The East European Plain on the Eve of Agriculture

Edited by

Pavel M. Dolukhanov
Graeme R. Sarson
Anvar M. Shukurov

BAR International Series 1964
2009

This title published by

Archaeopress
Publishers of British Archaeological Reports
Gordon House
276 Banbury Road
Oxford OX2 7ED
England
bar@archaeopress.com
www.archaeopress.com

BAR S1964

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ISBN 978 1 4073 0447 2

Printed in England by Blenheim Colour Ltd

All BAR titles are available from:

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Oxford
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England
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Introduction

This volume deals with the prehistoric human groups and their environments that occurred during the early and middle Holocene (roughly 10 – 6 thousand years before present) in a huge segment of the Eurasian continent forming the East European Plain, which predated the early manifestations of food-producing economies: agriculture and stock-rearing. In archaeological terms widely accepted in the West, this period corresponds to the Mesolithic, panoply of hunter-gathering communities that evolved in the aftermath of the Last Ice Age. According to the terminology which remains in use in most of East European countries, this period also includes Early Neolithic, which featured the large-scale manufacture of ceramic pottery, improvements in lithic and bone-and-antler technology, and increased sedentariness.

This important period which had a considerable impact on shaping the subsequent destinies of Europe, was the object of intensive studies by several generations of East European archaeologists, however it remains poorly known in the West. The scholarly studies of Prehistory in Russia started in the late 19th – early 20th centuries, associated with the names of I.S. Polyakov (1847-1887), V.A. Gorodtsov (1860-1945), A.A. Spitsyn (1858-1931) and many others. First studies of Neolithic sites in Russia were conducted predominantly by geologists and included the reconstructions of prehistoric environments. This included the studies of the sites south of the Ladoga Lake by A.A. Inostrantsev (1882), the discovery and investigations of early Neolithic sites near Moscow by B.S. Zhukov (1925) and the studies of Mesolithic and Neolithic sites in North-Western Russia by B.F. Zemlyakov (1922, 1928).

Intensive studies of Meso- and Neolithic sites conducted in the 1930s and 1940s were summed up by A.Ya Bryusov (1952, 1957). Large-scale investigations conducted in the second half of the 20th century resulted in the appearance of series monographs focused on regional studies. Mesolithic sites in the Russia's north-western and northern areas were discussed by M.E. Foss (1952), Pankrushev (1964, 1978) and Gurina (1961, 1997). The sequences of Meso-Neolithic sites in Russia's central areas were dealt with by L.V. Kol'tsov (1989), D.A. Krainov and N.A. Khotinsky (1968) and V. Tretyakov (1972). The developments in the eastern areas of European Russia were the subject of publications by O.N. Bader (1970), L.Ya. Krizhevskaya (1968) G.N. Matyushin (1982) and A.Kh. Khalikov (1969). Neolithic studies in the Ukraine started in the late 19th-early 20th centuries and were initially influenced by Vikenty Chvojka (1850-1914). Large-scale field works conducted in the 1930s-1970s have been summed up in several monographs, and especially by V.N. Danilenko (1969) and D.Ya. Telegin (1968, 1981).

In Estonia serious investigations of prehistoric sites were initiated by A.C. Grewingh (1819-1897). In the period of Estonia's independence between the two world wars the most spectacular achievement was the discovery and studies of the Mesolithic Kunda culture by R. Indreko (1900-1961). In the 1950s intensive studies of Mesolithic and Neolithic sites were conducted by the new generation of Estonian scholars and notably L. Jaanits (1968). K. Paaver (1965) summed up the archezoological evidence stemming from Estonia and meighboring Baltic countries. E. Šturms initiated intensive studies of prehistoric sites in Latvia,in the 1920 – 1940s. In the 1950s-1990s great number of Mesolithic and Neolithic sites were discovered and studied by F. Zagorskis (1987), L. Zagorska (1993), I. Loze (1979, 1988), and L. Vankina (1970). Intensive investigations of Mesolithic and Neolithic sites in Lithuania are reflected in numerous publications, including those by R. Rimantiene (1979, 1980, 1982) and Girininkas (1990) Neolithic studies conducted by V.I. Timofeev (1996) in the Kaliningrad District, resulted in the discovery of numerous important sites.

Likewise in Russia, initial studies of prehistoric sites in Finland were carried out predominantly by geologists and were connected with investigations of the displacement of ancient shore-lines (Ailio 1917, Hyyppä 1937). Several generations of Finnish archaeologists were involved in the investigations of Mesolithic settlements which resulted in their stylistic subdivision, detailed chronologies and the reconstruction of the subsistence and life-style (Pälsi 1915/1920 Luho 1956, 1967, Matiskainen 1989 a,b,c). Starting with pioneer works by Europaeus-Äyräpää (1915, 1925) Finnish archaeologists focused the studies of early pottery-bearing sites, and, especially, on their chronologies, subsistence and origins. Another major debatable topic in Finnish Prehistoric concerns the evidence of early agriculture in Neolithic sites on which accounts conflicting opinions have been voiced (Taavitsainen et al. 1998 Donner 1984 Nunez 1999). Further in this volume newly available evidence will be discussed pertaining to early forms of agriculture discernible in the Neolithic records of the Baltic States, Ukraine and Russia.

Sadly, these rich resources remain insufficiently known to Western readers. A seminal investigation by M. Zvelebil (1981) predominantly focused on Finnish materials makes a notable exception. The present volume aims at bridging the existing gap in the knowledge. It consists of regional chapters compiled by the archaeologies with the expertise in their respective areas and includes recently achieved evidence, and, importantly, series of radiocarbon measurements. These chapters also comprise recently obtained evidence on the subsistence, with an emphasis on signals pertaining to early agricultural activities. We also incorporated the chapters with state-of-the-art characteristics of the Holocene environments in the respective areas, focused on the Mesolithic and early Neolithic periods.

A group of papers concentrates on the mathematical modelling of the available archaeological, environmental and radiometric data, suggesting various scenarios of Neolithic dispersal and the Meso-Neolithic transition.

The final section of the volume includes the papers which suggest the reconstruction of the Neolithic languages, as well as the use of molecular genetic evidence indicative of human movements and interaction during this crucial period.

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Theoretical Background

P. M. Dolukhanov

Over the past 30 archaeology has witnessed several paradigm shifts, which may be visualised as the developmental pattern of mature science (Kuhn 1970, 12). The approach currently known as 'processual archaeology' and often classified as 'positivism', became the dominant paradigm in the Anglophone archaeology in the 1950-1960. It originally emerged as a reaction against culture history (or rather culture-ethnic school in archaeology), which Lewis Binford blemished as an idealistic approach. Essentially 'processual' (also known as 'new') archaeology was an attempt to refigure it along the lines of a scientific discipline. In the words of Binford (1989, 12) the pivotal issue was 'how to accurately give meaning to archaeological records and observations'.

The rise and subsequent demise of 'processual' archaeology were entangled with the fortunes of cybernetics. That discipline arose in the 1940s in the wake of the electronic revolution, which among other elements introduced the technique of 'negative feedback' in control amplifiers. Its ramification, the 'systems theory', developed into an interdisciplinary field of science, focused on the complex 'systematic' phenomena in nature, society and science. The application of principles of cybernetics to the wider, notably, biological sphere was largely due to von Bertalanffy, who in the 1960s built up the General System Theory (GST). Bertalanffy's main contribution consisted in the concept of open systems. He argued that traditional closed system models based on the second law of thermodynamics were inapplicable to living organisms. Bertalanffy claimed that the GST principles (such as feedback, information, and communications) were equally appropriate for the social sciences.

In archaeology the principles of GST were epitomized in the works of David Clarke (1937-1976). In many respects David Clarke stood mid-way between the classical, culture-focused archaeology and the emerging 'processualist' approach. According to Clarke's definition (Clarke 1968, 14), archaeology as a discipline, was primarily about 'the recovery and study of artefacts', and its data consisted in 'artefacts and their context'. The archaeology's aim, in Clarke's view (Clarke 1968, 20-22), and in accordance with the principles of 'classical' archaeology, consisted primarily in classification: identification of fundamental (typological) entities, the search of similarities, and, ultimately, the development of higher categories of knowledge such as 'archaeological cultures'.

Clarke viewed archaeological evidence as a segment of the real world. Archaeologists and anthropologists, according to Clarke (Clarke 1968, 84) were dealing with cultural data, each artefact being a 'solidified sequence of actions or activities'. Following the GST principles, Clarke viewed culture as an information system with subsystems (social, religious, psychological, economic and that of material culture), which are coupled with one another and with an external 'environmental system' by 'positive' and 'negative' feedback loops. This vision was close to that of Binford (1962), who defined culture as 'extrasomatic means of adaptation'.

Accordingly, Clarke articulated a model for 'archaeological procedure' (Fig. 1), which included the sphere of 'specific' analysis (typological, statistical and technological studies of artefacts) and the sphere of 'contextual analysis' (scientifically controlled retrieval of data and environmental attributes). On the basis of the recovered evidence, 'iconic', 'analogue' and 'symbiotic' interpetrative models are developed.

In epistemological terms, the processualist archaeology as exemplified by the Clarke's 'systemic' approach was akin to historical determinism, which lies within the *episteme* of modernity. It tends to reduce the behaviour of complex social aggregates to a limited number of universal laws. In many respects the principles of GST are similar to those of Marxist 'historical materialism' which shows the signs of recovery in present-day social anthropology. As Marx and Engels wrote in 1845 (Marx and Engels 1970), the first historical act of living human beings was the production of necessary means of life. Therefore the first attested fact is the social organisation of human beings and their socially conditioned relationships to the rest of nature'. The social basis of any human society consists of 'productive forces' (means of production, and human beings who use them), and the mode of production. The energy input is provided by the interaction of 'productive forces' with the natural environment (resources), which scope changes with the social progress. The Marixist theory sought the mechanism of social evolution in the contradiction between the social forces and mode of production.

The present-day Marxist 'structural' discourse in anthropology tends to concentrate on the economic/non-economic relationships in hunter-gatherers societies. Structural Marxists (Friedman 1975; Godelier 1977) argue that the material conditions not necessarily determine the ideology, regarding kinship as being simultaneously part of basic production-relations and superstructure.

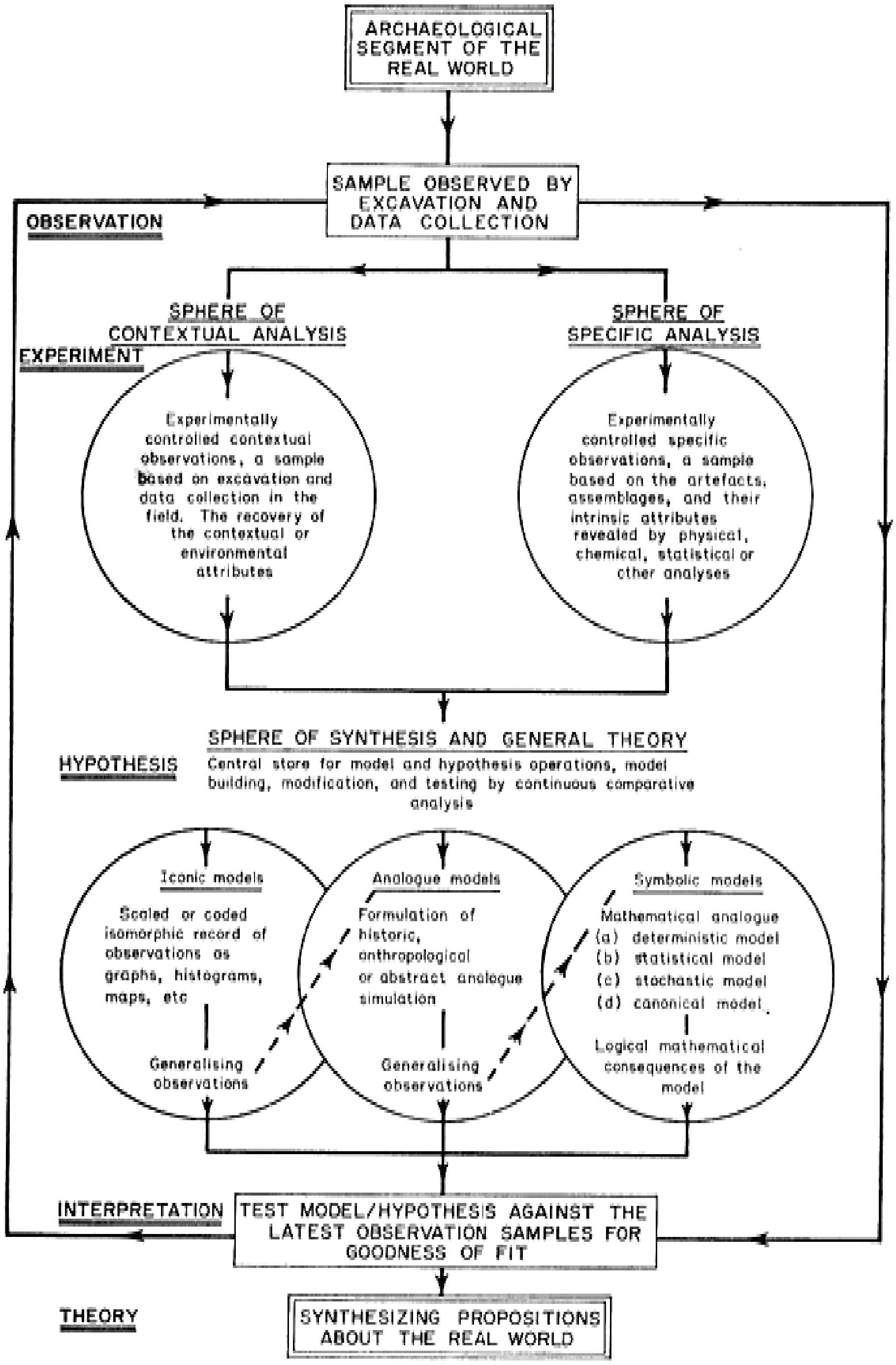

Figure 1. Model of 'archaeological procedure' (Clarke 1968).

Apart from global systemic approach, the processualist archaeology developed several interpretive models focused on the relationships between static archaeologically retrieved material culture and the dynamic society. One of such theories borrowed from the game theory was aimed at evaluating the cultural system trajectory in terms of chosen strategies (optimizer, satisfier, or minimax). Presently, in relation to human foragers' society, this approach took the form of the 'optimal foraging theory'. Its proponents argue that successful strategies of food quest tend to spread through a population at the expense of alternative strategies which less contributes to the individuals' reproductive success (Layton 2007, 162).

The widely debated Middle Range Theory advanced by Binford (1977, 1989) remains a popular concept in the processualist archaeology. Binford, using his observations of Nunamuit dwellings conceptualised the social and behaviour distinctions within a single culture on the evidence of spatial distribution and covariance of faunal remains.

The postprocessual school in archaeology (PPA) makes part of a wide *epistome* of postmodernism. Philosophical postmodernism (a synonym for deconstruction *sensu* Derrida) arose in Western Europe in the intellectual environment of social discontent of late 1960s- early 1970s, as a reaction on the concepts and values of modernity. According to Lyotard (1970), the essence of modernism was a 'carefree scepticism about any attempt to make sense of history and the rejection of all the 'meta-narratives' of progress, either Marxist or liberal'.

Following the lines of philosophical relativism, the postprocessual thought is based on the outright rejection of processualist dogmas, and its 'scientific' explanations (Hodder 1982, Whitley 1998). Postprocessualists put to the fore a 'humanistic' perspective, with the foregrounds of the individual's free will in any analysis and interpretation. In contrast to the processualists, the postprocessual approach tends to shift from explanation to interpretation and the quest for meaning, and highlighted the context in place of causality. As Shanks and Tilley (1987, 5) put it ' structuralist and contextual archaeologists have emphasized the meaning and symbolic dimensions of social practices, stressing the culturally specific and variable meanings of material culture rather than simply concentrating on its patterning supposedly 'explained' within s framework of reductionist cross-cultural generalisation'.

PPA draws on several poststructuralist principles:

The concept of 'decentring the subject' implying the separation of the narrator from the narrative;

All kinds of communications (including material culture) are viewed as a metaphoric text, subject to a 'textual analysis' or 'reading the past' (Hodder 1986);

'Deconstruction' is adopted as a primary method of analysis, as text by its nature is characterised by a plurality of meanings. In accordance with these principles PPA attaches utmost importance to hermeneutics, understood as the field of interpretation, the clarification and understanding of meaning.

It should be remarked that Leo Klejn (1983) was the first to diagnose 'the double rupture' existing between the level of archaeological entities, and that of social and cultural interpretation. Shanks and Tilley (1987) identify a 'fourthfold' hermeneutics in archaeology, viewed as four levels of interpretation. This implies the ubiquity of interpretation (Hodder 1986).

According to David Clarke (Clarke 1968, 21), one of the principle objective of archaeology as a science consists in 'the search of repeated similarities in form, function and association (of material culture)'on which basis 'increasingly comprehensive and informative general models and hypotheses' are developed. The PPA voices a scepticism, stressing that in each particular case, social, cultural and environmental context should be taken into account. As Hodder (2002, 47-48) writes: 'most if not all archaeological arguments from artefact typology to evolutionary theory, is based on analogy and comparison. In all such cases, information is transferred from context *a* to *b* on the basis of similarities and differences. But an underlying problem is that we cannot be sure, in the realm of cultural behaviour, that contexts are sufficiently similar for the transfer of information...'

The traditional 'culture historical' approach so vehemently criticised by postprocessualists emerged in the mid 19th century, as a pivotal element of the *epiteme* of modernity. Cultural taxonomy and he typological method developed by Worsae and Montelius were akin to major classificatory projects of Linnaeus and Mendeleyev and other prominent scholars of mid-late 19th century. The PPA basically rejects any cognitive or social value of artefact taxonomy, stressing that classification cannot be independent of theory (Shanks and Tilley 1987, p. 83). The same applies to the concept of archaeological culture (AC). Clarke stressed that 'an archaeological culture is not a racial group, nor historical tribe, nor a linguistic unit, it is simply an archaeological culture' (Clarke 1968,. 13), viewed as 'a polytetyhic set of specific and comprehensive artefact-type categories which consistently recur together in assemblages within a limited geographical area' (Clarke 1968, 188).

In contrast to 'traditional archaeology' the PPA 'expunged culture from any explicit archaeological considerations' (Huntley 1998, 17). Viewing culture in general as 'a shared system of symbols, values, meaning and beliefs', its proponents refused to conceptualise it as norms and mental templates. Shanks and Tilley (1987, 86) argue that 'realization developed that archaeological cultures ... were in fact multiple factors affecting the distribution of material culture items perceived as archaeological records'. The similar view is held by Renfrew (1987) who argued that (archaeological) cultures were 'little more than arbitrary taxonomic categories imposed on a continuum of change'.

This rejectionist attitude largely stemmed from the manipulation of AC for racist and nationalist purposes in the form of ''cultural-historic' or 'cultural-ethnic' school of thought. As Klejn (1993) notes the concept of 'archaeological culture' as an equivalent to ethnicity emerged both in Germany and in Russia at about the same time, in the late 19th and early 20th century stemming from a 'nationalist-romanticist school'. In Germany it is associated with the name of Gustav Kossina (1911). Kossina's method consisted in mapping the distribution of main types or archaeological artefacts and overlapping them with early maps showing the distribution of 'tribes' and 'nations' and linguistic reconstructions.. Basing on these arguments, Kossina made a surprising conclusion that northern Germany was the 'homeland' of Indo-Europeans ('Arians'), the bearers of 'battle-axe' cultures, which eventually conquered the primitive indigenous non-Aryan societies imposing upon them their will, culture and language. This concept was largely used by the Nazi propaganda long after Kossina'a death.The culture-historic principles were espoused also by Gordon Childe, a stalwart Marxist, who in his works usually recurred to the concept of 'culture' or 'culture groupings' which he identified based on similar types, pots, implements, burial rates, hoses, regularly recurring together (Childe 1929).

In Russia the 'cultural-ethnic' concept was developed by Gorodtsov (1860-1945) and Spitzyn (1858-1931). Both scholars used it as instruments of classification and distinguished on its basis several archaeological cultures most of which remain recognized to this day. The change of political decorum failed to affect the cultural-ethnic paradigm, which remains the leading concept in post-Soviet archaeology. In several cases it is even used in a much more straightforward manner, with apparent nationalist underpinnings (Shnirelman 2001). Ironically, this paradigm is used both by Russian and non-Russian archaeologists, yet obviously with diametrically opposed political agendas.

Another important direction in PPA discourse is referred to as 'cognitive or symbolic archaeology'. Flannery and Marcus (1998, 36) define it as 'the study of all those aspects of ancient culture that are the products of the human mind'. As all human-made objects are necessarily products of human mind (mental templates), one may preferably define them as 'material manifestations (or symbols) of spiritual culture: knowledge, customs, tradition, religion and art (Dolukhanov 1989, 27). In view of Hodder (1982) and Tilley (1982, 1984) symbols played an active role in past societies, being used to 'negotiate realities', to perpetuate the power and to manipulate the subordinates. In their interpretations of material symbols PP archaeologists recur to overtly formal similarities particularly with regard to megalithic burial sites. Megalithic tombs are seen as symbols of houses, or as 'cross-references to the axe and the body (Thomas and Tilley 1993).

In their vision of archaeology as a scientific discipline, processualists employ generalisations and induction as the instruments of logical reasoning by which means knowledge is revealed from the observed and recorded archaeological evidence (Clarke 1968, 15). On the other hand, Binford (1989, 17) while acknowledging 'the crucial role of the induction' placed the emphasis on deductive forms of reasoning, which consisted of testing the existing hypotheses.

Postprocessual archaeology generally rejects the logical reasoning as an instrument of interpretation. Shanks and Tilley (1987, 9) write that 'few archaeologists believe in induction any more'. They argue that verification procedures often 'give way to falsification', as both data collection and description are 'theory-laden'.

In their interpretation of material culture PPA adheres to a purely relativist approach. As Hodder (1999, 71) put it 'interpretation involves selectively linking events and materials and individuals with larger scale processes. It involves recognizing that general understanding may have to be reformed to make sense of a particular case. *The uncertainty of interpretation seems to put creativity centre stage*'.

In an attempt to combine archaeological structures with the principles of 'individual agency' British PP archaeologists developed a specific 'phenomenological'approach. It includes the Heidegger's idea of 'prehistoric actors' mind being not separated from the body or nature (Hodder 1999, 132). Hence prehistoric monuments were seen as 'locales' which 'structures future actions without determining them'. Neolithic houses are deemed as 'centres of experience of the self and the environment' (Thomas 1996). The 'fourthfold' hermeneutics implies that archaeologists 'can study the practices and mechanisms for creating and recreating meanings without knowing what the meanings were'. Hence, the LBK is treated as 'means by which the meaning of places and activities could be created' (Thomas 1996, 112). In a similar way, Tilley (1994) argues that monuments were placed in the landscape, to control and fix meanings and thus to control it'.

The abandonment of strict logistic reasoning which included the rigorous data collection, the formulation of models and hypotheses and their subsequent testing resulted in the general decline of the studies focused on the analysis of material culture in British archaeology. To test this statement, we analysed the contents of two leading archaeological periodicals, *Antiquity* in Britain and *L'Anthropologie* in France for 2007-2008. This analysis shows that only 6 out of 104 papers in *Antiquity* (6%) discussed the issues directly related to material culture. In *L'Anthropologie* the corresponding rate of material culture-related publications for the same period was 13 out of 26 (or 50%).

