a different scale, tion. At the same time, only the late-Atlantic phase, marked by the optimal ratio of heat supply and moisture, can be considered as the climatic Holocene optimum of the whole Northern Eurasia.

Paleopolynological, paleogeographic and soil-archeological studies of the Central Chernozem region revealed the dynamics of landscape-climatic conditions of the forest-steppe over 10 000 years. The maximum changes in warm and humidity availability in the Holocene took place at the boundary of the Boreal - the Atlantic, the Atlantic - the Saturday and in the early stages of the Late Subatlantic.

Properties of a large number of paleosols buried under the kurgans for the last 5000 years were studied and different trends of their development in different regions of the southern part of the East European Plain were revealed. The trend of soil properties deterioration is shown: a reduction in the thickness of the humus profile and an increase in the carbonate layer in the period from 4500-5000 to 4000-3700 yrs ago. The linear area of the delayed (previously 3600-3200 yrs ago), and then the accelerated formation of the humus profile of chernozems, in the zone of contact between the cyclonic and anticyclonic weather regimes were shown along the Voeikov line (from Mongolia to Kyzyl (RF) - Uralsk (Kazakhstan) - Saratov (Russian Federation) - Kharkov (Ukraine) - Chisinau (Moldova) installed [4].

Table 1. Characteristics of the Holocene climate of the Central Chernozemic Region of the Voronezh oblast and adjacent area

| Time, BP | Gerasimenko, 1997 | Kremenetsky, 1997 | D - dominant, L - locally, S - single | | |
|---|---|---|---|---|---|
| PB-1 10300-9500 | wet very cold | 9900, 9700 warm 9800, 9600 cold | | wet very cold | D - meadow and cereal steppes, pine-birch, Artemisia, S- elm |
| PB-2; 9500-9000 | Semi-dry cold | | | | |
| BO-1 9000-8400 | wet cold | 8900, 8500 warm 8700 cold | 9000-8500 | wet cold | D - birch-pine, forbs-cereal, medow, L - elm |
| BO-2 8400-8000 | Dry cold | 8300 warm 8400, 8200 cold | | cold | D -«-, L - oak, hazel |
| BO-3 7800-7400 | wet warm | 7800, 7500 Warm 7700 cold | 8000–8300 | warm, dry, cold-short | D -«-, L – ash, maple, cereal-forbs, meadow. Decrease oak, L - saltworts |

| | | | | | |
|---|---|---|---|---|---|
| AT-1 7400-6900 | Dry cold | 7400, 6900 cold 7100 warm | 8000-4500 | Dry, warm | D-oak, L-alder, aspen, elm and lime; meadow grass, pine-birch, |
| AT-2 6900-6300 | optimum wet warm | 6700 warm 6400 cold | | warm, wet | D - oak, lime, maple, serial-forbs-; L – pine, birch, juniper |
| 6300-5800 | dry cold | 6000 warm 5800 cold | | | |
| AT-3 5800-5300 | optimum. warm, semi- dry | 5500 warm 5200 cold | | wet, warm optimum | D -«-, forbs-meadow, L -«- |
| 5000-4800 4800 4700-4600 | warm dry wet, cold | 4900 cold 5000, 4700 warm | 4600-4200 | wet, warm | D -«-, L-hornbeam, beech |
| SB-1 4500-4300 4200-4100 | dry, cold very wet, cold | 4500 cold | 4200 | dry, cold-maximum | D – pine, lime-elm, L – oak, L - saltworts |
| SB-2 4000-3900 3900-3700 3600±90 - 3300 | dry, warm wet, warm maximum dry cold | 3900, 3500, 3300-warm 3700, 3400-cold | 4200-3200 | dry, warm | D - birch-pine on sand, terraces, oak-depression, forbs–meadow steppes on watersheds, Chernozems appeared |
| SB-3 3200-3000 2900-2700 2600-2500 2500-2200 | Very wet, cold dry, warm wet cold, 2360±50 | 3200 cold 2800 warm 2500 cold 2300 warm | | wet, cold Boundary | Increase forests and lime – elm among oak, birch-pine |
| SA-1 2200-1900 1900-1600 1800 | Dry, warm warm wet | 2200, 1900 1700 cold 2000,1800, 1600 warm | | Sb-AT, cold | Elm-lime forests, big area birch among pinery |
| SA-2, 1600 1550-1200 1200-1000 | dry cold warm | 1500, 1200 cold 1300 warm | | Wet, warm | D- pine, increase single-tiered oak forests with lime, L – elm; spruce migrate on south, cereals-meadow area |
| SA-3 1000-900 900; 400 900-800 800-200 | Wet, warm dry warm cold | 1000 warm 700, 500 - cold 600 warm | | Dry, cold | D – steppe, valleys forests, oak on watersheds, anthropogenic loads on landscapes |
| 200 | warm | 300,150 warm 200,100 cold | | Dry, cold | D – pine, cereals and meadow steppe, L -oak pine, oak |

Note PB-1, PB-2 - preboreal early and late; BO-1, BO-2 - early and late boreal; AT - Atlantic, SB - Subboreal, SA - Sub-Atlantic: 1-early, 2-medium and 3-late.

## CONCLUSION

1. Reconstruction of the dynamics of vegetation, landscapes and climate during the Holocene for the forest-steppe Central Chernozemic region according to the results of palynological and soil research (7 sites in the floodplains deposits and 8 - in the archaeological monuments) are carried out. During the Preboreal period the territory under study was covered mainly by meadow and grass steppes, pine and birch forests were locally spread. During the Boreal period they dominated, broadleaved species were noted in small content at its beginning, in its middle span oak and hazel appeared, in the final phase ash and maple added.

2. During the Atlantic period further warmth and humidity increasing promoted to domination of broadleaved forests, and gradually their area expanded and structure became more complicated, they transformed into multi-tiered oak forests with linden, ash and maple, the Latter Atlantic (thermal maximum of the Holocene) was characterized by the development of oak groves with beech and hornbeam. Transition between Atlantic to Suboreal was fixed as dry and cool stage with a sharp reduction in broadleaved species and the appearance of halophyte Salsola soda L.

3. In the Suboreal period forests area reduced and the herb-grass communities expanded. The span between Subboreal and Subatlantic due to temperature decreasing was characterized by the development of elm and linden communities on the watersheds and pinery with wide birch forests - in depressions.

4. The increasing humidity and temperature in the Middle Subatlantic promoted to development of single-tiered oak forests with linden and elm, and migration of the spruce border to the south and its introduction into pine forests. In the Late Sub-Atlantic, the climate and population activities led to the oak forests reduction and steppe vegetation expansion. The most sharp climate changes are timed in border of the Atlantic – Boreal, Boreal - Subatlantic and late Subatlantic early stages, and correspond to the main lines of the environment development in the Holocene.

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