The current archaeological debate is essential for understanding the concept of Neolithic. Sir John Lubbock (1865) who was the first to introduce this term, specified the main characteristics of the Neolithic to be the growing of crops, the taming of animals, the use of polished stone and bone tools, and pottery-making. V.G. Childe (1925) who combined the traditional vision of archaeological culture with the Marxist ideology, advanced the concept of 'agricultural revolution' which was focused on the introduction of agriculture. The neolithisation was viewed as the spread of colonists bearing ceramic containers, domesticated plants and animals, new architecture, long-distance trade, burial rituals, and eventually overwhelming indigenous hunter-gatherers to the cultivation of domesticated cereals and rearing the animal stock. New criteria included sedentary settlements, social hierarchy and symbolic expressions (Tringham 2000). Yet to this day the shift to agro-pastoral farming is deemed to be the most important single signature of Neolithic (Zvelebil 1996. 323). Significantly, recent archaeobotanic studies (Hather and Mason 2002, 4–5) show that it is often impossible to draw a clear distinction between agriculture and hunter-gathering, as hunter-gatherers may undertake agricultural practices and vice versa. This evidence shows that wild plant species were extensively gathered in most areas in the Neolithic Britain (Robinson 2000). On the other hand, as it will be shown in the present volume, pottery-making hunter-gatherers in the boreal forests of Eurasia display the attributes of complex societies, such as sedentism, high population density, intense food procurement, technological elaboration, development of exchange networks (that may include their agricultural neighbours), social differentiation, and territorial control. It becomes increasingly clear that the distinction between agricultural and non-agricultural Neolithic is rather loose, and the dominant manifestations of Neolithic are different in different parts of the world and even Europe (Sériadès 1993; Trigham 2000).

The postprocessualist approach introduced a new dimension into the Neolithic-focused debate. Thomas (Thomas 1996, 2003) argues against the concept of a fixed and universal 'Neolithic package' and views the Neolithic as a range of various processes, generating considerable variability of subsidence practices. Hodder (1990) identified durable structure (*domus*) that existed before the farming and provided a formidable impact for 'taming' the nature, on which basis the agriculture (*agros*) developed.

Traditional archaeology developed several models which tended to explain archaeologically observed spread of Neolithic in Europe. The model of neolithisation as a result of direct migrations is omnipresent in the works of Childe (1958). More recently, this idea took the form of the demic expansion or 'wave of advance' (Ammerman & Cavalli-Sforza 1973). This model was further substantiated by the genetic markers (Menozzi et al., 1978; Cavalli-Sforza et al., 1994), which have been interpreted as an indication of the diffusion of farming population from Anatolia into Europe. Renfrew (Renfrew 1987, 1996) linked up the dispersal of farming with the proliferation of the Indo-European speech.

There are several varieties of the migrationist concepts. These range from a direct colonisation of hitherto unpopulated areas or the annihilation of the previous Mesolithic groups (Childe 1958; Ammerman & Cavalli-Sforza, 1973) to the model of élite dominance (Renfrew, 1987). Zilhão (Zilhão 1993, 2000) views the neolithisation as 'leapfrogging colonisation' by small sea-faring groups along the Mediterranean coast. An alternative approach views the neolithisation as an adoption of agriculture by indigenous hunter-gatherers through the diffusion of cultural and economic novelties by means of intermarriages, assimilation and borrowing (Whittle 1996; Tilley 1994; Thomas 1996).A unifying position advocated by Zvelebil (Zvelebil 1986, 1996) distinguishes three phases in the transition to agriculture: availability, substitution and colonisation, each one operating in a broader context of an 'agricultural frontier' (see also Zvelebil and Lillie 2000). The 'individual frontier mobility' concept relates the neolithisation to 'small-scale' contacts between hunter-gatherers and farmers at the level of individuals and small groups linked by kinship. Several writers (Gronenborn 1999; Price et al. 2001) argue that the neolithisation involved small groups of immigrant farmers who came into contact with 'local forager-herder/horticulturalists'.

The advent of radiocarbon dating has provided a new instrument for testing the various models of neolithisation. The first series of radiocarbon measurements seemed to confirm the Childean concept of *Ex Oriente lux*, indicating that the 'Neolithic way of life penetrated Europe from the south-east spreading from Greece and the south Balkans…' (Clark, 1965. 67). Later publications based on comprehensive radiocarbon data for Neolithic sites suggested a more balanced view. Tringham (Tringham 1971. 216–7) discussed the spread of new techniques, and their adoption (or rejection) by the local groups, resulting from an expansion of population. Dolukhanov and Timofeev (Dolukhanov & Timofeev 1972. 29–30) considered this process as a combination of diffusion and local inventions. A recent analysis of a large dataset of Neolithic radiocarbon measurements (Gkiasta et al. 2003) has basically confirmed the earlier results (Clark 1965; Ammerman & Cavalli-Sforza 1973), showing a correlation of the earliest occurrence of the Neolithic with the distance from an assumed source in the Near East. Currently developed models taking into account environmental factors (rivers, elevation, soil) considerably improved the understanding of the Neolithisation. Several models based on the statistical processing of radiometric and environmental data are discussed in this volume.

The study of ceramics and especially, ceramic wares constitutes an important resource in the studies of Neolithic. Until recently it was generally accepted that the appearance of pottery in most European country broadly coincided with the spread of farming (Gibson and Woods 1997). This suggestion is now contested by numerous finds of fired clay that included anthropomorphic and zoomorphic effigies and fragments of 'constructional ceramics' in the Upper Palaeolithic sites of Moravia and Austria dated to around 26 kyr BP. The manufacture of these objects was carried out in the kilns with the temperature range of 500° to 800° C (Vandiver et al. 1989; Soffer et al. 1990).

Basically the same technology was used for manufacturing female figurines found at Upper Palaeolithic sites in Central Russia and Siberia (Vasil'ev 1985; Vandiver and Vasil'ev 2002). Numerous fragments of pottery have been recovered from Palaeolithuc sites in southern China, which direct radiocarbon dating yielded the age of in the order of 16-15 kyr BP. (Zhao & Wu 2000; Pearson 2005; Budja 206). Pottery from a group of sites in the middle stretches of the Amur River in Russian Far East shows the radiocarbon age of 13.3 – 12.3 kyr BP (Kuzmin & Orlova 2000). The pottery at Ust'-Karenga site north of the Baikal Lake in Siberia has been radiocarbon dated to 12-11 kyr BP (Kuzmin and Vartov 2007; Kuzmin 2007). The cases of early pottery sites on East European Plain are discussed in the present volume. Significantly all these sites are found in the context of predominantly hunter-gathering economies with no or little evidence of either farming or stock-breeding.

Importantly, early food-producing communities involved in the Neolithic revolution and located in the proximity of the Near Eastern centre of origin of domesticated plants and animals were apparently not involved in ceramic pottery-making. This was the case of Pre-Pottery Neolithic cultures in the Levant, Upper Mesopotamia, Anatolia (9800–7500 BC) and also in the Peloponnese (7030–6450 BC) and Thessaly Plain (7300–6250 BC). Significantly, as Kuijt (2000) has noted, the transition to early pottery Neolithic in the south-central Levant at coincided with the 'segmentation of living space', the abandonment of large settlements and the establishment of much smaller hamlets with clear identifications of group and individual identities.

Hayden (1995) linked the early pottery-making with the emergence of 'private ownership', 'economically-based competition' and the 'prestige technologies'. He saw the ceramic vessels as instruments aimed at 'impressing guests at communal feasts'. As will be seen further in the volume there are no evidence that could link the early pottery-making to any kind of social hierarchies or internal competition. Quite on the contrary, this evidence shows that these processes occurred in internally cohesive and basically egalitarian societies. On the other hand, there is strong evidence suggesting that ceramics played a significant role in signifying the group identities and intertribal connections.

Scientific studies including he analysis of food crusts and residues conform that pottery wares were used mainly as storage vessels, water containers, cooking pots (which included boiling water and organic food), drinking and eating vessels (Gibson and Woods 1997, 61). Yet the prolonged existence of aceramic farming settlements suggests that non-ceramic containers could have served the same purpose, such as skin bags, wicker baskets or stone vessels. This implies that from the beginning the ceramics were deeply embedded in the spiritual and symbolic existence of hunter-gatherers' communities (Budja 2007).

The early pottery was hand-made and open-fired (Gibson and Woods 1997, 26). Nonetheless, even at that stage the pottery manufacturing was a technology, which necessitated the existence of professional or semi-professional craftsmen. The operational chain included the choice of appropriate raw material, the preparation of fabric by means of adding additional tempering substances (organic materials, crushed pottery, mineral fragments etc.). The pottery forming included several techniques, of which the ring-building was most commonly used. This process consisted of coiling: rings of clay were applied to one another and squeezed together. Subsequently both the internal and outer surfaces were smoothed and burnished with the use of paddle and anvil. At this stage the surface decoration was applied. As experiments show, the open firing was a quick and economic process, providing a heat sufficient to for the clay minerals to go through the ceramic stage. This normally occurred at the temperature around 550-600°C. Lesser temperature of heating often mentioned in archaeological literature is deemed as unrealistic (Gibson and Woods 1997, 27). The operational chain also included the use, exchange and final disposal of the artefacts. The operational chain is non-deterministic and involves some degree of socially or culturally motivated choice (Hodder1999, 76). Ghorgihiu (2008) based on the ethnographic evidence, emphasised the ritual character of the production sequence, which combined both technological and symbolic actions. In the following chapters the concrete cases of early pottery-making operational chains will be examined in more details.

The existing classification schemes for pottery are based on the technological and formal (typological) variables. The former are based on the character of fabric (particularly the character of inclusions) and the techniques of coiling. One of the most successful typological sche,es was designed by David Clarke (1970) with regard to the Beaker pottery of Great Britain and Ireland. This scheme used the quantitative criteria for classifying the shape, motifs and style combinations.

There is little doubt that from the very beginning the ceramics combined purely utilitarian and symbolic functions. The latter are especially perceived in the ornamental patterns which are discernible even on the earliest archaeologically retrievable vessels. The ornaments consist of specific elements forming clearly recognisable (often geometric) motifs. These patterns might be perceived as language-like codes operating in a lineage-based system or signifying exchange relations between kin groups (Shanks and Tilley 1987, 108).

Interestingly the early pottery ornamental designs often consist of geometric designs. Similar designs found in the rock art are often seen as entropic motifs created in 'altered states of consciousness (ASC)' (Lewis-Williams 1998). Based on that suggestions are made that these types of pottery were manufactured by 'female shamans' who combined the knowledge of pottery-making with abilities to trigger ASC, particularly at public ceremonies (Budja 2007).

Interpretations of stylistic similarities vary considerably depending on prevailing paradigms. The views widely accepted in the 1960s and 1970s viewed the stylistic similarities in pottery as reflecting social interaction (Shanks and Tilley 1987, 89). Based on the ethnographic evidence of the American South-West the residence was seen as uxorial where the pottery was made by women and the traditions of pottery manufacture and decoration were transmitted from mother to daughter. The spatial concentration of macro traditions in design style was seen as reflecting a distinct clan of residence groupings.

These views were criticized from the postprocessual positions by archaeologists Hodder (1982) who argued that ceramics could be produced by groups rather than individuals and learning networks may differ considerably. They further stated that the identification of style with the group or social identities totally ignores the specifics of cultural context.

The present review, although incomplete, provides the theoretical background, against which the materials of the present volume may be visualised: the evidence pertinent to the situation that evolved on the East European Plain, prior or at the time of the initial spread of agriculture. The writers of the present volume were focused on the evidence, and possible interpretation models, leaving the room for multiple explanations. Yet paying tribute to the deductive reasoning, the writers could not abstain from formulating an initial hypothesis, subject to the subsequent testing.

First, in terms of structural anthropology, the Neolithic archaeological cultures, primarily defined on the base of stylistic similarities, may be viewed as kinship system (*sensu* Lévi-Strauss, 1949), with the, exchange of gifts and marriage partners being the forms of communication constituting the universal basis of the kinship system. Secondly, archaeologically perceptible pottery-making could be viewed as the oldest acknowledgeable form of social and cognitive organisation of humankind that paved the way for the Neolithic. Rather than the Hodder's *domus* it heralded the domestication of Europe.

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Geography of East European Plain

P. Dolukhanov

School of Historical Studies, Newcastle University, UK

Geological Setting

The East European (or Russian) Plain corresponds to one of the main stable blocks of the planet Earth, the East European platform, which takes up a considerable portion of the Eurasian lithosphere plate. Like similar structures in other parts of the world, the East European platform comprises two stages: an ancient crystalline basement and the cover of sedimentary rocks of various thicknesses deposited during the course of more recent epochs of its geological history.

The crystalline basement consists of Pre-Cambrian granite and gneiss, in most cases exceeding 1 billion years of age. Over the greater part of the Plain, the crystalline rocks are hidden beneath a cover of sedimentary deposits. The massive outcrops of the crystalline basement are observable in the extreme north of the Plain - in Finland, neighbouring Karelia and the Kola peninsula. They form the Baltic or Fennoscandian shield which occupies the northernmost extremity of Europe. In other parts of the platform, the crystalline basement lies at a considerable depth. Crustal movements resulted in several undulations of the basement, detectable in the thickness of sedimentary deposits. One of the depressions, the Baltic syneclise, lies immediately south of the Baltic shield. Its basement plunges to a depth of about 2000 metres. Another major depression, the Pripet syneclise, lies further to the south. The deepest depression of the basement is observed in the central parrt of the platform: it is the Moscow syneclise, where the basement plunges to 2,800 metres. The second crystalline outcrop, the Ukrainian shield, is situated further to the south. It crosses the middle stretches of the Dniepr River in an area the Dniepr Rapids.

The upper stage of the platform consists of sedimentary rocks that had been formed during the last 500 million years. Their more or less horizontally laying strata were deposited in the shallow parts of the seas which repeatedly transgressed the platform. The undisturbed deposition of the sedimentary cover is reflected in the flatness of the relief. The greater part of the Russian Plain lies between 100 and 150 metres above sea, rarely reaching an altitude beyond 300 metres (Fig. 1).

The present-day relief of the northern and north-western parts of the Plain was greatly moulded by the Quaternary glaciations that repeatedly occurred there during the last 300,000 years (Fig. 2). The area stretching from the Middle Dniepr to the Smolensk-Moscow Ridge was an arena affected by the glaciers during the Middle Pleistocene Dniepr and Moscow Ice Ages. Morainic till, usually less than 1.5 metres thick, lies directly upon Pre-Quaternary deposits, and is often overlain by the loess.

Intensive water erosion, which dissected the uplifted surface of the carbonate Palaeogenic deposits, formed the relief of the Central Russian Upland. Morainic deposits of the Moscow Ice Age (Late Middle Pleistocene) are found only on the watersheds.

The impact of the Late Pleistocene (or Valdai) Ice Age was much more conspicuous. Its limit stretches from Grodno and Vilnius in the west, to the Mologa-Sheksna Lowland in central Russia, and further northeast to the Vologda and the Northern Dvina Rivers basins. Its central or morainic section consists of closely set morainic hills alternating with deep furrows usually taken up by the lakes. The elevated hills, building the Valdai Heights, reach in places 300-350 metres and form an important watershed where the greatest rivers of the Russian Plain, the Volga and Western Dvina, have their sources. The starting point of the third major river, the Dniepr, is not far away. Huge areas to the north of the main morainic belt are taken up by vast sandy plains that were formed by the ice-dam lakes that arose during the final stages of Valdai Ice Age, and alternating with the terminal moraines built up during the ultimate transgressions of the glaciers. A major escarpment (the Glint), developed along the northern edge of the Silurian limestone plateau, it extends south of the Gulf of Finland and stretches further to the east. It separates a system of major waterways which include the Gulf of Finland, the River Neva and Lake Ladoga. Via the Volkhov river and Lake Ilmen this waterway led from the Baltic Sea into the Russia's interior. Throughout later Prehistory and Early History this was a window through which the inner areas of the Russian Plain had an access to the west. The low-lying littoral zone of the Baltic Sea consists of dune-crowned marine terraces, alternating with in-shore coastal lagoons that were formed during various stages of the post-glacial history of the Baltic Sea.

The southern part of the East European platform includes several major geological structures which are reflected in the present-day relief: the Ukrainian shield, with its major outcrops of the crystalline basement, being the most important. It forms a major fold, cut off from the surrounding areas by a system of faults deep. This elevated plateau consists of several hummocks (the highest one reaching 472 metres), crossed by terraced river valleys.

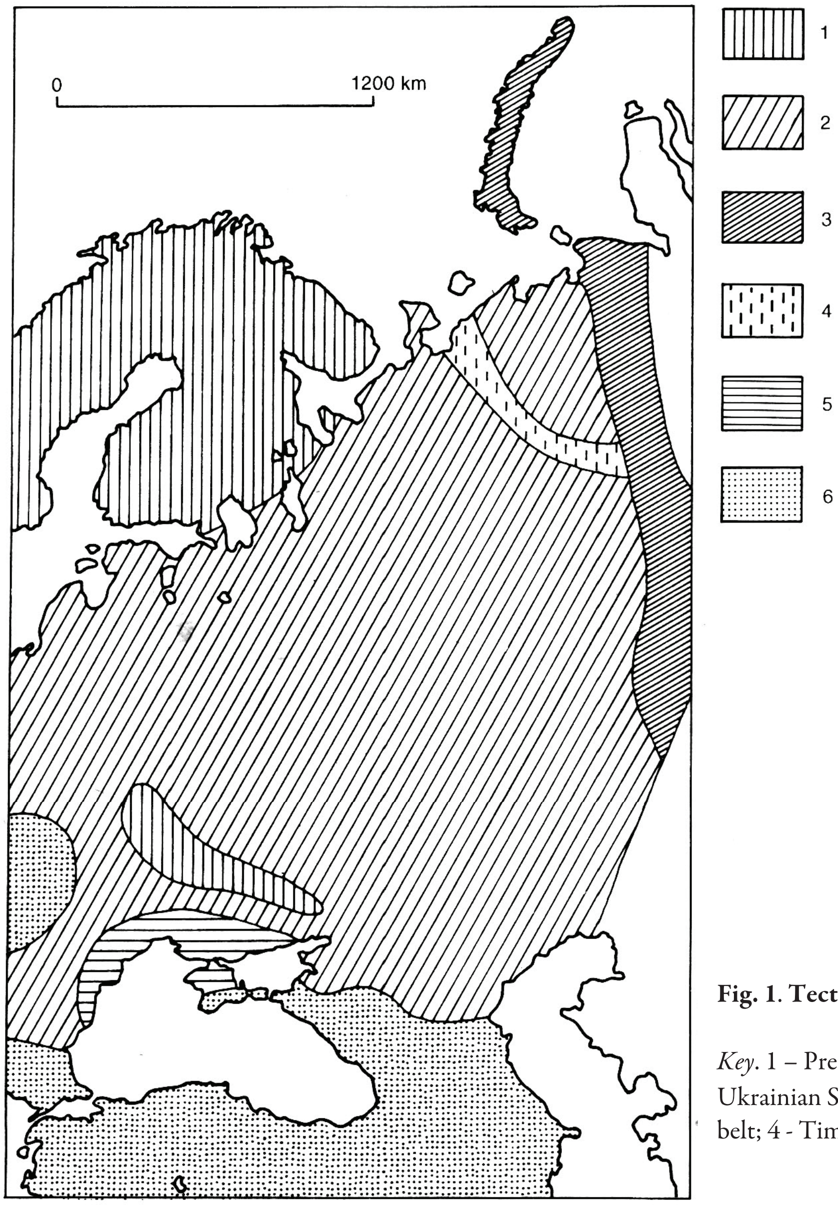

Fig. 1. Tectonic elements.

Key. 1 – Pre-Cambrian basement (Baltic and Ukrainian Shields); 2 – Russian Plate; 3 – Uralian belt; 4 - Timan Ridge; 5 – Alpine folded mountains.

The Volyno-Podolia Highland flanks the Ukrainian shield in the west. Here the crystalline basement lies hidden beneath the sediments of the Lower Palaeozoic Age. During the Tertiary epoch, several major erosion surfaces were formed there, later incised by numerous river valleys, many of them forming deep canyons.

The Donets Heights lie to the east, reaching the Middle Dniepr loop. They consist of a system of folds which had been essentially formed during the Hercynian orogenic event. Repeated thrusts that occurred throughout the Quaternary epoch, formed elevated and deeply eroded denudation surfaces on the folded basement. Its altitude reaches 200-350 metres.

Undulating and intensively eroded hills contrive a typical relief of the Moldavian Plate, restricted to the Dniepr-Prut interfluve. Its most elevated central uphills (known as Kodry) consist of erosional surfaces incised by numerous valleys and ravines.

The southern edge of the Russian Plain forms the Pontic depression: a gigantic trough or a foreland, separating the the Crimean and Carpathian from the Russian Plain. It as a major aggradation plain with an altitude of less than 200 metres, evenly tilted towards the sea. The plain is incised by the terraced valleys of major rivers (the Prut, Dniepr, Southern Bug, Dniepr and Don), often with well-developed estuaries. A system of in-shore lagoons stretches along the coastline, separated from the sea by mouth barriers.

One of the peculiarities of the natural setting of the South Russian Plain consists of loess deposits which are developed predominantly on the watersheds and reach, in places, the thickness of over 100 metres. According to the widely accepted theory, these deposits were formed during the colder episodes of the Quaternary epoch.

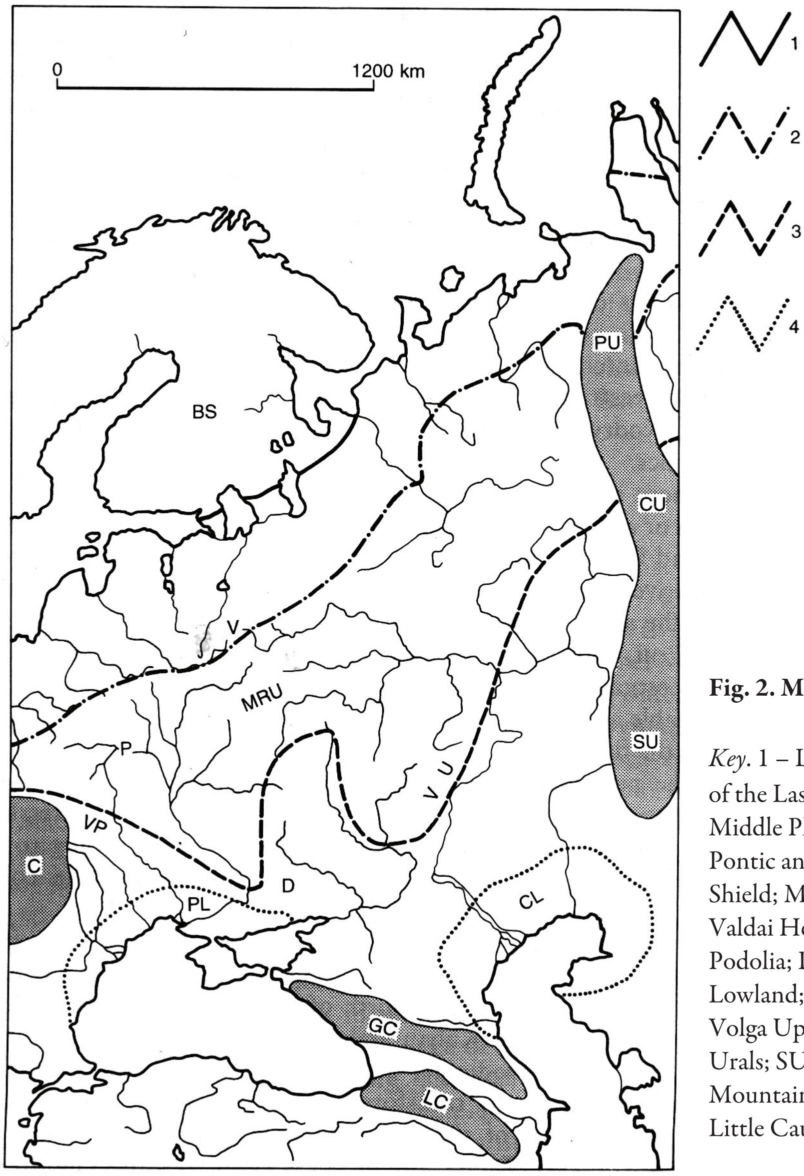

Fig. 2. Major relief features.

Key. 1 – Limits of the Baltic Shield; 2 – Limits of the Last (Valdai) glaciation; 3 –Limits of Middle Pleistocene glaciations; 4 – Limits of the Pontic and Caspian Lowlands. BS – Baltic Shield; MRU – Middle Russian Upland; V – Valdai Heights; P – Polessye; VP – Volyno-Podolia; D – Donets Heights; PL – Pontic Lowland; CL – Caspian Lowland; VU – Middle Volga Upland; PU – Polar Urals; CU – Central Urals; SU – Southern Urals; C – Carpathian Mountains; GC – Greater Caucasus; LC – Little Caucasus.

Another major trough, the Manych, separates the Russian Plain from the highest folded mountains of eastern Europe - the Greater Caucasus. In the northern Caucasus, north of the Greater Caucasus Ridge, two major lowlands, the Azov-Kuban and the Terek-Kuma, flank the hilly Stavropol plateau, correspondingly, from the west and the east. The Terek-Kuma lowland gradually transforms into the Caspian depression in the east. The greater part of the latter lies less than 20 metres below the sea-level. The present level of the Caspian Sea is 27 metres; this land-locked lake, the largest in the world, has no access to the ocean.

The elevation of the Middle Volga forms an uplifted and intensively eroded surface. It resulted from a major dome-like uplifting in the early Tertiary epoch.

Medium-high (300-800 metres) Ural mountains mark the eastern limit of the Russian Plain, separating it from the West Siberian Lowland. The Urals are the remains of a huge Hercynian mountain system. Subjected to a prolonged sub-aerial denudation, the Urals now form a system of uplifted erosion plains (or peneplaines) open in the north-to-the southern direction. The highest peaks (such as Mount Narodnaya, 1894 metres) are found in the north. The elevated Polar Urals form the eastern pillar of the north Russian facade which is open to the Arctic Ocean. It includes the intensively eroded Timan range. The other parts of the Russian North consist of near-horizontal marine sediments, predominantly of Permian Age. In places, the glacial and fluvio-glacial deposits partly enliven the monotony of the relief.

Hydrology

Several major rivers cross the East European Plain. These rivers were always of great importance as major waterways linking together various parts of the huge land-mass and opening an access to the outer world. These rivers drain into

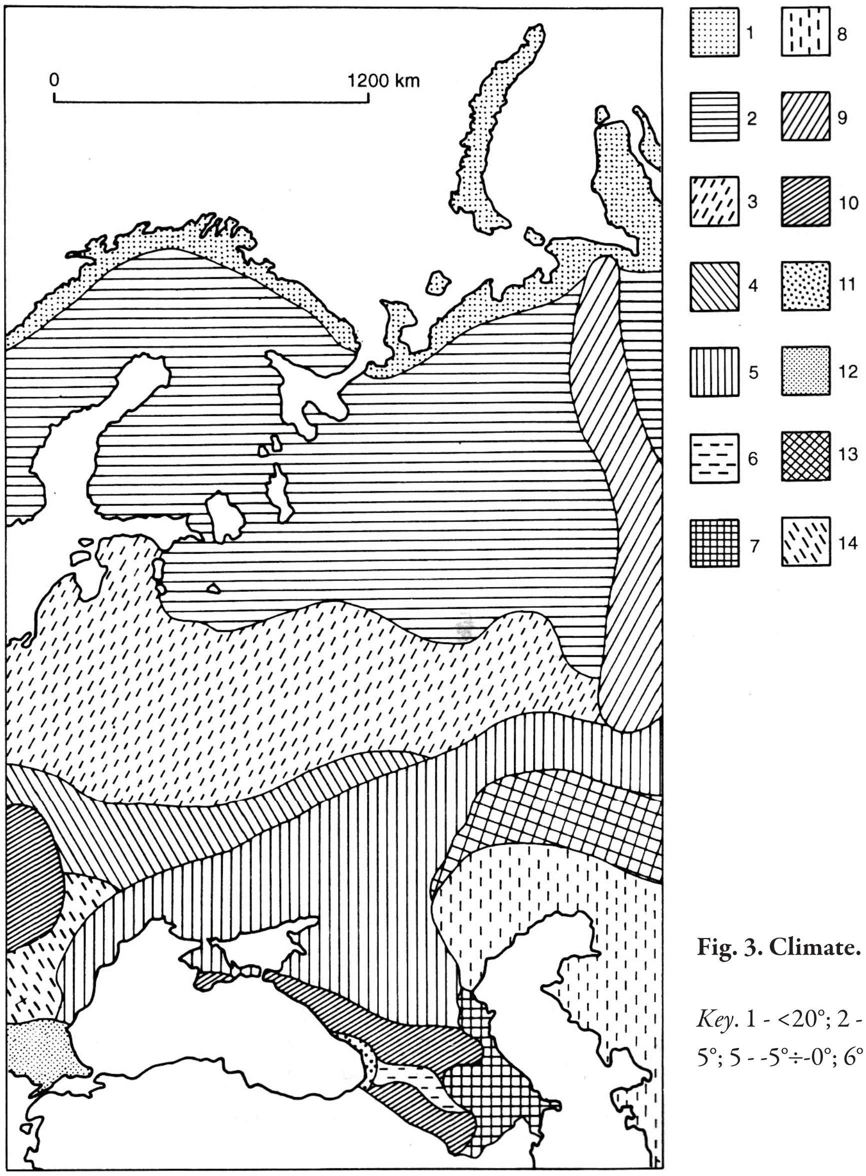

Fig. 3. Climate. Mean January temperature (C°)

Key. 1 - <20°; 2 - -20° ÷-15°; 3 - -15°÷-10°; 4 - -10°÷-5°; 5 - -5°÷-0°; 6° - 0°÷+5°.

the Arctic ocean (the Northern Dvina, Pechora), the Baltic Sea (the Western Dvina, Nieman, the Neva-Ladoga system), and the Black Sea (the Prut, Dniestr, Southern Bug, Dniepr, Don). Both the Baltic and Black Seas are the gulfs of the Atlantic Ocean transgressing deep inland. The Volga, the longest river in Europe (3,530 km), flows into the land-locked Caspian Sea, which has no outlet to the ocean.

Rivers in the morainic area are of a relatively recent age (although their valleys in most cases were inherited from much older epochs) with a few terraces. In contrast, the rivers in the extra-glacial area boast a much longer history. Their valleys are often well developed and contain numerous terraces (particularly notable along the high right bank). Many rivers flowing in a southerly direction (such as, the Dniepr and its tributaries; the Don and the Volga) have huge terraces (up to 20-30 km wide). The rivers of the Russian Plain are generally snow-fed; melting snow in the spring often causes high water and even floods. During warmer seasons in the Ice Age these rivers often turned into chains of lakes.

Climate

The climate of the Russian Plain is, and always was, predominantly continental; it results from its geographical position, at a great distance from the Northern Atlantic, where humid air-masses are formed. The main features of the climate are a large annual range of air temperature with hot summers and cold winters, considerable diurnal variations, and insufficient rainfall (the maximum usually falls in summer). Another peculiarity of the climate consists in its the latitudinal zonality. It follows from the geographical position of the Russian Plain - a huge land-mass stretching from 75°N in the north to 45°N in the south.

During the winter the atmospheric circulation over the

Russian Plain is severely affected by a high-pressure system which develops over northern Asia (Siberian anticyclone) and pushes the masses of cold air over the entire Russian Plain. During the coldest months (January-February) the temperature there may drop below 20-25° C (Fig. 3). Precipitation markedly increases with the intrusions of the westerlies (particularly common in the north-western areas), and these winds bring thaws with wet snow and mists.

Although precipitation in winter is usually relatively light, a stable snow cover persists in the greater part of the Russian Plain from December until March (longer in the north and east). The depth of snow reaches 20-30 cm in the Baltic countries, 50 cm near Moscow and over 70 cm in north-eastern Russia. The depth of frozen soil may reach 50-100 cm. Some areas of the north are affected by 'permafrost'; the upper layers of the ground are permanently frozen. During the coldest stage of the Last Ice Age, 22,000-15,000 years ago, the petmafrost affected the entire Russian Plain. Traces of permanently frozen ground were found near the city of Rostov, in the low stretches of the River Don. An area of low pressure envelops the greater part of the Russian Plain in summer. At that time, the Atlantic cyclonic circulations often bring rainy weather, the total amount of rainfall reaching 500 mm in the western areas but rapidly diminishing to the east and, particularly, the southeast. Mean July temperatures in western and central Russia vary between 15 and 20=C. The temperature is considerably higher in the southeast. The highest temperature in southern Ukraine may reach 37-38° C. These high temperatures, combined with shortage of moisture, often cause severe droughts in that area.

Vegetation and soils

Contemporary vegetation of the Russian Plain generally follows its climatic zonality (Fig. 4). *Tundra,* or arctic waste, occupies the northernmost part of the Arctic Ocean and its islands. The vegetation there consists of cold-resistant plants, predominantly, mosses and lichens. It includes perennial herbs (grasses, sedges, and rushes), as well a as shrub-like trees, such as dwarfbirch *(Betula nana*).

The greater part of the Russian Plain is taken up by forests. The northern part is the *Taiga* or boreal coniferous forest. Its dominant needle-leaf species are fir, pine, spruce and larch. The taiga also includes several deciduous species, such as light-loving birch and aspen.

Mixed coniferous-broad-leaved deciduous forests dominate in the area which lies to the south and southwest of the taiga. As the special geobotanical studies in north-western Russia have shown, these forests are of a complex character. Until the later Middle Ages, oak forests grew predominantly on the clay .soils of morainic hills and on the upper terraces .of the rivers. Mixed forests consisting of oak, hornbeam, ash and alder were restricted to the river floors. Spruce forests occupied wet areas in the depressions of the morainic relief. Pine forests to this day dominate poor sandy soils on the fluvio-glacial plains. This type of vegetation, which is sufficiently rich in biomass, was particularly common during the warmer episodes of recent geological history. It was able to support large groups of prehistoric hunters and fishers. At a later stage, these forests these forests were cleared by advancing groups of farmers.

Further to the south, the mixed forests gradually transform into *deciduous forests,* by their composition essentially similar to forests of Central and Western Europe. They consist of elm, oak and lime, with beech and hornbeam, the latter being more common in the south-western areas.

The forests gradually rarify in the southern direction, giving way to the *forest-steppe,* which form narrow belt stretching across central Ukraine and south-eastern Russia, where open treeless steppe areas alternate with deciduous woodlands.

Still further south, the forest-steppe gradually passes into the *steppe.* Its natural (not modified by human activities) vegetation consists of drought-resistant perennial and annual herbaceous plants. These are various species of grass and their composition changes from place to place. The steppes are richest in the north where they include meadows, in which grasses are mixed with legumes, daisies and irises. In the southern dryer areas, the vegetation is dominated by narrow-leaved feather grasses. Halophytes, or salt-resistant plants, are abundant in to some areas along the coast of the Black Sea.

The soil mantle in the greater part of the forested area of the Russian Plain consists of various types of *podzolic* soil (Fig. 5). They were formed under the specific conditions when the loss of moisture through evaporation is much less than the input from precipitation. The downward movement of moisture transfers the surface mineral material to the lower layers and results in the ashy-coloured bleached upper layer (hence the name *zola* meaning 'ashes' in Russian). The agricultural productivity of such soils is generally low. In normal conditions, the introduction of organic and mineral fertilizers and intensive liming are essential. In the Russian northwest the most fertile soils have developed on the carbonate till; they belong to the 'sod-carbonate variety'. Yet, in all cases, the successful cultivation of these soils necessitated the use of sufficiently sophisticated iron tilling implements together with a farming system that included animal husbandry.

The soils in the steppes and forest-steppes include the *chernozem* (or 'black earth') which are the richest in Europe. The layer of dark-grey or black (hence the name) organic matter is the product of the decay of plant roots due to the intense activity of bacteria. This soil develops from the parent material of loess which is a reservoir of nutrients. The natural fertility of the chernozem is often reduced by droughts which are common there. Thus, notwithstanding the natural fertility of the soils, the southern Russian steppe and forest-steppe were always high-risk areas in the agricultural sense.

The poorest soils in the steppe are the *solonchaks* and *solonels* (from the Russian *'sol'* for salt). These soils usually develop in the depressions deprived of continuous drainage. Ground-water rich in salt rise by capillarity to the surface and form the crusts of salt. The agricultural value of these soils is minimal.

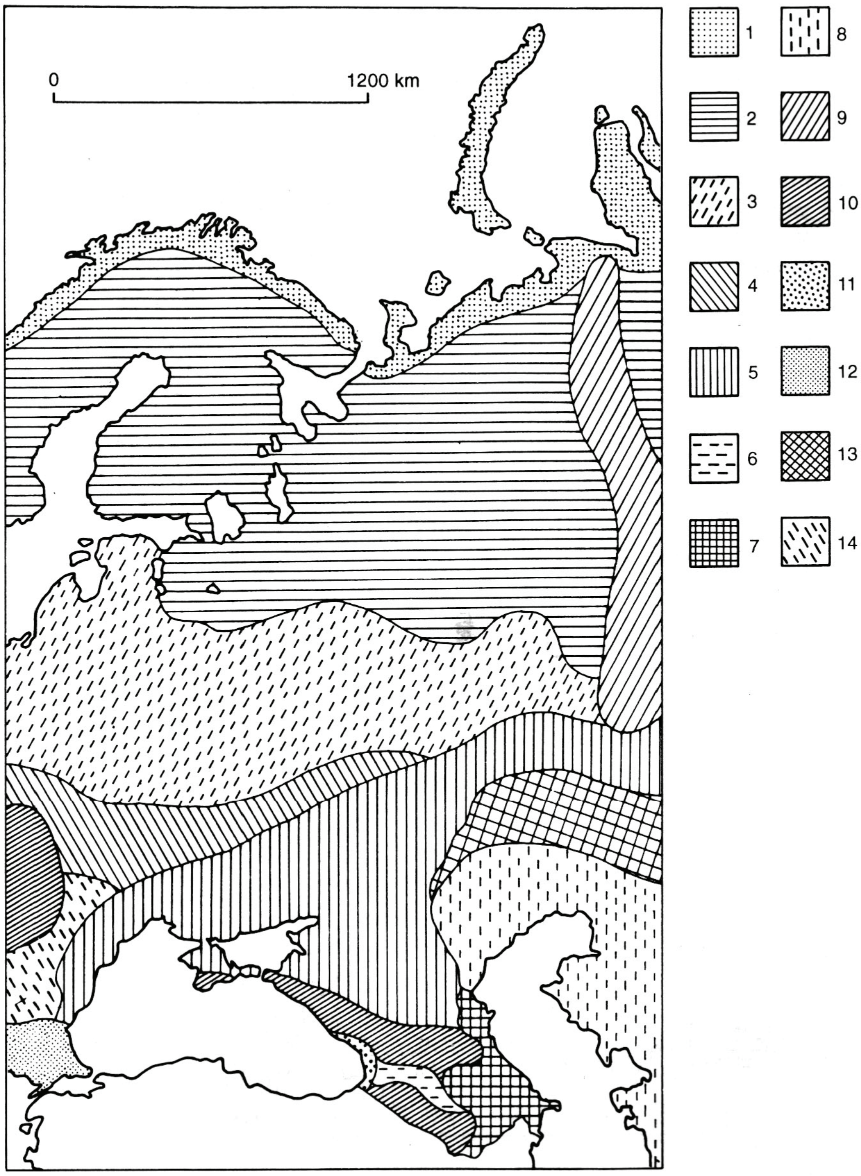

Fig. 4. Vegetation.

Key. 1 – Tundra; 2 – Tundra-Forest; 3 – Mixed Deciduous Forest; 4 – Forest-Steppe; 5 – Steppe; 6 – Mountain Steppe; 7 – Mountain Semi-Desert; 8 – Desert; 9 – Mountain Taiga Forest; 11 – Sub-Tropical Forest and Grassland; 12- Mediterranean Grassland; 13 – Semi-Desert; 14- Mountain Deciduous Forest.

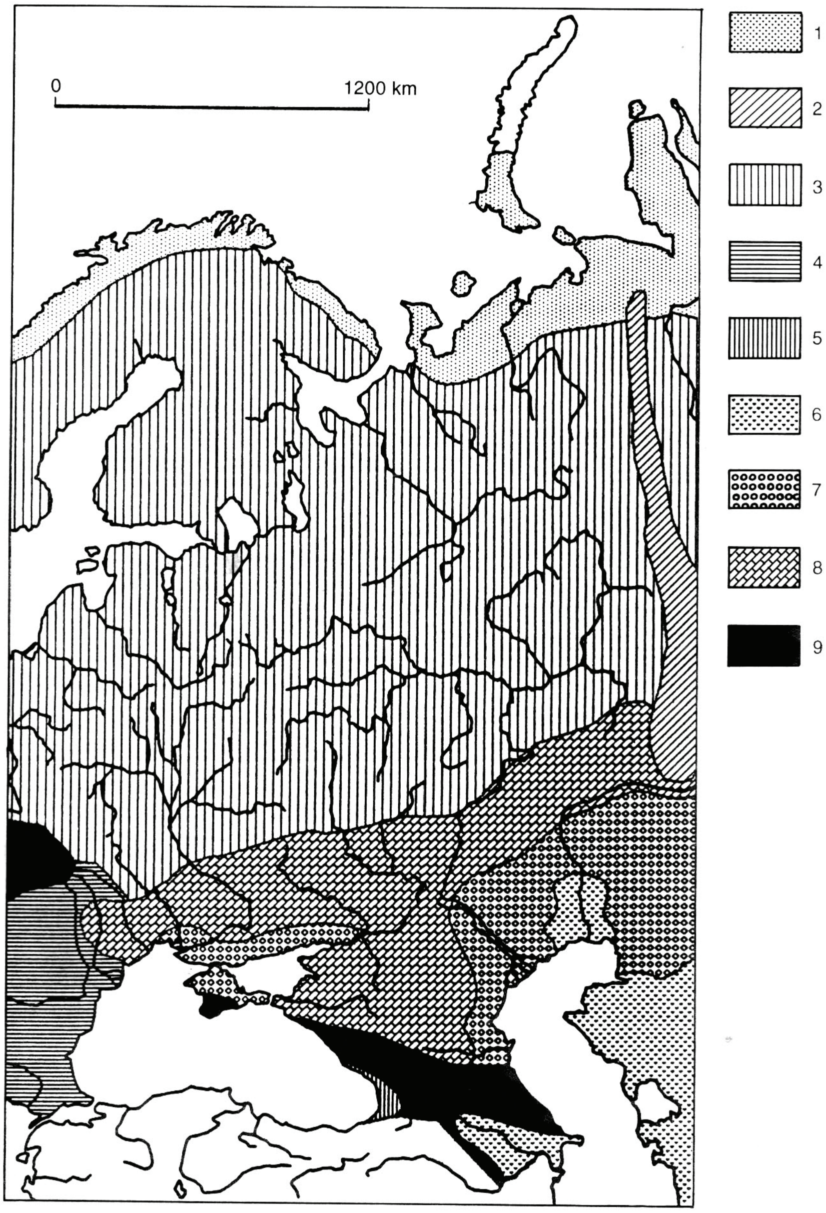

Fig. 5. Soils.

Key. 1 – Tundra soil; 2 – Mountain tundra soil; 3 – Podzolic soil; 4 – Brown soil; 5 – Red soil; 6 – Solonchak; 7 – Chestnut soil; 8 - Chernozem; 9 – Mountain soil.

Initial Human Settlement of East European Plain

A.A. Velichko,[1] P.M. Dolukhanov,[2] Yu.N. Gribchenko[1] and E.I. Kurenkova[1]

[1] *Institute of Geography, Russian Academy of Sciences, Moscow, Russia*
[2] *School of Historical Studies, Newcastle University, UK*

Newly available evidence suggest an early penetration of hominids (presumably, *Homo erectus*) into the southern confines of East European Plain. Oldowan-type pebble tools have been identified in the context of Tamanian faunal assemblage (0.8 – 1 m yrs) at the site of Bogatyri/Sinyaya Balka on the Taman Peninsula, northern Caucasus (Shchelinskii and Kulakov 2008). Still older age (1.8 – 1.2 m y) has been suggested for Oldowan-type assemblages at several sites (Ainikab I and II, Mukhkai I) in central Daghestan (Amirkhanov 2007).

The sites featuring the Acheulean-type technology were also found predominantly in the southern mountainous fringe of East European Plain. Yet already at that time one notes northbound movements directed mainly to the lower stretches of the Don and Seversky Donets Rivers (as evidenced by Khryashchi and Mikhailovskoye sites).

During the Marine Isotope Stage (MIS) 5d-a, the southern part of the East European Plain and its mountainous fringes, notably the Crimea and the Caucasus, sustained considerable populations of Neanderthal humans. These are witnessed by the sites with Mousterian-type inventories in some cases (as in the Crimea and the Caucasus) associated with Neanderthals skeletal remains. Chabai (2007) distinguishes three main periods of Mousterian occupations in the Crimean mountains: c. 125-60, 60 – 38 and 38-<28-27 kyr BP. A much later occurrence of Mousterian sites is acknowledgeable in the Caspian Sea basin, where they could have survived until LGM and even later.

The early manifestations of anatomivally modern humans (AMH) in Europe are acknowledged by the appearance of sites with upper Palaeolithic (UP) technologies. The fully developed UP industries classified as Aurignacian appear in the eastern Carpathian area at about 32.7 ka (Noiret 2004). A similar age (30-28 ka BP) has been obtained in the (Chabai 2009) and northern Caucasus (Golovanova et al. 1999).

An even earlier Upper Palaeolithic occupation is signalled for the central areas of East European Plain as exemplified by Kostenki sites on the River Don (Fig. 1, *1*; Fig. 2). The earliest UP layers have been reached in the lowermost strata of Kostenki 12 site, radiocarbon dated to 40 – 42 and with OSL dates between 52 and 45 ka (Anikovich et al. 2007). Still more important evidence comes from the Kostenki 14 site, which level IVa produced a consistent series of radiocarbon measurements ranging from 36.5 to 32.6 ka BP (Sinitsyn 2003; Haesaerts et al. 2004). This level yielded a rich industry which includes a typical UP tool-kit combined with archaic bifacial, mainly oval convex-flat implements. The level includes symbolic manifestations, a head of a female figurine made of mammoth tusk, a perforated pendant made of a Mediterranean mollusc and a tooth attributable to a modern human.

The sites of a comparable age have been identified in the extreme north-east of East European Plain, close to the Polar Circle (Fig. 1,*2*). A series of radiocarbon dates obtained for bones and mammoth tusks from the Byzovaya site, yielded the age in the range of of 25.5-30.0 ka, with one sample showing the age of 33±2 ka (Mangerud et al. 2002). At the site of Mamontovaya Kur'ya still further to the north, bones of large mammals and a few artefacts were found in river-channel deposits. Radiocarbon dated bones yielded the age of 37-35 ka (Mangerud et al. 2002; Pavlov et al. 2001). A group of early UP sites has been found on the Chusovaya River in the western foothills of the Ural Mountains. One of the sites, Zaozer'ye yielded a series of radiocarbon dates in the range of 31.5-30.7 ka (Pavlov 2004; Gribchenko 2006).

In this case the links between human migrations and the climate change became apparent. The northbound movement coincided with the latest stage of the Mid-Valdai mild interval (the 'Leningrad Megainterstadial', or Bryansk Interval). One should add that the Ural foothills at that time formed an expedient corridor for migrations directed to the north that was not affected by the ice-sheets from either (western or eastern) direction. One might further suggest that large-scale migrations were preceded by groups of 'rangers', who estimated the perspectives of new terrains for permanent settlement.

Once having penetrated the northern East European flatlands during the Megainterstadial, the humans never abandoned them, while conducting long-range migrations within their limits. The domineering 'cryo-xerotic' conditions never constituted a serious obstacle for human existence in this severe, albeit not hostile environment, as the adaptive potentialities of early humans at this stage were sufficiently high. The most serious impediment that had marked the previous stage, namely, the forested landscapes, were no longer in place.

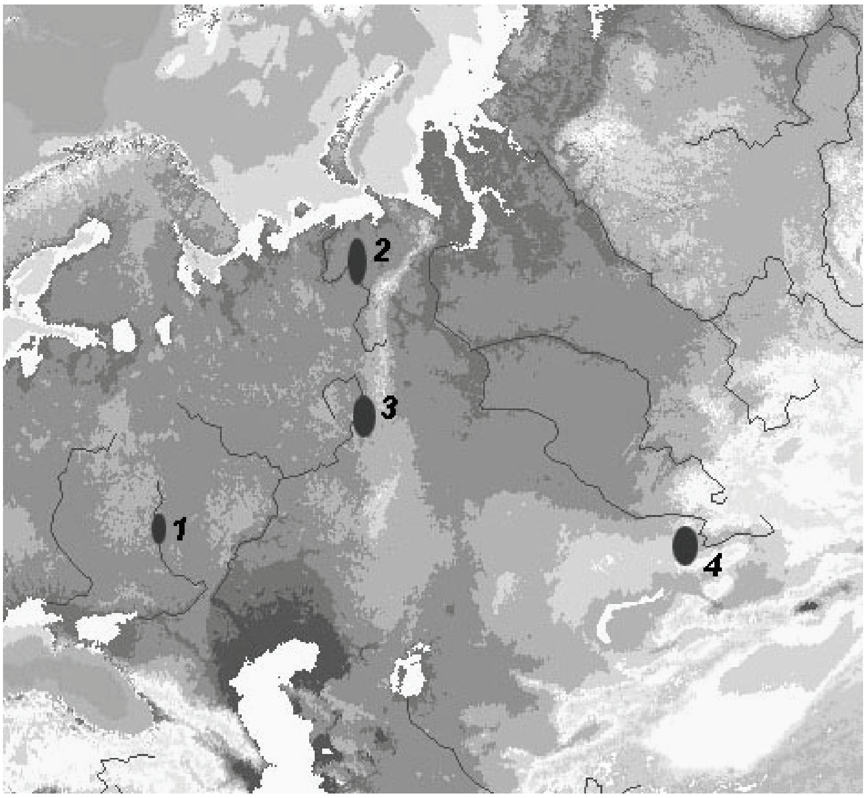

Figure 1. Early Upper Palaeolithic sites in Russia.
Key: - 1 - Kostenki; 2 – Byzovaya-Mamontovaya Kurya; 3 – Chusovaya River sites; 4 – Altai Mountains sites.

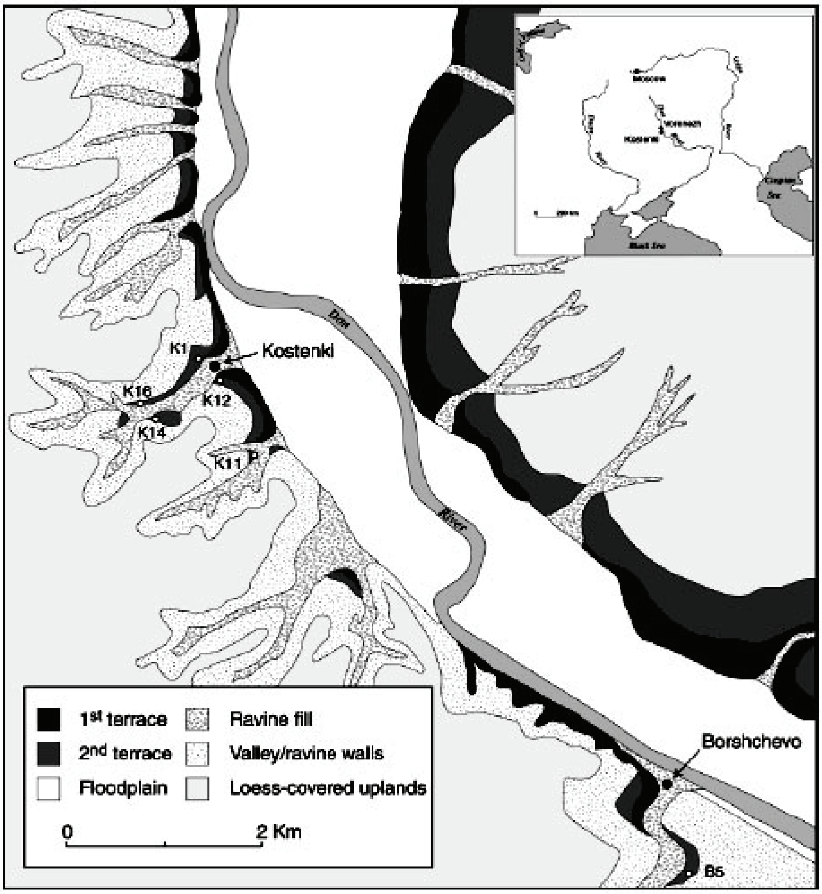

Figure 2. Kostenki sites (after Anikovich et al. 2007)

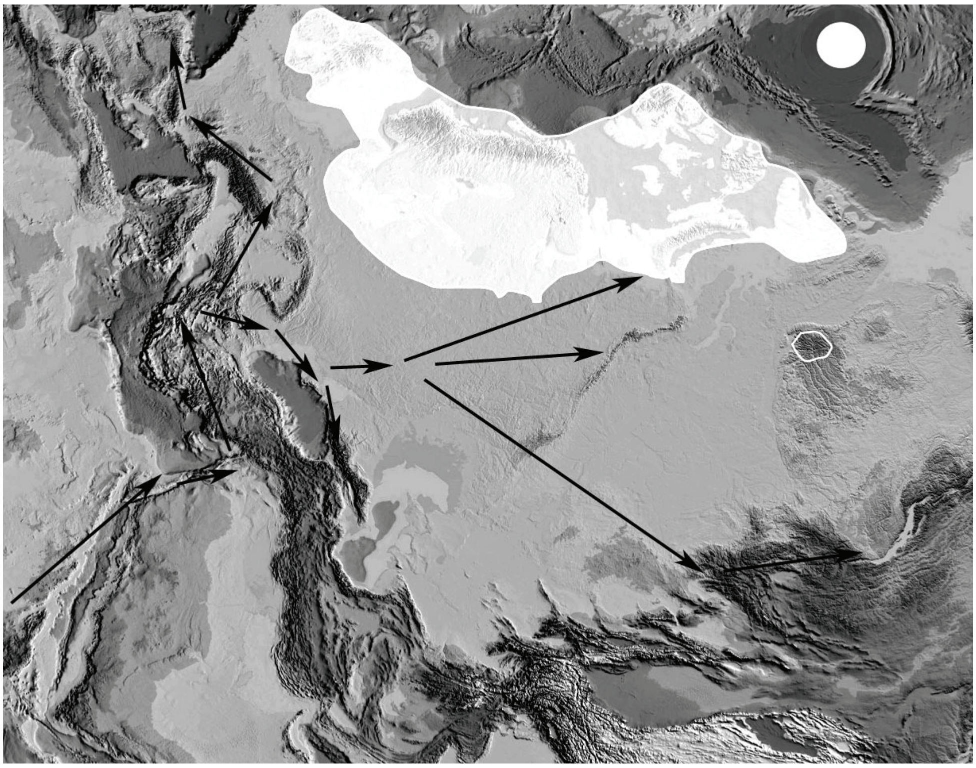

Fig. 3. Trajectories of early AMH dispersal.

Based on the faunal evidence, one may acknowledge the regional specialisation of hunting

Mammoth bones were most common in the central areas of East European Plain (Khotylevo 2, Yurovichi), the abundance of horses in noted the eastern areas (Garchi I, Zaozer'e, Sungir'), while the bison was the [predominant hunting prey in the River Dniestr basin (Molodova V, Korman' IV).

Eastern European Plain remained populated even during the Last Glacial Maximum (LGM), 20 – 18 k a BP that featured a rigorous continental climate and a specific zonal structure having no direct analogies in present-day landscapes. The high frequencies of radiocarbon-dated sites show a clear increase in population densities in the periglacial areas of East European Plain in the interval of 24 – 18 k a BP (Dolukhanov et al. 2001). At that time the population densities in Central and Western Europe markedly decreased with some areas being virtually depopulated (Houseley et al. 1997). At this stage the forest belt receded throughout the entire area of moderate latitudes, with hyperzonal open-type landscapes gaining a dominant position. On Eastern European Plain, the tundra-steppe landscapes were spread in the areas 200-300 km south of the ice-sheet edge. They gave way to the cold-resistant steppe with small patches of forests in low-laying areas and along river valleys further south. The greater part of East European Plain was affected by continuous perennial permafrost (Velichko, 1973, 1991). Average summer temperature was by 4-5^{o}C below the present values. The winters were extremely harsh, with temperature falling to –30^{o} - 40^{o}C (Velichko et al.., 2002). Yet these predominantly open and severe landscapes, abundantly rich in high-energy biomass, were attractive for Palaeolithic hunters (Velichko & Zelikson, 2006). Large herbivores that constituted the base of human subsistence at this stage were plentiful in the local landscapes; this was the main reason why the humans remained in those areas even during the LGM. Yet a limited-scale shift to the south is acknowledgeable at 20 – 19 k a BP, as at that time one notes the efflorescence of UP settlement on the Lower Don, the Azov Sea and North Pontic areas (Stanko et al. 1989). This was rather a migration-type adaptation. Although no changes are acknowledgeable in the main categories of hunting prey at this period as compared the previous stage, its spatial distribution is slightly different. Remarkably, the sites corresponding to the LGM include huge amounts of polar fox bones (Yeliseyevichi, Avdeyevo, Kostenki) (Soffer, 1985). The proportions of mammoth noticeably diminished at the sites of the south-western area, while their rate markedly increased in the Upper Dnepr basin (Avdeyevo, Berduzh, Pushkari and others). At the same time, one notes an increase in the rate of reindeer bones at the sites on the Dniestr River (Molodova V, layers 4 and 6), as well as those of the North-East of European Russia (such as Talitsky site in the Kama River basin), where the horse bones prevail (Pavlov 2004). The subsistence of UP sites in the south of East European Plain, beyond the area of continuous permafrost such as

Muralovka, Amvrosievka and Zolotovka) was nearly entirely based on the bison hunting (Stanko 2007). Seen as a whole, one might argue that there is no evidence of long-time human settlements on East European Plain during the greater part of Palaeolithic epoch. Archaeological deposits are rather suggestive of human dependence on landscape-climatic environments and on the availability of hunted animal species.

The spectrum of adaptive strategies of UP humans markedly diversified at the final stages of Upper Palaeolithic, by the end of Late Pleistocene. At that time, the impact of human activities on the natural surfaces becomes conspicuous not only within large permanent settlements, but also in the surrounding areas. The construction of large bone-and-turf structures, causing the distortion of soil and vegetation cover, and active creeps not only within the settlements but also in their vicinity. These changes in the character of adaptation became possible after the enhancement of the intermediate component in the system which included the human populations – socio-economic structure – natural environment. This took the form advanced social organisation and new technologies.

Judging from the frequencies of radiocarbon-dated sites, the population density ion Eastern Europe significantly increased during the time-span 16-14 k a BP (Dolukhanov et al. 2001). Numerous sites arose at that in the Middle Dnepr area, many of these sites included remains of large structures predominantly made of mammoth bones (Mezherich, Dobranichevka, Mezin, Yudinovo, Yeliseyevichi and others). Similar structures are also known at the sites in the Middle Don area, which remained densely populated

Hence, basing on the available evidence on the UP of Eastern Europe one may identify two principle types of adaptation in the system which includes the human populations – socio-economic structure – natural environment. The former type (the 'migratory') was the main mechanism of the initial human dispersal, as in the conditions of insufficiently developed socio-economic structures, the migration into more suitable habitats was the most effective strategy of adaptation to changing environments. The same strategy was acknowledgeable also at later stages, where dynamic Late Palaeolithic groups swiftly reacting to landscape and climate change, moved to other areas in quest of more comfortable livelihood.

The latter type ('the autochthonous') implies the advancement and the improvement in the mode of life in the concrete given areas. In that case, human groups remained at the same place over millennia, only occasionally abandoning it, but always to return back (as exemplified by the sites in the Middle Dnepr and Middle Don areas). Hence the remarkable shift in the adaptive strategy. Taking into account the Late Pleistocene environmental dynamics, the human adaptation in this case took manifested itself predominantly in the improvement of hunting weaponry, the development of dwellings, storage facilities etc. This type is particularly conspicuous in the second half of the later UP, when human groups remaining stable, opted for local adjustments to rapidly modifying landscapes and climate.

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The Mesolithic of East European Plain

P. Dolukhanov

School of Historical Studies, Newcastle University, UK

Introduction

Mesolithic sites in Russia were first identified in the late 19th century (Merezhkovskii 1880*)*, yet the term 'Mesolithic' only came into general use much later (Rudinskii 1929). In accordance with the typological-stylistic concept, the Mesolithic had been initially viewed as an archaeological period featuring the wide use of projectile points and especially geometric microliths. Essentially similar definitions of the Mesolithic may be found in more recent post-Soviet publications (Kol'tsov 1989a, Stanko 1997). Soviet scholars of the 1930s and early 1940s attached paramount importance to the 'invention and introduction of bows and arrows, which, in accordance with the concepts of Lewis Morgan and Friedrich Engels, constituted the basic feature of a 'later stage of savagery'. The end of the Mesolithic period was marked by the introduction of pottery. S.N. Bibikov (1950) developed a different approach, which viewed the Mesolithic as a period of crisis of Palaeolithic-style hunting subsistence triggering a diversification of food-gathering strategies with an eventual emergence of early forms of stock-breeding and agriculture.

The cultural-typological approach remains to this day the leading paradigm in Russian and Ukrainian Mesolithic studies. Discussing the typological criteria of the Mesolithic, Stanko (1982: 95–6) mentioned as its principle attributes the improvement of prismatic core reduction technique, the general microlithisation of the inventory and the emergence of composite tools. Mesolithic society is viewed as a mosaic of 'archaeological cultures' defined as 'a set of synchronous sites sharing common attributes and clearly distinct from all others'. Telegin (1985: 87) argues that these attributes include typological features such as specific types of cores, types of blanks (flake/blade ratio), and specific frequencies and types of 'secondary trimmed tools': endscrapers, burins, arrowheads, retouched blades, and, especially, microliths. In consequence, the analysis of the Mesolithic is all too often restricted to the discussion of interrelations between 'archaeological cultures' and their evolution in time and space. Here, the Mesolithic is viewed as the period of hunter-gatherer economies adapted to the environment and resources of the early and middle Holocene.

The lower boundary of the Mesolithic coincides with the beginning of the Holocene and the Younger Dryas - Preboreal boundary, c.10400-9200 cal BC. Radiocarbon dates of that order have been obtained for several early Mesolithic sites in Russia and the Ukraine. The upper limit of the Mesolithic is usually considered by East European archaeologists as corresponding to the introduction of pottery. In various parts of the East European Plain pottery making started between 6,900 and 5,300 cal BC (see this volume).

As follows from proxy evidence, the emergence of Neolithic on East European Plain proceeded against the background of major environmental changes. The preceding period, that of Late Glacial, featured two major warm episodes, the Bølling (13-12 ka BP) and Allerød (11.8-11 ka BP) interstadials, separated by cold phases: Older Dryas (12-11.8 ka BP) and Younger Dryas (11-10 ka). Existing records for thermal optima in Western Europe (which show a certain chronological inconsistencies) indicate a rapid rise of temperature of about 7°C per century, reaching the maximum value of 16-18 °C in July and temperature increase by c. 20 °C for the coldest month (Lowe & Walker 1997). Recently available data for the long sequence at Dziguta on the eastern Black Sea coast (Arslanov et al. 2007) indicate two warm phases at 12-11.7 and 11.5 – 11 ka, separated by a short-lived cooling. The pollen-based reconstructions for the Allerød show the July temperature being essentially similar to that of today over the greater part of the East European Plain (Velichko et al. 2002). At the Younger Dryas to Preboreal transition, c. 10,500 cal BC, summer temperatures in Europe rose by at least 6°C (Isarin & Bohnke 1999). In northern Russia, as elsewhere in northern Eurasia, summer temperatures between 8,500 and 2,500 cal BC were higher than now by values ranging from 2.5 to 7.0° C (MacDonald *et al*. 2001). The spread of mixed forests with a considerable presence of thermophilous species occurred during the Atlantic period. This period lasted from c. 7,000 until 3,500 Cal BC and comprised several warmer and colder episodes (see in this volume).

Changes in vegetation and climate, in addition to hunting pressures during the Late Glacial period, led to the massive extinctions of large herd animals, such as mammoth (with the possible exception of northern Siberia), woolly rhinoceros, wild horse, and bison. The subsistence of Mesolithic groups which emerged with the beginning of the Holocene coincided with the diversification of landscape structure and the formation of present-day tundra, forest and forest-steppe. No less important was the emergence of wetlands: inshore lagoons and lacustrine basins, rich in diversified aquatic food resources.

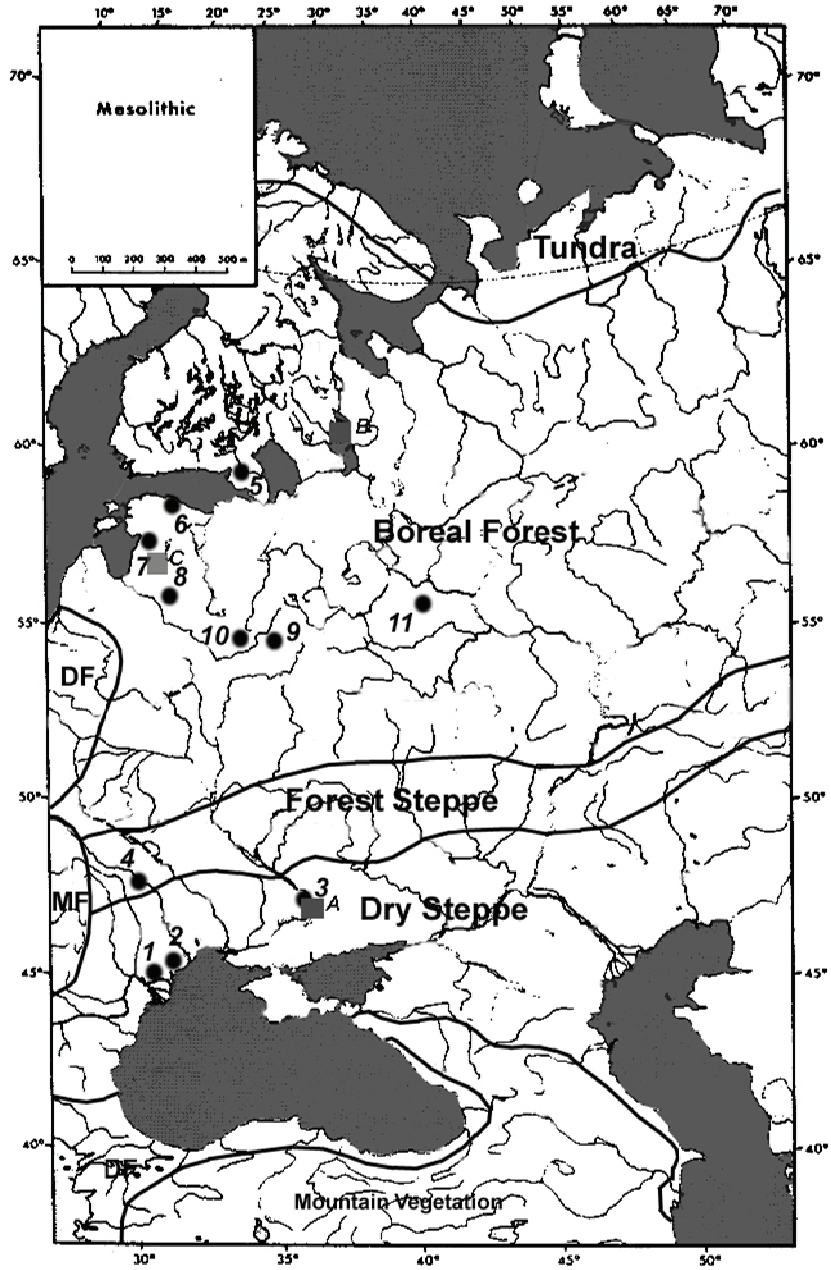

Figure 1. Mesolithic sites on East European Plain.
Key. 1 = Mirnoe; 2 – Beloles'e; 3 – Dniepr Rapid sites; 4 -Molodovo; 5 – Antrea; 6 – Kunda; 7 –Pulli; 8 - Lubana Lake sites; 9 – Upper Western Dvina sites; 10 – Upper Loval sites; 11 – Upper Volga sites.emeteries: A – Dniepr Rapids; C – Reindeer Island; C – Zvejniekj. MF - Mixed forest; DF – Deciduous forest.

Mesolithic sites which arose in a range of Holocene environments (Fig. 1), varied in their subsistence and cultural manifestations. For that reason, the following review is organised according to geographical divisions into four main categories: 1) the Mountainous Fringe (the Crimea and the Carpathians); 2) the Steppe; 3) Mixed Forests; 4) Boreal Forests.

The Mountainous Fringe

Mesolithic sites in the Crimea are identified by their topographic position (predominantly in mountainous valleys), their subsistence (hunting of forest and forest-steppe animals, with an increased role of gathering and fishing), and their lithic inventories. Stanko (1982: 99) stresses that in most cases the stone tools retained their Upper Palaeolithic character, the main distinctions being the refinement of core-reduction technique, resulting in the increased production of regular prismatic blades and bladelets. Retouched tools are dominated by small endscrapers with varying frequencies of geometric microliths.

Mesolithic levels are known in at least 20 caves and rockshelters located in the canyons of small rivers and streams draining the northern range of the Crimean Mountains. The thickness of Mesolithic deposits varies from a few cm to 4–6 m. Based on the stratigraphy of the deposits, Bibikov *et al.* (1994) conclude that at least several sites bear evidence of prolonged habitations.

Animal remains in stratified rock shelters show a gradual transition from the Late Palaeolithic to the Mesolithic. According to Vekilova (1971: 160–5), the early Mesolithic ('Azylian') saw the disappearance of mammoth, reindeer, cave

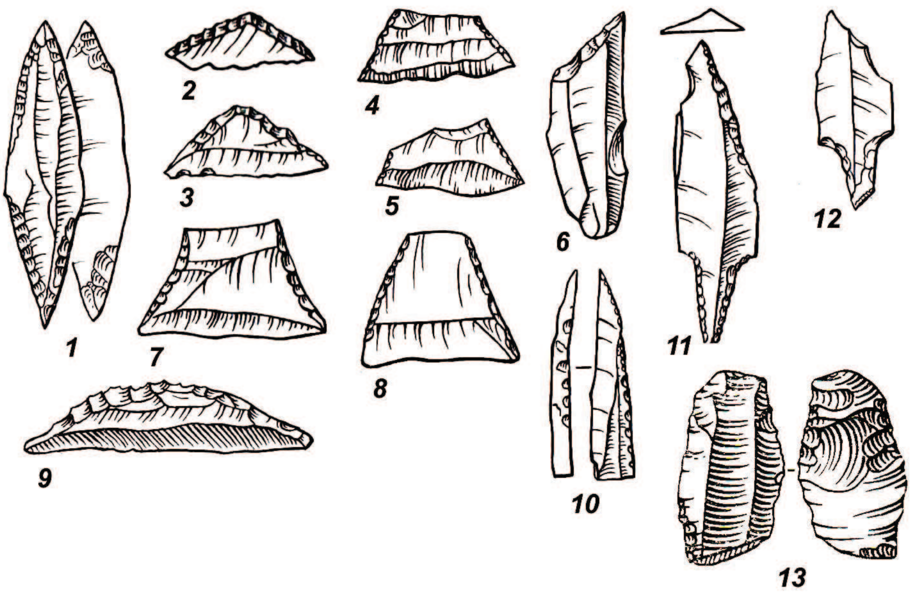

Figure 2. Stone tools in the Ukraine Mesolithic (Telegin 1989).
Key. 1: point (Syuren 2); 2: triangle (Shan-Koba); 3: segment (Vodopadny); 4, 5: trapezes (Oskorivka); 6: asymmetrical point (Syuren 2); 7: trapeze (Sursky); 8: trapeze (Shan-Koba); 9: segment (Zamil Koba); 10: Gravettian point; 11: point (Nobel 1); 12: point (Korost); 13: Kukrek armature (Kukrek).

bear and cave hyena. The Mesolithic hunting prey included grassland species (wild horse, antelope-saiga, aurochs, wild sheep and goats, increasingly supplemented by those adapted to forests (red deer, roe deer, wild boar and brown bear) (Bibikov *et al.* 1994). Mesolithic deposits include numerous bones of large-size fish, both freshwater (salmon, trout and roach), and brackish-water ones (pike-perch and catfish). Several sites (Shan-Koba, layer 3, Fatma-Koba and Kurzak-Koba) include large concentrations of the shells of edible common snails (*Helix aspera)*. This snail forms the shell-midden site of Laspi 7 located on the seashore in Sebastopol Bay. Earlier reports suggested the occurrence of domesticated pig at the Mesolithic site of Tash-Air (Krainov 1960). Tsalkin (1970: 261–6) has convincingly demonstrated that the bones identified as pigs either penetrated from the younger deposits, or belong to wild boar.

Several archaeological cultures are distinguished from differences in typology of lithic tools (Fig. 2, Telegin 1982, 1989). The Shan-Koba Culture, typified by several cave sites and the coastal site of Laspi 7, has industries manufactured on small-size prismatic blades, with a high proportion of backed blades, end-scrapers, burins and geometrics (lunates and trapezes). The Murza-Koba industries are found at Crimean cave-sites above the Shan-Koba levels. They include notched and backed blades and end-scrapers made on truncated blades. Geometrics are rare, but include a diagnostic *fossil directeur*, the Murza-Koba trapeze. Bone and antler tools are not numerous, but include characteristic small-size harpoons. The small rockshelter of Syuren'2 in the middle chain of the Crimean Mountains occupies a special position. The inventory of the lower level includes tanged points with direct analogies in the Polish Swiderian.

Level 3 of Murzak-Koba rock shelter includes a double burial of a male and a female. Partly preserved skeletons were found beneath stone slabs, side-by-side, in an extended posture, facing the east. The age of the female is estimated as 20–25, that of the male as 40–50 (Bibikov et al. 1994: 105–8).

A burial of an adult male, with an estimated age of about 40 years, was also found in the Fatma-Koba rockshelter. This skeleton was found in a contracted posture lying on the right side in a shallow grave.

Telegin in his earlier publication (Telegin 1982: 49) using typological criteria and statigraphic evidence divided the Crimean Mesolithic into two stages: the Shankobian, 9000–7000 Cal BC, and the Murzakobian, 7000–5000 Cal BC. Since that time a large series of radiocarbon dates has become available for Laspi 7 site, placing it in the time-range of 8900–6000 Cal BC.

The Steppe

Numerous Mesolithic sites occur on the Danube-Dniestr interfluve in the western segment of the Pontic Lowland (Fig. 3). They form a hierarchy of settlements linked to topographic position. The largest sites (Mirnoe 1 and Beloles'e are on the shores of estuaries in the coastal area. They are seen as base-camps inhabited on a year-round basis. Based on the size and number of dwelling structures and

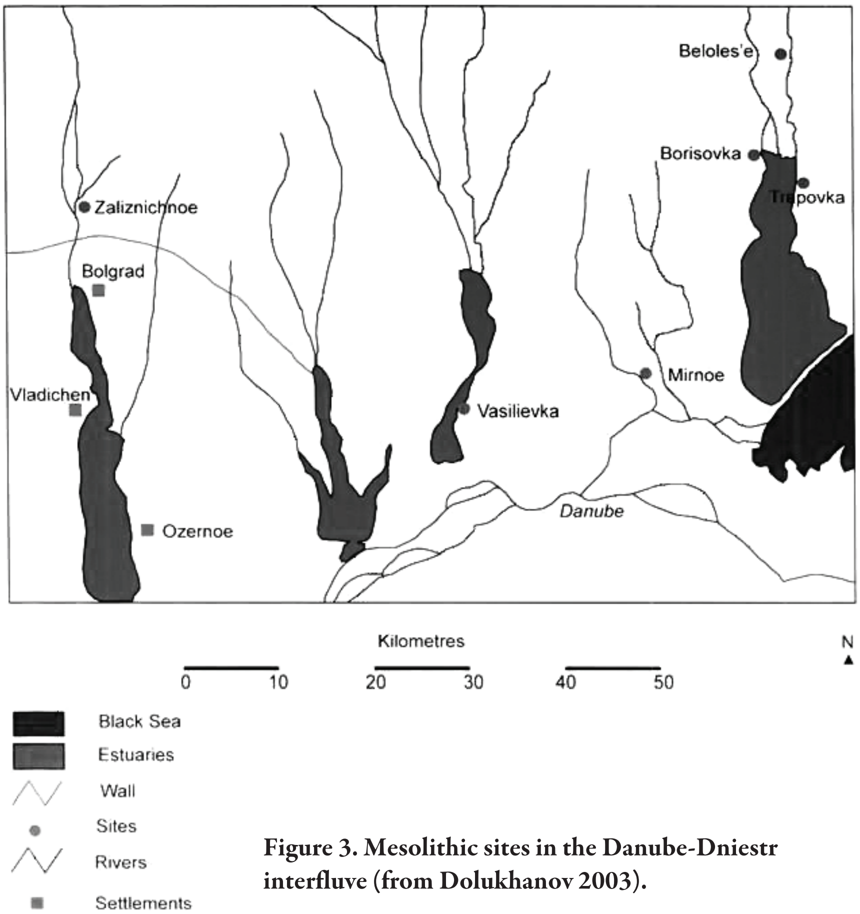

Figure 3. Mesolithic sites in the Danube-Dniestr interfluve (from Dolukhanov 2003).

using ethnographic evidence, Stanko (1982) argues that the Mirnoe community consisted of twenty to twenty-five individuals, representing three or four nuclear families each with four to six individuals. Smaller sites in a similar setting supposedly belong to task groups budding off from the main centre. The location of several sites at higher elevation in the foothills implies seasonal transhumance.

Mesolithic settlements are also located in the terraced valleys of the major rivers (the Dniepr, Dniestr and Severskiy Donets). A dense cluster of sites is found in the middle reaches of the Dnieper at Igren', Oskorivka, Vasylivka, Yamburg and others.

The Mesolithic economies developed in an environment of growing scarcity of hunting resources, bison, the principal Palaeolithic hunting prey, being largely exterminated by that time. Mesolithic groups targeted the less numerous herds of wild horse (or tarpan) and antelope-saiga, or more solitary animals such as aurochs. Fishing and gathering increasingly supplemented the hunting of land mammals. Elevated ^{15}N values in human bones from Mesolithic cemeteries on the Dnieper Rapids show the diet being strongly depended on animal protein with a significant freshwater input (Lillie et al. 2008).

Stable isotope analysis of human bone shows shifts at the transition from the earlier Mesolithic (Vasyliuevka III) to its later stage (Vasylievka II), as signalled in the concentration of barium and strontium and increased ^{13}C values indicating a greater consumption of plant food (Jacobs 1994; Lillie 1996).Significantly Korobkova (1993) identified at Mirnoe prismatic blades with microscopic traces of linear use-wear, which she and Stanko (1982) view as evidence of 'reaping knives' used for harvesting edible plants. Pashkevich (1982: 136) has found the grains of several potentially edible plants in the deposits of Mirnoe: white goosefoot *(Chenopodium album)*, black bindweed *(Polygonum convoluvulus)*, vetch *(Vicia hirsuta)* and sorel *(Rumex acetosa)*.

Based on stylistic and technological criteria, two 'archaeological cultures' were identified in the steppe area. The Kukrekian is typified by the 'Kukrekian armature', a truncated, notched and ventrally retouched blade (Fig. 2*:* 13), and was first recognised at the open-air site of Kukrek in the Crimean steppe. Later, implements of this type were identified at other sites in the Crimea, on the Dniepr River (Igren 8) and in various areas of the Pontic Lowland. The Grebenikian, as exemplified by Mirnoe, Girzhevo and other sites, is yet another culture grouping, predominantly in the Odessa District. The inventory includes endscrapers and microliths consisting exclusively of trapezes.

Large communal cemeteries, unknown in earlier periods, reflect new social developments in the Ukrainian Mesolithic. A group of impressive cemeteries, Vasylivka, Volos'ke and others, lies near the Dniepr Rapids, south of Dnipropetrovsk (Stolyar 1959; Telegin 1982). Individuals within the same cemeteries are associated with distinct burial rites, suggesting cultural homogeneity: most were buried in a contracted position, and some in an extended supine position. Still more importantly, the skeletons belong to at least three distinct physical types (Gokhman 1966, 1986; Potekhina 1999). A first group of individuals with broad and high-relief faces is viewed by Gokhman (1966: 187) as belonging to the autochthonous 'Cro-Magnon' population stemming from the Upper Palaeolithic of Central and Eastern Europe. A second group was found only at Volos'ke cemetery and includes individuals with very narrow and long faces typical of the 'Mediterranean race'. The third type, found at Vasylievka 1 and among the dead buried in extended supine postures at Vasylievka 3, features narrow faces and protruding jaws. At Volos'ke, and at Vasylievka 1 and 3, there are numerous cases of ribs and verteberae penetrated by flint arrowheads, indicating death by violence.

Stanko (1982) and Telegin (1982, 1989), using typological criteria, distinguish in the Ukrainian steppe Mesolithic an early stage as exemplified by Beloles'e with an essentially Late Palaeolithic technology, regular prismatic blades and a limited number of geometrics. The later stage includes Grebenikian (Mirnoe, Girzhevo and others) and also Kukrekian sites.

Radiocarbon dates including AMS measurements, obtained for human bones from Vasilyevka 3 cemetery and apparently not affected by radiocarbon reservoir effect, suggest the aged of Epi-Palaeolithic – Mesolithic transition as 10,230-9,050 cal. BC (Lillie et al. 2008). On the other hand, the age of Mesolithic-Neolithic transition suggested based on the Vasilyevka V cemetery as about 5500 cal BC (Lillie 1998), is now deemed as unreliable (Lillie et al. 2008). Radiocarbon dates for Igren 8 lie in a wide range between 6200 and 5600 cal BC.

Mixed Forests

Dense concentrations of Mesolithic sites are found in the Polissya Lowland of northern Ukraine and southern Byelorussia. The sites usually lie on the lower terraces of rivers and lakes belonging to the Upper Dniepr catchment, often on sand dunes. These sites are usually small and recognisable only by accumulations of lithics. The largest site, Nobel, in the upper part of the Pripet River basin, a tributary of the Dniepr, covers 500 m^2 and includes traces of a rectangular dwelling with hearths in each corner (Matskevoi 1991). The sites in the Volyn-Podilsk Upland in the Northwest of the Ukraine are similar to those in Polissya: accumulations of lithics on the lower terraces of rivers and lakes. Only one site, Vorotsev 2, is of any size or complexity, with seven structural complexes, each comprising two to four oval-shaped dwellings 5–10 m^2, a flint 'workshop', hearths, and several smaller hollows supposedly used as storage-pits (Matskevoi 1991: 99). Zaliznyak (1991) distinguishes two types of dwelling sites, winter ones, larger in size and located at higher elevations, and summer habitations of much smaller size, close to rivers and lakes.

Rare animal bones belong exclusively to reindeer. Zaliznyak (1991: 138) suggests a wider spectrum of subsistence including the hunting of land mammals (elk, aurochs, red deer, roe deer and boar), fishing and gathering of edible plants. At a later stage, as typified by Janislawician sites, the hunting prey consisted of aurochs, boar, wild cat and beaver (Kol'tsov 1989).

The lithic tools (Fig. 4: 1–8) were manufactured on small-size flint blades, and include two main categories: projectile points and geometrics. The earlier sites with tanged points (Nobel, Perevoloka, Senchitsy and others) are viewed as the local variant of the Polish Swiderian (Matskevoi 1991). Available dates for Swiderian sites in Poland place them into the Younger Dryas, c. 11,000-10,500 Cal BC (Schild 1998). The later stage, supposedly of Preboreal and Boreal age (10,500–7,000 Cal BC) and referred to as Kudlevian (Zaliznyak 1991), is marked by a high proportion of backed knives. Its climax is in the Early Atlantic, when rare trapezes appear. This line of development was interrupted in the later Atlantic by an intrusion of the Janislawician. This cultural unit first identified in Poland (S. Kozłowski 1965) and includes in its inventories so-called Janislawicy-type points and triangles combined with commonly occurring trapezes.

In Byelorussia and in neighbouring Lithuania the sites attributable to the Janislawician are found mostly in the Nieman catchment and on the Sozh River (the tributary of the Upper Dnieper), where the important site of Grensk was located. In contrast to the western sites, the eastern ones feature the occurrence of 'heavy-duty' axe-like tools and the absence of trapezes (Koltsov 1989). Simultaneously, a distinct Pisochnyi-Riv Culture developed in the Northeast, with tanged points of Ahrensburg and Lyngby type combined with asymmetrical trapezes. Several sites (Teterev and others) include the 'Kukrekian armature'. Zaliznyak (1991: 42–3*)* views this as an indication of yet another migration coming from the Black Sea via the Dniepr basin.

Mesolithic sites are found in the catchment of the Upper Volga, and the Oka, its largest tributary. One may distinguish, first, sites located on upper and middle river terraces, often on the dunes, and, secondly, wetlands sites, often embedded in peat deposits. In the former case, three oval-shaped dwellings were found at the site of Sobolevo 5. These dwellings are c. 5 m by 3 m in plan, with one or two hearths inside and potholes along the periphery. At the wetland site of

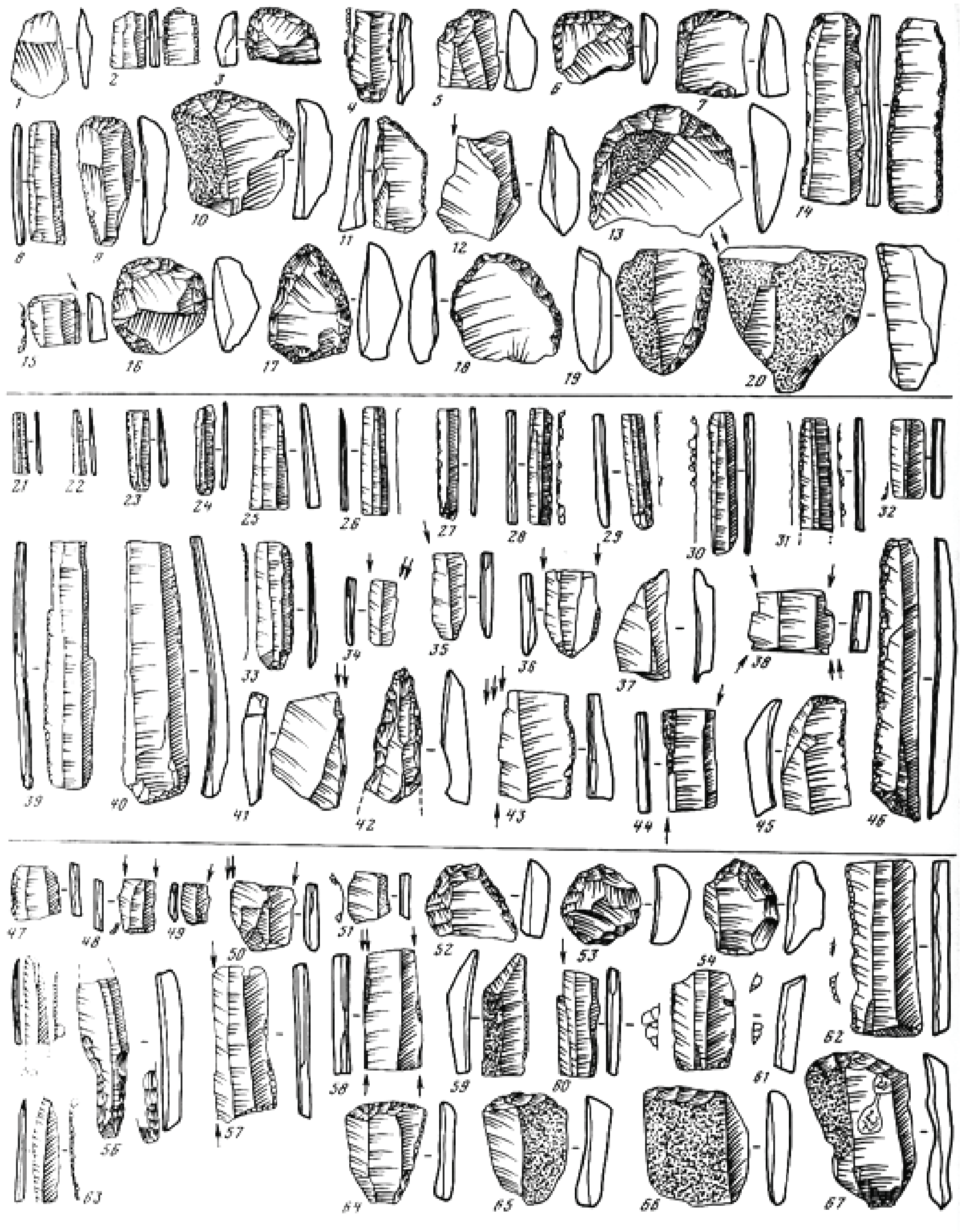

Figure 4. Butovian stone tools (Central Russia).
Key. 1-20 Berendeyevo; 21-46 Ugol'novo; 47-67 Novoishino (after Koltsov 1989);

Berendeyevo 3, in the Yaroslavl District, a large platform consisting of several layers of birch bark and wooden logs has been found. In several cases (Ugol'novo 1 and Petrushino) storage pits were located in the immediate vicinity of the dwellings (Kol'tsov 1989b).

Animal remains are better preserved at wetland sites and are predominantly of elk and beaver. Red deer, brown bear, hare and wolf are present in lesser quantities. The bones of fish and waterfowl are numerous (Krainov & Khotinsky 1984).

Kol'tsov (1984, 1989b) has identified two Mesolithic archaeological cultures in the area: Butovian and Ienevian. The former *(*Fig. 4*:* 9–26*)* contains a high proportion of arrowheads, which include Ahrensburgian, Swiderian and Post-Swiderian varieties. Other tools are endscapers, mainly circular and 'unguiforme', and burins, mostly made on broken blades. Microliths are rare and consist mainly of retouched bladelets. Ienevian industries (Figure 4*:* 26–34*)* include various strategies of flint splitting techniques reflected in the greater variety of core types. Flakes are the

Figure 5 a,b. Human and zoomorphic effigies from the Reindeer Island Cemetery (courtesy of the Museum of Ethnology and Anthropology, St. Petersburg).

most commonly used blanks. End-scrapers include circular and irregular varieties, and burins are manufactured on broken blades. Numerous microliths comprise variegated trapezes, truncations, isosceles triangles, and also micropoints, backed points and 'bi-truncated' points. Heavy-duty tools include several varieties of axes and adzes. The wetland sites have a rich bone and antler industry, which includes spear- and arrowheads, axes of Kunda type, harpoons, and personal adornments made of animal teeth and bones.

Kol'tsov (1989b) distinguishes two stages in the development of the Butovian. The earlier stage, featuring the occurrence of Ahrensburgian, Swiderian and Post-Swiderian arrowheads, may be dated by analogy with the sites further west to the Younger Dryas-Preboreal transition, c. 10,500 Cal BC. The later Butovian is exemplified by the Ivanovskoe-Berendeyevo sites, with radiocarbon dates in the range of 8,300–6,000 Cal BC.

Boreal Forests

Mesolithic sites in Eastern and North-Eastern Baltic area start appearing soon after the recession of the icesheets. The earliest evidence of human settlement in north-eastern Baltic Area is attested at Antrea-Korpilahti (8800-8500 cal BC) (Pälsi 1920; Jussila et al. 2007), where artifacts were found in the deposits of a channel between the Baltic basin and the Ladoga Lake. The waterway connecting the Ladoga and minor lakes with early Baltic basins were the channels via which the entire area was settled by Mesolithic hunter-gatherers, apparently stemming from the south-east (see in this volume). The existing radiocarbon dates and the geomorphic setting of the sites suggest that the Mesolithic sites were located mostly along the coastal landforms in the time-span between 9200 – 7000 cal BC (Lisitsyn & Gerasimov 2008). According to Siiriäinen (1982) the subsistence pattern of Mesolithic hunter-gatherers and seasonally varied and included the hunting of land mammals (autumn-spring), seal (winter – summer), water fowl (spring), fishing (summer) and food-collecting (summer).

Mesolithic sites in the coastal area of Estonia are commonly referred to as the Kunda Culture. The earliest dates are obtained for the site of Pulli: 9300–8600 cal. BC (Raukas *et al.* 1995, 121). The sites at Kõpu on Hiiumaa Island) show a later age, in the order of 5260–5040 cal BC (Kriiska & Lõugas, 1999).

Another type of Mesolithic settlements, usually of a smaller size is found in the land's interior. These sites are exemplified by Osa and Zvidse settlements on the Lubana Lake in Eastern Latvia, which yielded the age of ca. 5500 cal BC (Loze 1988).

The Zvejnieki Stone Age complex in northern Latvia includes one of the most significant hunter-fisher-gatherer cemeteries in Northern Europe. The burials of 319 individuals were excavated here by Francis Zagorskis in the years 1964-1970. Radiocarbon dates obtained from the cemetery range from 8150 to 4190 cal. BC. Two settlement sites have been identified close to the cemetery: Zvejnieki II (Mesolithic) and Zvejnieki I (Neolithic). The osteological material was well preserved, so that as many as 139 individuals could be included in the estimation of palaeodemographic indices. As hunting, fishing and gathering remained the main subsistence basis throughout the existence of both cemeteries, the observable changes in population dynamics remained insignificant. One notes a marked prevalence of males, exceeding females by a factor of 1.8-2.2. In the later periods, the rate of child and juvenile burials has fallen by half; with a slight increase in male and the decline of female life expectancies.

In northern Russia the Mesolithic sites are found on the lower terraces of rivers, notably the Northern Dvina, Pechora, Sukhona, Vychegda and their tributaries. The larger sites are found on the wetland shores of the Kubenskoye, Vozhe and Lacha lakes and several smaller lakes. Nizhnee Veret'e I, which lies in the catchment of the Lacha Lake, is the largest site in the whole area with a total area of 1500 m^2. It includes several surface-type rectangular post-framed houses with one of two hearths inside (Oshibkina 1989a, 1989b).

Due to the prolonger survival of tundra-like landscapes, reindeer remained an important hunting prey in the Mesolithic of Northern Russia, along with elk, beaver, waterfowl (especially swan) and fish. The bones of pike are the most common fish remains. The dog, the only domesticated animal, was fairly common. Burned and broken dog skulls were found at the site of Nizhnee Veret'ye I (Oshibkina 1989a, 1989b).

The stone industry includes endscrapers, burins (mostly on broken blades), tanged arrowheads and backed bladelets. There is also a variety of heavy-duty tools, including axes, adzes, chisels and 'hoe-like' instruments. A rich industry in bone, antler and wood includes a large variety of spear- and arrowheads, harpoons, scrapers and barbed points (Oshibkina 1989a, 1989b).

The Mesolithic layers at the Vis peat-bog in the Vychegda River catchment yielded a large collection of wooden implements, which included ornamented bows, skis, sledge runners, an oar, a bark float, a bark vessel, a fishing basket and a net made of sedge fibre (Burov 1989, Oshibkina 1989a, 1989b).

Reindeer Island (Olenii Ostrov) Cemetery on the Onega Lake is the largest in Europe. It includes 174 burials, and prior to its partial destruction, is thought to have had no less than 400 graves (Gurina 1956). The funerary remains suggest that the cemetery belonged to a large and stable community with considerable internal differentiation in wealth and status (O'Shea and Zvelebil 1984). Four individuals in the northern part of the cemetery (the 'shamans') were interred in a standing position facing west in funnel-shaped shafts 1.3–1.8 m deep. The richest graves contain sculptured or ornamented objects with representations of elk, snakes and humans carved in stone, wood and bone (Fig. 5). Hunting equipment is more common in male graves, and comprises bone and stone points, bone daggers slate knives, harpoons, fishhooks and quivers. Female graves generally had fewer grave goods than the male examples, and these comprise household artefacts, flint blades, awls, polishers, burins and scrapers, as well as perforated beaver incisors and snake effigies. A smaller cemetery consisting of ten burials was discovered at Popovo on the river Kinema,1.5 km upstream from the site of Nizhnee Veretye I. The grave goods include several complete fish skeletons, two complete dog skeletons and a necklace made of dog teeth (Oshibkina 1989 a, b).

Large series of radiocarbon dates for the Reindeer Cemetery indicate a time-span of 9,600–6,000 cal BC. This may be viewed as a reliable age estimate of the Mesolithic for the entire area of Northern Russia. Mesolithic sites occurred at about the same time in the Higher Arctic, as one may judge by the dates for Lak-Lesa, Vis and other sites, which lie in the range of 8,300–5,600 cal BC.

Discussion

The above evidence supports the view of the Mesolithic as a protracted period of hunter-gathering subsistence adapted to early and middle Holocene environments, and showing both continuities and contrasts with the preceding Palaeolithic period and the succeeding Neolithic.

The origins of the Mesolithic on the East European Plain are sought in the collapse of an extensive Upper Palaeolithic network. As it has been shown (Dolukhanov 1989, 2000), under the critical conditions of the Last Glacial Maximum (22 – 18 ky) the Palaeolithic populations in Europe were effectively restricted to two refugia, one in the west (Franco-Cantabria), and one in the east (the 'periglacial zone'). Remarkably, one notes a marked increase in the density of Late Palaeolithic sites in the middle Dniepr basin during the time-span of 15 – 12 ky (Velichko et al. 2006).

During the Late Glacial period 12,000–10,000 cal BC, in an environment of rising temperature and humidity there occurred a gradual recolonisation of European plains stemming from the two refugia (Dolukhanov 1989, 2000; Gamble et al. 2006). After c. 12,000 cal BC, first the mammoth and later the bison, disappeared, the reindeer becoming the principle hunting prey. Large sites vanished in the core area of the Dniepr and Don basins. A new network consisting of smaller, seasonal sites arose along the banks of small rivers and lakes, apparently oriented to the pursuit of seasonally migrating ungulates (the reindeer, in the first place).

The west-bound migrations are recognisable on East European Plain in the distribution of sites with distinctive projectile points, notably, the Ahrensburgian, the Bromme-Lyngby and Swiderian varieties. The Bromme-Lyngby points were identified in the Neman and Propet basins, and, recently, at several sites in the Upper Volga basin (Sinitsyna 2005). The largest concentration of Swiderian sites are found in the catchment of the Upper Neman and the Pripet rivers, usually on the dunes developed on the banks of ice-dammed lakes. At one site (Pribor 13) five clusters of lithics, each 10 m in diameter, allegedly corresponding to living areas, have been identified (Zalizhyak 1979). The easternmost penetration of the Swiderian tradition is acknowledgeable in the sites in the Upper Western Dvina and Upper Volga basins (Miklyaev 1995; Sinitsyna 2005). Zaliznyak and Yanevich (1987), based on the occurrence of Swiderian-type points in the inventory of the Syuren' 2 site, suggest that Swiderian groups reached the Crimea

The beginning of the Holocene was marked by the further depletion of hunting resources in an environment where increased temperatures and humidity led to the expansion of forests. At this stage a gradual reorientation in subsistence activities of local groups proceeded without any large-scale immigration from outside. Based on the similarities of main types of stone inventory, cultural and demographic continuity between the terminal Palaeolithic and early Mesolithic on North-Eastern and East European Plain is now generally accepted (Schild 1996). Zaliznyak (1991) suggests that the Mesolithic groups in the Pripet and Neman basins developed from the local Swiderian units The Swiderian is also viewed as the source of the Upper Volga and Kunda Mesolithic (Kol'tsov 1989). More specifically, the Ienevian culture in the Upper Volga area is seen as containing the Palaeolithic 'eastern Gravettian' elements (Amirkhanov 2004; Kravtsov 1998).

In contrast to the Upper Palaeolithic, the Mesolithic strategies of food-quest increasingly relied on the exploitation of aquatic food, resources, combined with the procurement of water fowl, gathering of edible plants and hunting of solitary animals adapted to the forest and forest-steppe environments (such as elk, roe-deer, red-deer and wild boar). The reindeer, which was the principal hunting prey during the late glacial period, disappeared from the greater part of the East European Plain in the early Holocene. Northern Russia, which included tundra-like landscapes, was a notable exception, where reindeer remained an important hunting prey. Hunting was increasingly complemented by the use of aquatic resources and harvesting of plant food. An increasing role for plant food in the Mesolithic diet became apparent in the steppe area .

In contrast to Upper Palaeolithic settlements, which are restricted to loess soils in the periglacial area, Mesolithic sites are found in all landscape zones, including those that had been only recently freed from ice-sheets. The northernmost Mesolithic site in Eurasia dated to 7100–6700 Cal BC is found on Zhokhov Island (The New Siberian Archipelago, 76° N latitude), on the exposed shelf of the Arctic Ocean (Pitul'ko 1998).

Mesolithic sites were concentrated in selected landscapes with diverse and predictable resources, and especially in wetland environments near marine estuaries, lakes, and in river basins, both on the plain and in the mountains.

The Mesolithic lifestyle featured an increased sedentism combined with limited-scale seasonal transhumance. In several cases there is clear evidence for larger permanent base-camps associated with a network of smaller seasonal occupations. Jacobs (1992), based on the analysis of dental records from Mesolithic burials, views Mesolithic society as consisting of large 'mating networks' of a closed or semi-closed type.

Principal changes in social organisation are signalled by the appearance of large 'communal' cemeteries, which were unknown in the Palaeolithic. The largest known cemetery on the Reindeer Island on the Lake Onega, in Russian Karelia with at least 400 graves is particularly significant. The occurrence of social hierarchy within an apparently large and stable community is highlighted by the burials of male individuals ('shamans') in vertical shafts with clear signals of wealth and status. No less important Mesolithic cemeteries were found in the steppe area, near the Dnieper Rapids. Their most significant element was the evidence of warfare. In several cases the deceased at these cemeteries bear witness to violent death, with flint arrowheads embedded in ribs and vertebrae.

The evidence from cemeteries clearly signals gender distinctions. At Reindeer Island cemetery, hunting equipment and armaments are found in male graves. Female graves are normally poorer in funerary goods, which were commonly restricted to household artefacts and artwork. The Dnieper Rapids cemeteries with evidence of warfare contain almost exclusively male individuals.

This suggests a society consisting of large male-dominated social aggregations, which included an important segment of military-oriented bands (particularly in the steppe, where food resources were scarce).

There is strong evidence of cultural segregation within Mesolithic societies. This is particularly apparent in the Dniepr Rapids cemeteries, where the deceased were often buried following distinct burial rites within the same burial ground (Stolyar 1959; Telegin 1982). The fragmentation of cultural space becomes apparent in the form of 'archaeological cultures' with more locally restricted distributions manifesting their identity in similar material symbols. Stylistic variables which lie at the base of both 'archaeological cultures' and '*chaînes opératoires*' may include both *fossils directeurs,* such as 'Swiderian points' or 'Kukrekian armatures', and general technological characteristics, such as the proportion of flake versus blade blanks, the proportion of microliths, 'heavy-duty' tools etc. At least in some cases, the stylistic and technological characteristics may be seen as a signal of a common cultural tradition, and their changes through time as reflecting trans-cultural interaction and displacement of Mesolithic communities. Thus the occurrence of 'Swiderian points' in Late Glacial assemblages might identify the expansion of reindeer-hunting communities on the East European Plain, who originated in the Vistula-Pripyat core area. The occurrence of similar points in later Mesolithic contexts is an indication of a genetic relationship between their makers and the earlier communities of the Late Glacial. In the steppe area, two distinct archaeological cultures, the Kukrekian and Grebenikian, with sites that are often found in similar landscape settings, obviously denote different cultural affiliations and origins. On the other hand, the common occurrence of 'heavy-duty' tools and the almost total absence of geometric microliths at Mesolithic sites in the Boreal zone clearly signal the impact of the local forested environment.

Another important issue relates to residential mobility. Older views of Mesolithic groups as peripatetic hunter-gatherers are no longer tenable. The occurrence of Mesolithic cemeteries persisting over considerable periods of time (such as at Reindeer Island) is an obvious indication of the stability of these communities and their territorial control. The Mesolithic life-style included a limited number of permanent or semi-permanent (apparently cold season) base-camps and a network of much smaller sites resulting from a seasonal transhumance.

There are also indications of larger-scale directional migrations. The original peopling of the northern Boreal zone, previously covered by ice-sheets, occurred during the Late Glacial period, resulting from a migration from the Vistula-Pripyat area. At the same time, the influx into the steppe area proceeded from the north. The steppe area with its vulnerable and rapidly changing environment remained an arena of repeated human displacement. Significantly, at the Dniepr Rapids cemeteries, the skeletons buried according to different burial rites belong to at least three distinct physical types (see above). Even allowing for the caution with which morphological data should be treated in the absence of molecular genetic analyses, these groupings may be seen as proxy evidence of demographic dynamics.

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Late Quaternary Environments of Northern Black Sea Area

E.P.Larchenkov,[1] S. V.Kadurin[1] and P.M. Dolukhanov[2]

[1]Department of Physical and Marine Geology, Odessa National University, Ukraine
[2]School of Historical Studies, Newcastle University, UK

Introduction

The continental area of south-western Ukraine included the Pontic Plain limited in the north by the Podylian, Dnieprian and South-Moldavian Uplands (Molodykh et al. 1984). The adjoining Black Sea shelf forms a sub-horizontal plain evenly tilted southwards under 1-2°. It lies at the depth of 15 - 40 m reaching 60 m at several points. A coastal off-shore slope 10-15 m high and tilted under ca 20° separates the shelf from the continent. Southwards from this slope and until the depth of ca 40 m one may distinguish several linear depressions with the trenches 10-15 m deep. The flowing landscape types are distinguishable:

1. The Danube and Dniester avandeltas at the depth of 7 – 26 m (14-18 on the average) formed by clayey ooze with the *Polychaeta* as domineering organism;
2. Coastal offshore submarine slopes – are identified in the abrasion coast area until the depth of 10-15 m with the detritus coquina and mussel biocenoses, and also on the outer shelf slope predominantly in the depth range of 35-45 m with coquilla and ooze coqiola transforming in the east into shelly ooze.
3. Palaeovalleys are found predominantly along fault lines connected with the Dniepr trench (and the Odessa depression), Pra-Dniestr, Pra-Sarata and Kirkinitide trench, in the depth range of 23-30 in their upper stretches and reaching 40-42 m in the lower ones. The bottom deposits consist of ooze coquille transforming into shelly ooze and ooze. The mussel biocenoses with *Polychaeta* as sub-dominant species.
4. Submarine uplands (the Budak, Dniester, Western Tendra, Tendra slope and others) which usually correspond to tectonic upliftings are found at the depth of 17-23 m. The coquina and detritus shelly sands are the predominant sediments. The mussel biocenoses.
5. Submarine plains in the shelf's central area are found at the depth ranging from 45-50 to >60 m. These are flat uneroded plains slightly tilted to the south with ooze coquille.

The sedimentary cover consists of the deposits of Palaeozoic, Mesosoic and Cenozoic age, the thickness of the latter increases seawards south of the Odessa deep fault, reaching 2-3 km and 5-6 km within the Kyrkenitide depression (Larchenkov et al. 2002).

The Quaternary sediments on the continent are of aeolian, talus, alluvial, lacustrine, deltaic and lacustrine origins. The loess deposits are widely spread on the watersheds. Inside the river valleys one finds the system or terraces of Quaternary age. Characteristically, in the rivers' lower stretches the alluvial deposits gradually transform into the estuarine, deltaic and lacustrine ones resulting from repeated sea ingressions and recessions. These deposits predominantly of Late Quaternary and Holocene age consist of dark and dark greenish clays and clayey sands, with both brackish- and fresh water molluscs. They may reach the thickness of 30-40 m in the estuaries. The coastal landforms of Holocene age include barriers, spits and shorelines formed by sands with molluscs.
Chronologically marine deposits of Pleistocene age include (Fedorov 1982; Varushchenko 1975):

1. Chaudian (Lower Pleistocene) formed in an environment of a vast alluvial and marine coastal plain;
2. Old Euxine and Uzunlarian (Middle Pleistocene) fine-grained coastal marine and estuarine deposits found on the edge of the present-day shelf;
3. Karangatian (Upper Pleistocene) estuarine and alluvial deposits;
4. Neoeuxine alluvial, alluvial-estuarine and talus deposits occupy the entire area of the shelf.

The Holocene deposits consist mostly of coquina, shelly sand and oozes and include:

1. Bugazian formations varying in thickness from 0.1 to 2 m on elevations and reaching 3-5 m in trenches include a typical Ostracoda assemblage with an admixture of fresh-water forms;
2. Vityazian deposits which conformly overlay the former ones consist mostly of oozes and vary in thickness between 0.2 and 1.0 m, reaching 3,5 – 6 m on the trench slopes and at the bench bottom and 10 m on the slope of the Odessa sand bank. The mollusc and Ostracoda assemblages reflect a gradual transition from the blackish water Caspian-type to the saline Mediterranean-type environment.
3. Strongly eroded Kalamitian deposits consisting of oozes and coquina in most cases 0.3 – 1 m thick and

Table 1.

Transgression stages		Transgression-regression cycles	Age ky bp	Sea level position, (-) m
Neoeuxinian		Early Neoeuxinian	25 - 20	-85 - -87
		Middle Neoeuxinian	19 - 15	-55 - -57
		Late Neoeuxinian	14 - 10	-37 - -35
Chernomorian	Early Chernomorian	Bugazian	10 – 8.5	-25 - -22,5
		Vityazevian	9.0 – 6.5	10.5 - 12,5
	Late Chernomorian	Kalamitian	7.1 – 4.0	- 7.5
		Jemetinian	since 4.2 -4.0	-2 - +2

reaching 4 m in trenches. The mollusc fauna is dominated by Mediterranean species.

4. Widely distributed Jemetian deposits consisting mostly of oozes and coquina, and rarely, sands and gravel. They average thickness is 2-3 m reaching 4-10 m in trenches. The molluscs are dominated by moderately stenoihaline Mediterranean species combined with eurihaline ones.

Methods

The reconstruction of the submerged relief features was based on the statistical processing of lithological characteristics of marine sediments and ecological parameters of fossil mollusc biocenoses. The mathematical modelling of the palaeorelief was obtained for major periods of stabilisation acknowledgeable for Late Pleistocene and Holocene (Larchenkov and Kadurin 2007). The reconstruction of continental environments was carried out with the use of geomorphic and pollen evidence (Gerasimenko 2004). The correlation with the stages of early human settlement was based on the existing archaeological and geochronological data (Dergachev and Dolukhanov 2007; Stanko et al. (1989), Stanko (1997, 2007), Kotova (2002), Telegin (1982).

Dynamics of Black Sea level fluctuations and human settlement over the past 25 ky.

As it is now widely accepted by the scholarly community, the main trend in the geological history of the Black sea basin over the last 25 ky consisted in its gradual transformation from the land-locked Neoeuxine mega-lake into an inner continental marine basin, connected via the Mediterranean Sea, with the World Ocean. Nonetheless, considerable controversies persist regarding the altitudinal position, the exact chronology and the mechanism of these transformations. The principle hazards preventing the solution of these problems reside in the scarcity and unreliability of exsiting radiometric dating. As a result one has to admit the lack of consistently dated ancient shorelines in the Black Sea basin.

The lack of acknowledgeable active tectonic movements in the area of North-Eastern Black Sea shelf at least since the Pliocene that could have significantly distorted the position of geologic bodies is a positive factor facilitating the reconstruction of fossil shorelines. Hence the geologically established depths corresponding to the transitions from the underwater to the supraqueous environment may be accepted as an estimate of the altitudinal position of the corresponding shoreline. The problem is complicated by the fact that the Late Pleistocene – Holocene transgression proceeded in a pulsatory manner by means of transgression-regression cycles. Thus in a transgression phase, the sea-level could exceed by 10-15 m that of the regression one. One may reasonably argue that the regression levels are better recorded in the bottom sediments.

It is generally accepted (Fedorov 1982; Konikov 2007) that two major transgression stages, the Neoeuxine and Chernomoryan each consisting of several transgression-regression cycles, are distinguishable for North-Eastern Black Sea shelf for the past 30 ky. Based on the available records we suggest the following age and altitudinal position of past shorelines (Table 1).

Black Sea Oscillations

During all the **Early Neoeuxinian** stage the Black Sea depression was taken up by a fresh-water mega-lake with the Caspian type molluscan fauna. At 30-25 k y BP its level was 87-90 m below sea-level (mbsl) The exposed shelf jointly with the North-Pontic Lowland south of the Dnepr formed a huge erosion-accumulation plain, which included the Pra-Prut, Pra-Dniestr and Pra-Bug alluvial plains. Its surface which evenly tilted to the south (from 180 to 80 m) was formed

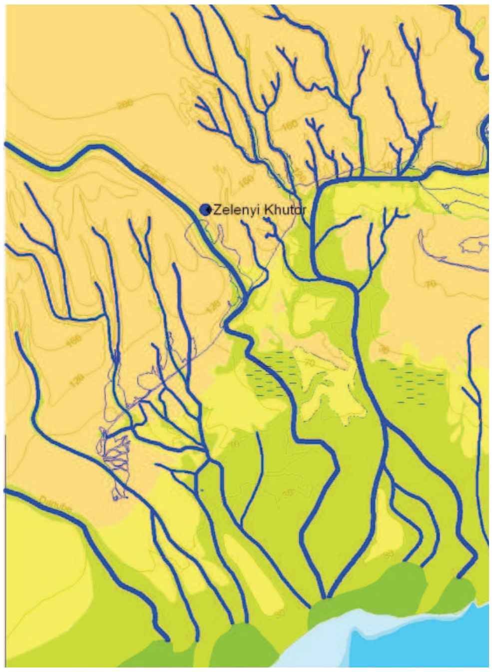


Fig. 1. Early Neoeuxine stage (ca 25 ky).

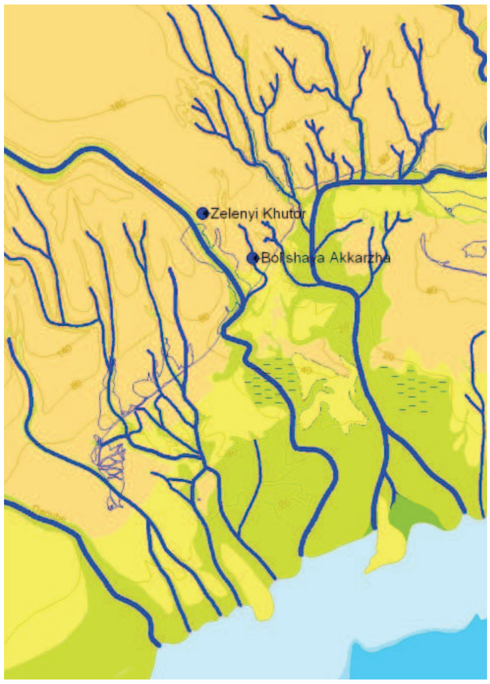
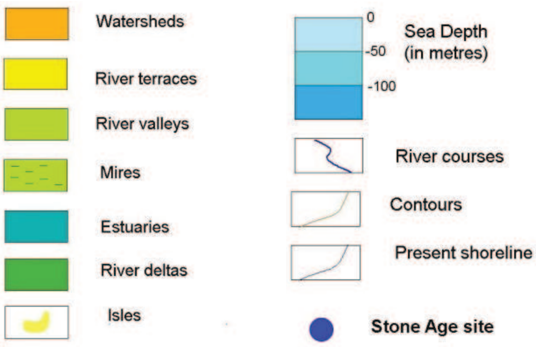


Fig. 2. Middle Neoeuxine stage (ca 18 ky).

Fig. 3. Late Neoeuxine stage (ca 12 ky).

Fig. 4. Early Chernomorian stage (ca 10-8 ky).



predominantly by the loess deposits. Further south lie the terraced alluvial plain, formed by the lower stretches of the Dnepr, Dniester and Danube with their extended marshy flood-plains, separated by local watersheds. A low-lying coastal deltaic plain was located closer to the shelf outer rim. This was actively developing deltaic accretion plain which consisted of numerous river branches with sand bars separating marshes and mires (Fig. 1**)**.

The existing pollen evidence (Gerasimenko 2004) suggests, that the vegetation of the erosion-depositional plain consisted of forest-steppe on the watershed with mixed forests (consisting of pine, birch, elm, oak, maple and hornbeam and hazel in underwood) restricted to the slopes and bottoms of the river valleys.

With the onset of the **Middle Neoeuxine** stage at 18 ky BP, the sea-level raised reaching 55 mbsl, submerging the deltaic accretion plain and more than a third of the alluvial plain. The rise of the base level led to an intensive lateral erosion, and an increased deposition inside the river valleys. The accrete Dnepr-Dniester valley with its large marshy areas remained in place on the terraced alluvial plain at an altitude of less than - 40 m. The Danube valley became separated by an extended watershed saw through by smaller river valleys. Significantly no deltas in the mouths of major rivers (except the Dnepr), are discernable, apparently due to the active hydrodynamics in the coastal area **(Fig. 2).** The pollen analysis (Gerasimenko 2004) shows the domination steppe-like cold resistant vegetation of nearly complete absence of arboreal species.

At **Late Neoeuxine** stage (12 y BP), the sea-level reached 37 mbsl, submerging the greater part of the terraced alluvial plain. The sea transgressed into the Dnepr and Dniester lower stretches, forming huge estuaries, separated by small-size watersheds. The Danube estuary formed the plain's western limit (**Fig. 3**).

The onset of the Holocene marked the beginning of the transgression in an environment of increased temperature of precipitation. During the Bugazian stage, 11 – 9 ky. BP, the level of the brackish-water basin with rare occurrences of Mediterranean salt-water molluscs, indicative of the initial penetration of Mediterranean water (Yanko-Hombach 2007) reached 18 mbsl. During the Vytyazian stage, 9 – 7.1 ÷ 6.5 ky BP, the sea-level attained c. 9 mbsl. During these stages, the sea nearly entirely submerged the terraced alluvial plain, deeply transgressing into the estuaries. The Dnepr estuary took form of a large gulf with the coast-line close to the present one. A large section erosion-denudation plain remained south of the Dnepr Valley.

Starting with 8-7 ky BP (7-6 ky cal BC), in the Altithermal environment, the Black Sea level raised above its present level partly flooding the estuaries of large rivers including the Danube and Dnieper (**Fig. 4).** As show the evidence obtained on the Bulgarian coast (Filippova-Marinova 2007) the influx of saline Mediterranean water and the rise of sea-level occurred between 7.5 and 6.8 ky BP (6.0 – 5.5 cal. ky BC) (the Varnian regression) The transgressive shore line at 3-4 mbsl dated to 6.5 ky BP has been identified at various points of North Pontic shelf (Balabanov 2007). Based on the studies of the Anapa coastal sequences on the northern Caucasian shelf, Izmailov (2005) has identified the Jemetian transgression which culminated at 5.7 and 5.4-5.3 ky BP.

A large-scale regression occurred between 5.6 – 5.4 ky BP, which resulted in the 5-7 m drop of the sea-level, identified on the Bulgarian coast (Filipova-Marinova 2007; Filipova-Marinova and Bozilova 2003). The ensuing rise of the sea-level acknowledgeable in the sequence of Durankulak Lake occurred at 5.2-5.0- ky BP, probably coeval with the Jemetian second 5.4-5.3 and third (4.6-4.4 .ky BP) peaks.

A deep regression resulting in the complete drying up of the Durankulak Lake occurred 4.4 – 4.0 ky BP. The simultaneous drop of the sea-level of c. 6 m has been reported on the Caucasian coast at 4.2 -4.0 m. (Izmailov 2005; Balabanov 2007).

The next rise of the sea-level is acknowledgeable on the Bulgarian sea coast between 3.5 - 3.1 ky BP, and linked to an abrasion terrace 4 m high (Filipova-Marinova 2007). The so-called Phanagorean regression (2.7– 2.4 ky BP; 900-400 cal BC) has been first identified by Fedorov, based on the occurrence of Greek pottery dated to 6th – 5th centuries BC at Phanagoraea settlement (the Taman Peninsula) at the bottom of the wells reaching 4-5t mbsl. After that the evidence of that regression estimated at reaching 10-15 mbsl, has been found at other points of Black Sea coastal area (Balabanov 2007).

Human settlement

The **Early Neoeuxine stage** coincided with the initial expansion of anatomically modern humans (AMH) and the spread of Upper Palaeolithic (UP) technologies in the Northern Black Sea (ca 40 – 25 ky BP). UP sites of that age (Sagaidak 1, Anetovka 2, Amvrosievka, and Muralovka) are usually found inside deep valleys of the small river, which provided for natural protection in harsh environment (Stanko et al. 1989). This type of landscape was excessively rich in biomass, guaranteeing stable and diversified food resources. The common occurrence of similar landscapes makes one suggest, that similar settlements occurred in the actually submerged part of the shelf. The most probable location of UP sites may be expected within the submerged valley, particularly at the point of their confluence with smaller tributaries.

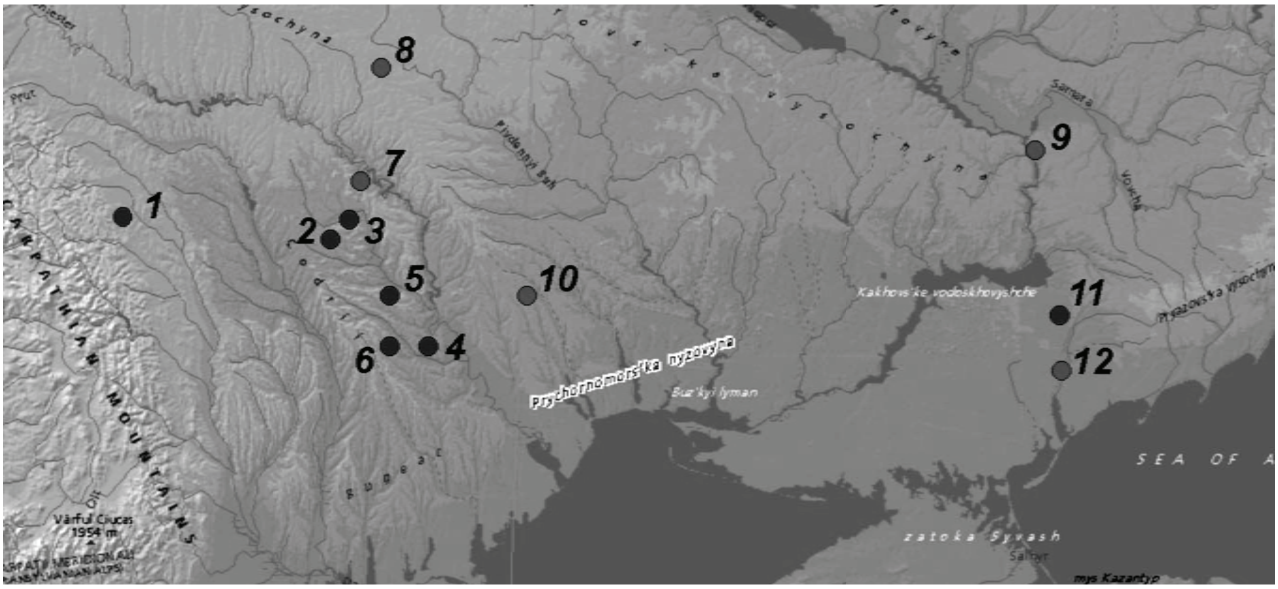


Fig. 5. Later Chernoimoryan stage (8 – 6 ky BC)
Key: Early agricultural sites. Criş Culture – 1 - Erbiceni, 2 - Sacroviţa, 3 -Selishte; Linear Pottery Culture – 4 - Foreşti; 5 - Robozhany; 6 - Novye Ruseşti; Sites with predominantly hunter-gathering economies: 7 - Soroca; 8 – Baz'kov Ostrov; 9 – Surskii Ostrov; 10 – Semenovka; 11 – Kamennaya Mogila; an early stock-breeding site: 11 – Sredni Stog.

During the Middle **and Late Neoeuxine stages,** the Palaeolithic population was greatly affected by the critical decrease in the availability of wild game resources. Both the mammoth and woolly rhino were totally exterminated by 18ky BP, and the bison became the principle hunting prey. The subsistence strategy increasingly relied on the exploitation of wetland resources, with the prominence of waterfowl hunting. Correspondingly, the microliths and retouched blades, seen as elements of projectile tools, became dominant in lithic inventories. One notes the general outflow of the population in the southern direction and an intensive settlement of the wetland-type landscapes. A network of settlements arose in the valleys of smaller rivers and ravines in southern Bessarabia. Occasional finds of laminar stone tools in the course of sea floor dredging suggest common occurrence of similar type of settlements in the submerged part of the shelf (Stanko 2007).

The **Early Chernomoryan (Bugazian and Vytyazian**) stages correspond to the spread of Mesolithic sites (10 – 8 ky BP), which show diversified subsistence and settlement patterns. The largest settlements (such as Mirnoe) are found on the lower terraces of smaller-size estuaries. As suggests the use-wear analysis, the lithic tools at this site were used predominantly for butchering and skin dressing. Retouched blades were also numerous, while the cores were few in number. The animal bones included aurochs, antelope saiga and fox. Prismatic blades with 'sickle-gloss' were identified as 'reaping knives' intended for harvesting edible plants. Another low-laying site in the same area, Beloliss'e, included a larger proportion of geometric microliths: crescents, lunates and rectangles. Animal remains consisted of wild horse (57%); aurochs (28%) and antelope saiga (14%). Bith sites are viewed (Stanko 1997, 2007) as base-camps inhabited on the round-the-year basis by several blood-related families.
Several sites (Girzhevo, Vasilievka and Zaliznichnoe) are found in elevated areas at a considerable distance from the river statuaries, implying seasonal transhumance. The occurrence of large 'communal' cemeteries in the area of the Dniepr Rapids (Telegin 1982) wes another characteristic feature of Ukrainian Mesolithic. One may expect the occurrence of Mesolithic settlements within the smaller valleys in the submerged part of the shelf.

The Jemetian transgressions coincided with the initial penetration into the northern Pontic area of early farming communities belonging including Karanovo I-II (6.1 – 5.8 ky cal BC); Karanovo III (5.4 – 5,1 ky cal BC), Karanovo IV (5.3 – 4.8 ky cal BC), Starčevo-Körös-Criş (5.9 – 5.5 ky cal BC) and Vinča (5.5 – 4.0 ky cal BC). The expansion of early agriculture in Central and Western Europe took the form of Linear Pottery Culture spreading at c. 5154 ± 62 BC with an average speed of 4-6 km/yr (Dolukhanov et al. 2005). (**Fig. 5**).

Still earlier dates were obtained for the sites of pottery-making communities with restricted evidence of stock-breeding and agriculture: Rakushechnyi Yar; c. 7 ky; Surian, Dniepr-Donetsian and Bug-Dniestrian, 6.2 and 5.0 ky (Dolukhanov et al. 2009). Early farming settlements were located on the edges of erosion-denudation plain bordering river valleys in the areas of chernozem of degraded chernozem

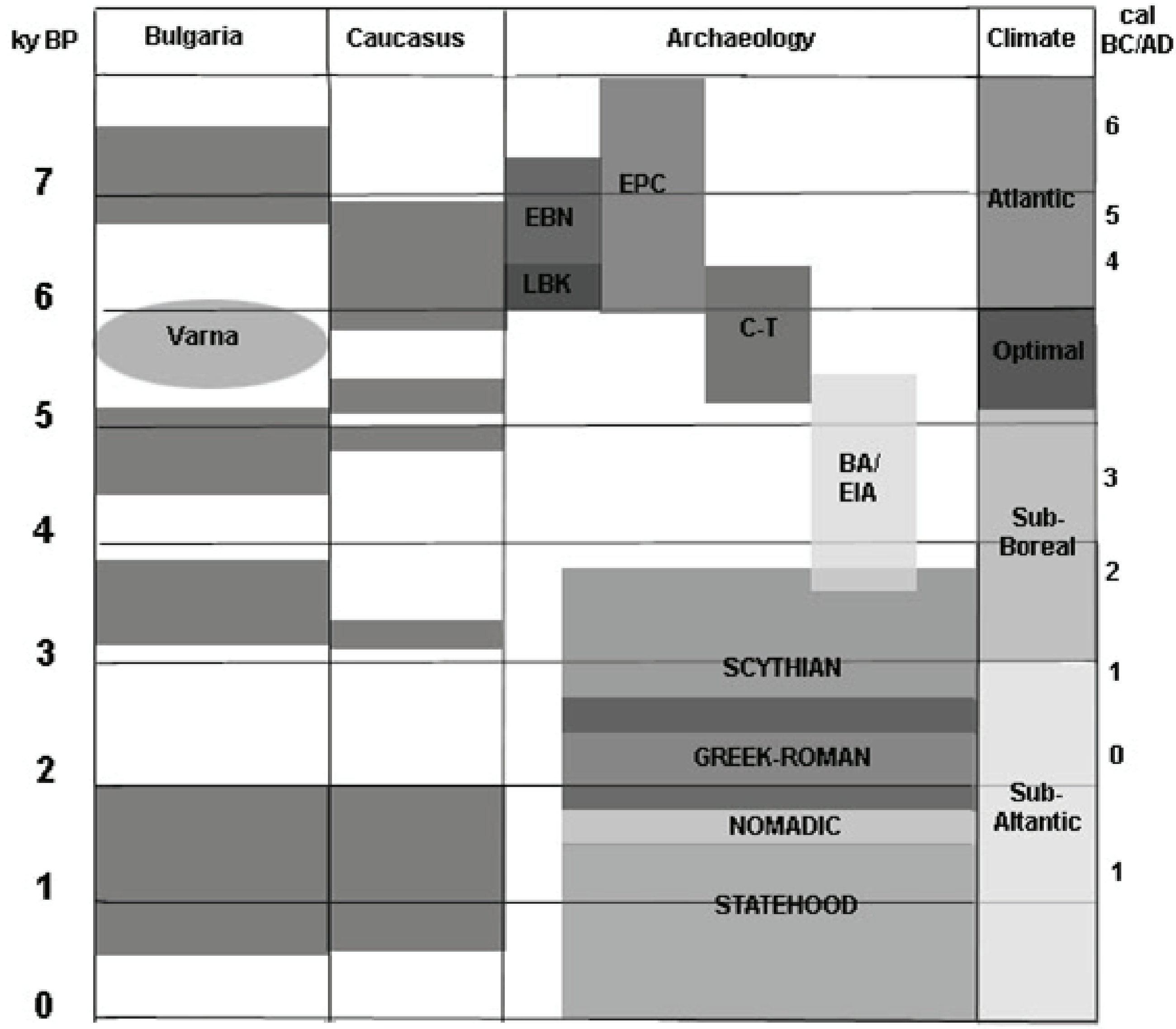


Fig. 6. Black Sea transgressions (grey areas on the left), archaeological/historic periods, and climatic stages in the Holocene Northern Pontic area.

Key: EBN – Early Balkan Neolithic; LBK – Linear Pottery Culture; EPC – Early Pottery cultures; C – T: Cucuteni-Tripolye; BA/EBA – Bronze Age – Early Iron Age.

soils (Dergachev and Dolukhanov, 2007). As all these settlements coincided with the rise of the sea-level, the occurrence of similar sites on the submerged shelf is unlikely.A large-scale regression occurred between 4.5- 4.0 ky BC which resulted in the emergence of coastal settlements in the Varna-Belostav estuary, Sozopol harbour and Kiten on the Bulgarian coast, which remains are found at 5-7 mbsl (Filipova-Marinova 2007; Filipova-Marinova and Bozilova 2003). The Late Eneolithic cemetery at Varna related to the agricultural colonisation of the coastal area has been dated with the use of AMS technology to 4560-4450 cal BC (Higham et al. 2006). In view of the large-scale sea-level recession, one may reasonably expect the occurrence Eneolithic and Early Bronze Age sites in other parts of the submerged shelf.

Large-scale colonisation of the northern Pontic area occurred during the Phagorean regression during which course mean e Black Sea level stood at 1-2 mbsl (Shilik 1997). Archaeological deposits of the Greek colony of Olbia dated to the 6th – early 5th centuries BC) were found on the bottom of Bug-Dnieper estuary in an area of no less than 20 hectares (Kryzhitsky 1997).

Discussion

As follows from the previous review, during the Late Pleistocene – Early Middle Holocene panoplies of prehistoric cultural entities succeeded each other in the littoral Black Sea area. They demonstrated considerable transformations in the subsistence, settlement pattern, and cultural affiliations These changes that might have implied human migrations of various scale, cultural diffusion, interactions or combination of these processes, proceeded against the background of major environmental shifts, which included the climate, vegetation and soil types, as well as migrations of Black Sea shoreline. The latter became in the focus of both scholarly and public interest particularly after series of publications by W. Ryan and W. Pitman. These writers argued that the Black Sea remained a freshwater lake with a surface at 140 mbsl between 14.7 and 10 ky BP. Then at 5.2 ky BC (according to the initial hypothesis) or 6.5 ky BC (according to the modified version) this lake was catastrophically inundated my Mediterranean water flowing through the Bosphorus, resulting in an abrupt drowning of more than 100000 sq. km of previously exposed Black Sea continental shelf. This, in the writers view, led to a rapid spread of farming "from Greece, Bulgaria, Romania and the coast of Marmara Sea" inland, along the major river valleys of South-eastern Europe.

Numerous investigations conducted by marine geologists in the Black Sea area and clearly demonstrate the occurrence of multiple fluctuations and migrations of Black Sea coastline in the course of the Holocene, yet contrary to the Ryan-Pittman hypothesis they never had a catastrophic character (Yanko-Hombach et al. 2007). Migrations of the shoreline proceeded at a sufficiently slow rate (2.5–5 cm/year) and were restricted to the present-day continental shelf, could not have had any direct effect on prehistoric groups beyond the littoral zone. The maximum rise of sea-level which resulted in the formation of transgressive shoreline at the altitude of 2.0÷2.5 m above the present sea-level, occurred 3000–2800 cal. BC. The effect of this and similar sea-level rises was restricted to the river estuaries and firths which were repeatedly transgressed by the sea. Existing evidence is strongly indicative of the gradual character of the spread of agriculture in Europe. The earliest manifestations of agriculture in south-eastern Europe are acknowledgeable at c. 8.6-7.5 ky cal BC (Franchthi Cave). The next stages of early Neolithic in Central and Northern Greece include Proto-Sesklo (6.5-6.0 ky cal BC) and Sesklo (6.0-5.3 ky cal BC). Further north, in the northern Balkan area and Middle Danube basin, several early farming cultures were recognised, including Karanovo I-II (6.1 – 5.8 ky cal BC); Karanovo III (5.4 – 5,1 ky cal BC), Karanovo IV (5.3 – 4.8 ky cal BC), Starčevo-Körös-Criş (5.9 – 5.5 ky cal BC) and Vinča (5.5 – 4.0 ky cal BC). The expansion of early agriculture in Central and Western Europe took the form of Linear Pottery Culture spreading at c. 5154 ± 62 BC with an average speed of 4-6 km/yr (Dolukhanov et al. 2005).

The earliest signals of pottery-making are apparent in the North Caspian area, the Middle-Lower Volga (Yelshanian, c. 8-7 ky and the Lower Don (Rakushechnyi Yar; c. 7 ky). The radiocarbon age of early pottery-bearing sites in the South Ukraine and Moldavia, Surian, Dniepr-Donetsian and Bug-Dniestrian, lie in the time-span between 6.2 and 5.0 ky. In the latter case they overlap with early farming entities (Starčevo-Körös-Criş and Linear Pottery), which is perceptible in archaeological materials.

All these sites are located at a considerable distance of the coastal area and could hardly be affected by the sea-level rise. On the other hand, they are basically coeval with the Altithermal conditions, which featuted a consirebla rise of temperature and precipitation thus creating conditions for novel forms of subsistence.

The present review indicate the periods with most probable occurrence of archaeological sites on the presently submerged areas of the northern Pontic shelf (**Fig. 6**). This includes the Upper Palaeolithic and Mesolithic (25 – 8 ky BC). The second period of mostt likely settlement of the shells falls to the Black Sea regression.

Another time-span of probable occurrences of Chalcolithic and early Bronze Age settlements in submerged areas corresponds to the major Black Sea regression between 4.5 and 4.0 kyr cal BC.

The third likely period of the settlements of the presently submerged shelf corresponds to the Phanagorean regression of the first millennium BC and coincides with the Greek colonisation of the coastal area.

Conclusions

1. The periods of the human settlements of the presently submerged Black Sea shelf corresponds to the low stands of the sea level, of which most important are:
1. Neoeuxinian (25 – 10 ky BP);
2. Early Neochernomorian;(10-8 ky);
3. Varnian (6.0 – 5.5 cal BC) .

There is no evidence suggesting a catastrophic character of sea-level changes and their impact on the spread of agricultural subsistence.

Acknowledgement

The writer would like to express their deep gratitude to IGCP 521 Programme "Black Sea-Mediterranean Corridor during last 30 ky: Sea level change and human adaptation"

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The Holocene Vegetation, Climate and Early Human Subsistence in the Ukraine

G.A. Pashkevich[1] and N.P. Gerasimenko[2]

[1]*Institute of Archaeology, National Academy of Sciences, Kiev, Ukraine*
[2]*Department of Earth Sciences, Taras Shevchenko National University, Kiev, Ukraine*

The vegetation and climate in the Ukraine's steppe and forest-steppe area are reconstructed based on the pollen data supplemented by the evidence of soil profiles. The subsistence of Mesolithic, Neolithic and Chalcolithic groups is evidenced by ethnobotanical data, which enabled us to restore the assortment of both domesticated and wild plants that were used for food.

The amelioration of climate that marked the beginning of the Holocene led to the disintegration of the vast area of periglacial-type vegetation which encompassed the entire ice-free area of East European Plain and the gradual formation of present-day zonal structure. The 'mammoth' fauna which consisted of large herd herbivores became extinct, with the assemblages of forest and steppe adapted animals emerging at its place. In this environment the first farming communities appeared in Europe.

The detailed evidence regarding the environment and subsistence of Mesolithic groups has been obtained for two localities in the Odessa Oblast, in the western part of the steppe zone: Beloles'e and Mirnoe sites (Pashkevich 1967a, 1982). Presently this area of Pontic Lowland is taken up by the treeless fescue-feathergrass steppe, with typical xerophytic Gramineae grasses, including *Stipa ucrainica* P.Smirn., *St.lessingiana* Trin., *St. Capillata*, *Festuca sulcata* Hack.), and *Koeleria gracilis* Pers., and an admixture of xerophytic forbs, such as *Lynosyris villosa* (L.), *Limonium sapertanum* (A.Beck Gams), *Medicago romanica* Prod.), and *Tanacetum millefolium* (Tzvel.). Salt-marsh plant communities commonly occur on river flood-plains and ravine bottoms.

Based on the obtained pollen spectra from the Beloless'e site, that-time vegetation is seen as fescue-feathergrass steppe with poorly developed forbs, and commonly occurring barren soils, salt-marshes and small-size water bodies surrounded by mesophytic meadows and rare alder trees. Amongst identified plant species are those typical of the eroded barren soils: *Ephedra distachya, Chenopodium botrys, Ch. polyspermum, Eurotia ceratoides, Kochia prostrata, Coryspermum hyssopifolium*.

The subsequent changes in the vegetation are acknowledgeable in the growing abundance and increased variety of forbs and Compositae, decreased participation of Chenopodiaceae and *Artemisia*, growing rate of Gramineae with a constant amount of xerophytes, (*Eurotia ceratoides, Kochia prostrata*), and rare occurrences of arboreal species (*Pinus, Betula, Alnus*). This type of vegetation remained in place during the entire Preboreal and Boreal periods. The limited amount of tree pollen suggests the occurrence of rarefied forests along the slopes of river valleys and estuaries.

The flotation of archaeological deposits at the Mirnoe site identified the seeds of white goosefut (*Chenopodium album);* black bindweed (*Polygonum convolvules)*; hairy vetch *(Vica hirsuta)* and sorrel (*Rumex acetosa).* Supposedly these wild growing plants were part of the Mesolithic diets**.**

In the eastern part of the Ukraine's steppe the pollen data were obtained for several Mesolithic sites and coeval early Holocene deposits at Zimovniki, Rogalik 12, Rogalik 12, Peredelsk and Podgorovka (all in the Lugansk Oblast) **(Fig. 1).** The studied deposits are of Preboreal (9.5±110 BP) and Boreal age (8.5±1,0, 8,6±0,9, 8.1±1.2 ky BP) (Gorelik 1986; Gerasimenko 1955, 1997a and b). As follows from the pollen evidence, the watershed areas were taken up by bunchgrass steppe communities, while the mesophytic Gramineae communities were dominant on the river floors and low-laying areas. The occurrence of Late Glacial vegetation, Chenopodiaceae, *Artemisia*, *Ephedra*, Cruciferae, Polygonaceae, Plantaginaceae and Hellianthemum is noteworthy. Forests supposedly covered the watershed slopes and included oak, elm and hazelnut, with alder on wetter grounds. The grass cover was of a mesophytic character. This type vegetation was essentially similar to that of present-day Central Russian Upland (Isaeva-Petrova 1967). The increased abundance of steppe xerophytes and the decreased amount of arboreal macrofossils is indicative of the climate becoming cooler and dryer by the end of the Preboreal. The bunchgrass steppe communities dominated the vegetation cover with the diminished abundance of mesophytic hygrophilous grasses even on river floodplains.

Forests further expanded in the East Ukrainian steppe during the Boreal, with an increased abundance of sedges amongst floodplain communities. The bunchgrass steppe with a significant participation of Compositae developed on the watersheds, while sedge-forbs meadows and elm forests took up river floodplains. Pine forests with a significant presence

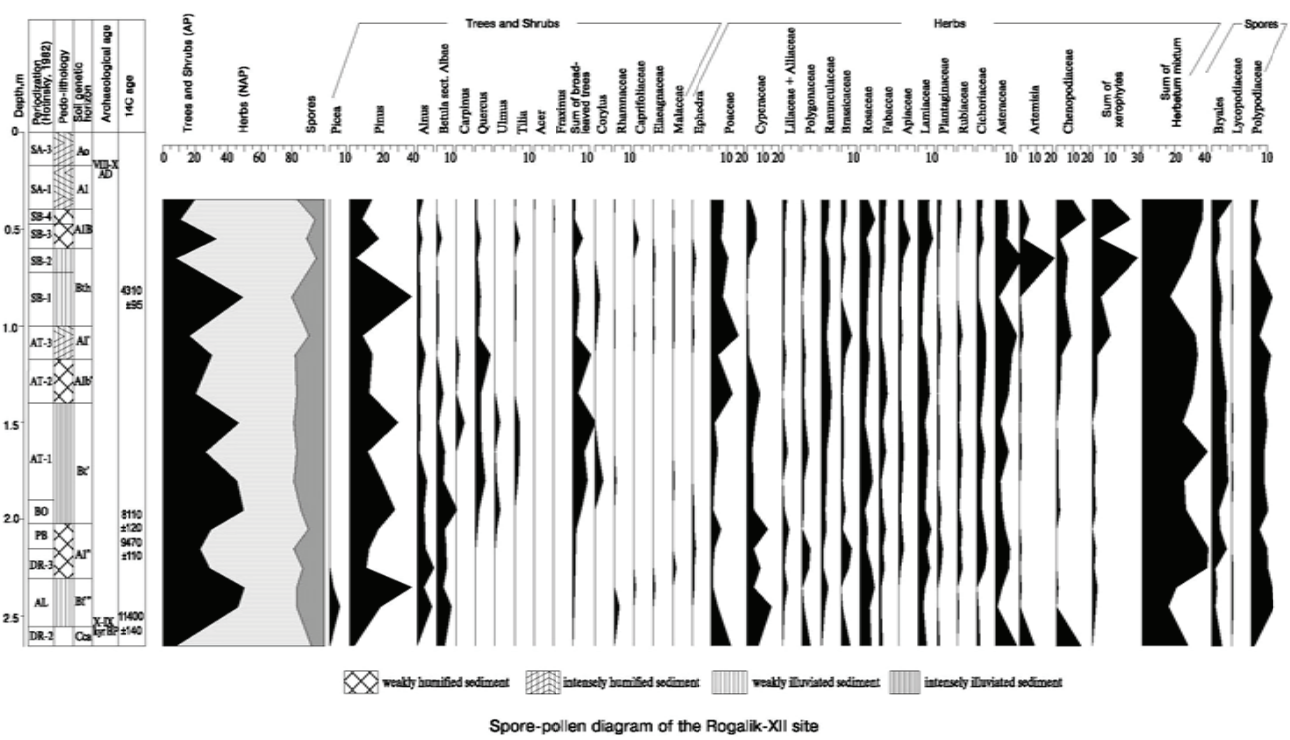

Fig. 1. Pollen diagram of Rogalik 12 peat-bog.

of birch trees expanded along the sandy terraces, while birch and oak forests with an admixture of elm, lime and hazel trees, and forbs occupied the ravines. An abundance of arboreal birch (*Betula pendula* and *B.pubescenes*) was a typical feature of the Boreal pollen spectra in that area. The Boreal climate became wetter as compared to the previous period, and the vegetation acquired a pronounced mesophytic character. The episode of the Boreal (c. 8100 BP) was marked by an abrupt fall in the abundance of broad leaved species (of which only the hazelnut remained accountable) and the rise of xerophyte grasses (notably, *Ephedra* and Chenopodiaceae) indicating the cooling and increased continentality of the climate.

As show the pollen data for Mesolithic sites on the Kerch Peninsula in the eastern Crimea, Lugovoye I and II, Leninskoye and Frontovoye (Pashkevich 1967b, Matskevoi and Pashkevich 1973), the steppe vegetation in that area had a more mesophytic character as compared to the present time, and consisted of bunchgrass communities with sparse forests and aquatic vegetation with *Sparganium,* Hidrocharitaceae and *Lycopodium* along water courses.

The Neolithic and Chalcolithic periods in Europe broadly coincided with the Atlantic period (**Fig. 2**). During that period, mixed forests with broad-leaved species, oak, lime, elm as well as hygrophilous elements, ash tree (*Fraxinus excelsior)* and ivy *(Hedera helix)* were widely spread in Central Europe. Considerable changes are acknowledgeable in the vegetation of the southern steppe. The early Atlantic pollen spectra in the south-western steppe (at Beloles'e and Mirnoe sequences) show the higher values of pine and broad-leaved arboreal species (*Quercus, Tilia, Carpinus, Ulmus*), the grassland dominated by forbs steppe, Compositae and Chenopodiaceae acquired a mesophytic character. The similar character of Early Atlantic vegetation has been identified further west, in the Lower Dniestr area (Volontir 1989).

According to quantitative estimates for various areas of East European Plain (Dolukhanov & Pashkevich 1977; Kremenetsky 1991, 1997, 2003), the climate during the time-span of ca 6000-4500 BP was of a less continental character with milder winters and mean annual temperature exceeding the present one by 2°. In the steppe, the January temperature was higher than now by 1°C, and the July one, lower by 2°C. The annual precipitation was higher by 100 – 150 mm (Kremenetsky 2003). Under these conditions the forests expanded both northwards and southwards with respect to their present-day locations. The entire valleys of the Dniepr, Dniestr, Southern Bug, Seversky Donets and Don were forested, and the forests reached the Black Sea shores. Broad-leaved forests transgressed into the steppe, considerably diminishing the treeless area.

The southern foothills of the Volyn-Podilsk and Dniepr Uplands which presently lie on the northern steppe were covered by forest-steppe vegetation (Kremenetsky 1991; Gerasimenko 1997, 2004). Kremenetsky (1991) reported the pollen data for Orgeyev (Orhei) palaeolake sequence, which is presently located in the steppe area of the Dniestr-Prut

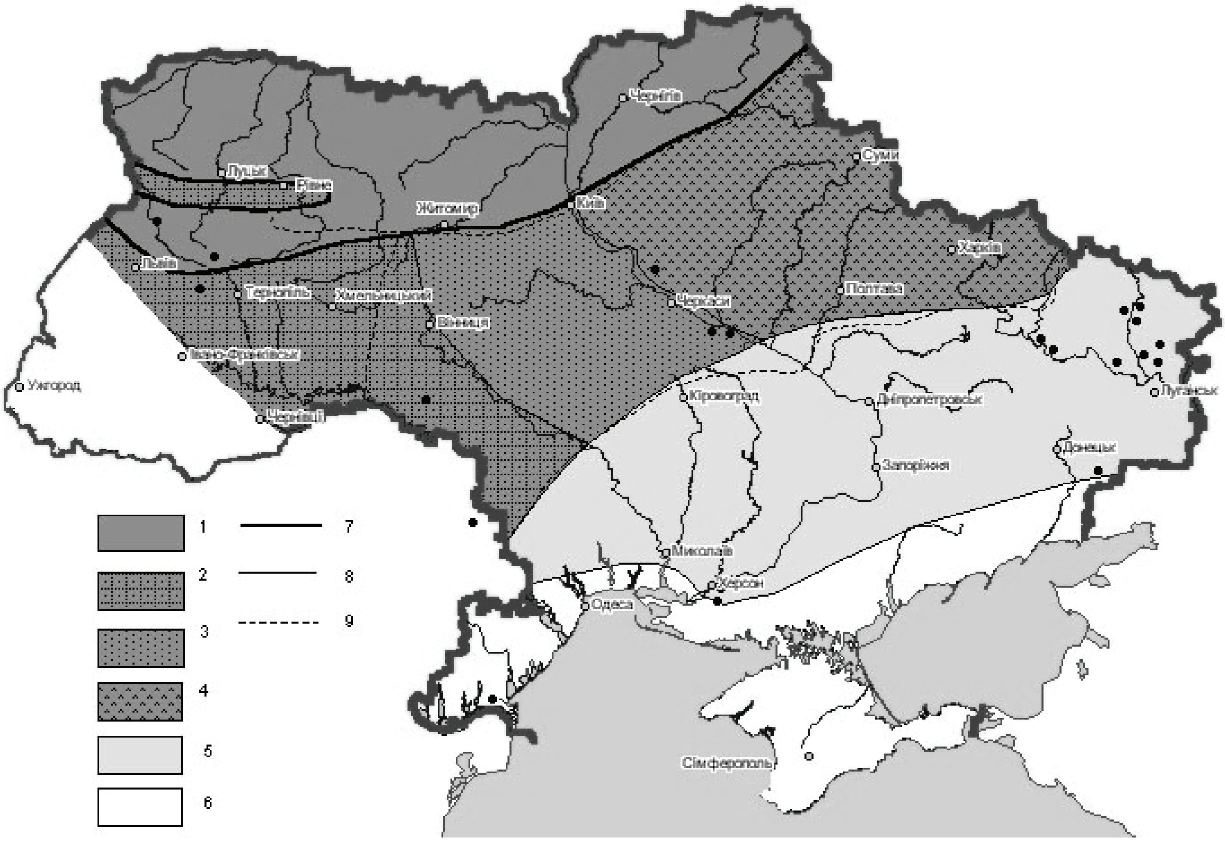

Fig. 2. Ukraine vegetation cover during the Altithermal period (5.8 – 5.5 ky BP)

Key. 1 -pine-oak forests on turf-podzolic soils; 2 – oak-hornbeam forests with beech on grey forest soils; 3 – oak-hornbeam forests on grey forest soils; 4 – lime-oak forests on grey forest soils; 5 – forbs steppe on chernozem soil and oak-hornbeam forests on dark grey soils, 6 – *Gramineae* steppe on chernozem soils and broad-leave forests with hornbeam on grey-podzolic soils; 7 – zone boundaries; 8 – sub-zone boundaries; 9 – present-day zone boundaries; black circles: investigated sequences.

watershed in Moldavia. The Atlantic period spectra show the occurrence of broad-leaved forests alternating with bunchgrass steppe.

The typical steppe was restricted to the southern margin of the Pontic lowland. The grass cover was quite distinct from the present one, being of mesophytic character and richer in meadow elements. The animals adapted to dry steppe, such as wild horse, wild ass and antelope saiga, were evinced by the species more accustomed to forest-step landscapes: aurochs, fallow deer, wild boar and red deer (Bibikova 1975).

High temperatures and precipitation in the early Atlantic is equally acknowledgeable in the Ukraine's south-east (Gerasimenko 1997), which triggered the maximum proliferation of broad-leaved forest-steppe vegetation. During the thermal optimum (5.8-5.4 ky BP) a small fall in temperature is noticeable, apparently due to an increased evaporation, while the forest-steppe-type vegetation remained unchanged. Following 5.2 ky BP, the vegetation acquired the northern forest-steppe sub-type. The continentality increased, and the climate approached the present-day parameters.

The vegetation of the Atlantic period in the steppe area of Pontic Lowland is evidenced by the pollen data for Kardashinsky peat-bog, located at the bottom of the first terrace of the Dnieper River near Tsuryupinsk (Kremenetsky 1991). This peat-bog developed at the place of an ox-bow lake during the early Atlantic period (8 - 6 ky BP). At that time the bunchgrass-wormwood steppe occurred on the watersheds, pine forests with birch alternated with grassland on river valley slopes, while the floodplains were taken up by forests with elm, oak, lime, hornbeam and ash-tree alternating with steppe meadows. During the later Atlantic, one notes an increased abundance of broad-leaved species and the replacement of pine by birch forests on sandy terraces. *Artemisia* becomes dominant in the grassland communities, and the sedge-hypnum raised bog developed into a reed fen. By the end of the Atlantic and the beginning of the Subboreal period (4.5-4.2 ky) the grassland acquired a mesophytic character with the spread of steppe- meadow and steppe communities, and continued occurrence of both pine and broad-leaf forests.

Typical steppe spectra dominated by Chenopodiaceae and Compositae with the limited occurrences of arboreal species

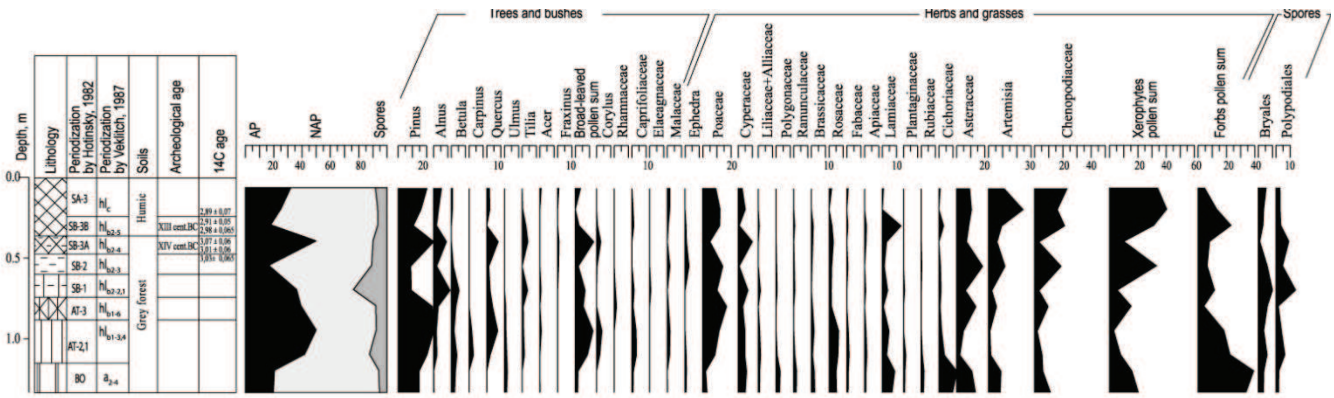

Fig. 3. Pollen diagram of Glubokoye Ozero 2 sequence

(the pine, birch, alder, elm, hornbeam and oak) have been identified by G.A. Pashkevich in the deposits of Early Neolithic site of Kamennaya Mogila, located in the flood-plain of the Molochnaya River (Melitopol Oblast, Ukraine).

Similar pollen data were obtained for stratified site of Razdolnoye in Donetsk Oblast (Bezus'ko et al. 2006), on the right bank of the Kalmius River in an area of forbs-fescue-feathergrass steppe and limited occurrences of hardwood forests in the ravines. The early Neolithic layer has been radiocarbon-dated to 5825±80 BP [Ki–8004] and 5630±90 BP [Ki–8005] The pollen spectra obtained for Early and Middle Chalcolithic layers show the prevalence of steppe-like vegetation with an abundance of mesophytic forbs and the occurrence of broad-leaved forests which included hornbeam *(Carpinus betulus)* and alder. The occurrence of Cerealia pollen is indicative of agriculture, which is further corroborated by ethnobotanic showing the occurrence hulled wheats, hulled barley and millet.

Following the Altithermal, which age on East European Plain is generally estimated as 5.6-5.3 ky, the pollen spectra of eastern Ukraine indicated a reduced precipitation with mean annual temperatures remaining above the present-day values. In the Razdolnoye sequence the corresponding spectra feature the reduced abundance of forbs, combined with an increased rate of Chenopodiaceae, the latter being apparently caused not only by the climate change, but also by human impact.

As show the pollen sequences in the eastern Ukraine's northern steppe area (Rogalik-Peredelski sites, Glubokoye Ozero 2, Podgorovka and Amvrosievka) the Early Atlantic climate (8 – 6 ky BP) was favourable for the spread of forests in the northern part of the Donetsk Basin (Gerasimenko 1955, 1977a,b) (**Fig. 3**). That-time landscape had a forest-steppe character with pine-broad-leaf forests alternating with meadow grassland. The forests consisted of oak, elm, hornbeam and ash-tree with hazelnut, euonymus, Nymphaeaceae, Caprifoliaceae and cornel *(Cornelian cherries)* in underwood. The subsequent cooler and drier climate is acknowledgeable in the reduction of arboreal pollen, and especially broad-leaf species at c. 7 ky. One notes the disappearance of hornbeam and the development of forbs-bunchgrass steppe, which became the dominant grassland community. The forest-steppe vegetation with an increased abundance of broad-leaf species reappeared between 7 and 6 ky.

Following 6 ky the forested areas became generally reduced, but abundance of broad-leaf species reached its maximum during the thermal optimum, 5.6-5.3 ky. That-time forests included hornbeam (*Carpinus betulus*), which present-day eastern limit lies far to the west. The occurrence of broad-leaf arboreal species and notably hornbeam is indicative of the oceanic climate. Judging from present-day distribution of hornbeam, the Late Atlantic summer and winter temperatures in the Donetsk Oblast were by 1° higher, and rainfall, by 60 mm greater than now.

Following the thermal optimum at 5.3 ky BP, one notes an increased continentality of climate, acknowledgeable by the reduction of arboreal broad-leaf species with the total disappearance of hornbeam, and less abundant mesophytic forbs. The forest-steppe gave way to the forbs-bunchgrass steppe, essentially similar to the present-day vegetation. Rare hardwood forests inside the ravines included oak, lime and ash-tree. The steppe grassland included arid-resistant grasses, such as Chenopodiaceae and *Artemisia*.

Early farming Starčevo-Körös-Criş communities in the Balkans (7900-7500 BC), at their later stage spread east of Carpathian Mountains reaching Moldavia and western Ukraine. The studies of culturally related site of Sakarovka I in Moldavia yielded the impressions of grains of emmer wheat, spelt, hulled and naked barley, millet (apparently wild) and pea and bitter vetch among the pulses. Charred grains of emmer and spelt two fragments of pea, together with green and yellow bristle-grass (*Setaria viridis*, *Setaria glauca*), seeds of *Galium sp, Polygonum sp.*, and imprints of *Allissum sp.,* *Agrostemma sp., Setaria sp.* were identified on the plaster house platforms. These latter plants could be either weeds or elements of local vegetation (Kuz'mynova, Dergachev and Larina 1998).

Cultivated plants indicated in archaeological deposits of the Neolithic Bug-Dniestr Culture (BDC), are generally considered as resulting from the Starčevo-Criş influence. If this was the case, this influence apparently directly affected the Southern Bug settlements, as indicated by the occurrence of hulled barley, not found at the Dniestr sites (Yanushevich 1989). The pottery of the southernmost sites, Pugach and Gard, shows no plant imprints.

The studies of multiple pot sherds from nine BDC sites (Baz'kov Ostrov, Sokol'tsy, Mit'kov Ostrov, Savran', Ladyzhin, Zan'kovtsy, Mikulina Broyaka, and Shumilovo) currently initiated by N.S. Kotova, have indicated an insignificant number of imprints of cultivated plants implying a negligible role of agriculture in their subsistence. These were rare imprints of emmer wheat *Triticum dicoccon,* hulled barley *Hordeum vulgare*, millet *Panicum miliaceum* and two more seeds, supposedly, linen *Linum usitatissimum*. An easily identifiable imprint of emmer spikelet has been found on a pot sherd from Zan'kovtsy (Kotova 2002 ;Kotova and Pashkevich 2002). At the BDC sites on the Dniestr River, Soroki 1, 3, 5, Ruptura and Sakarovka I, apart of the above-mentioned species, the imprints of spelt, naked barley, and oats *Avena sp.* were identified (Yanushevich 1989).

The large-scale agricultural colonisation of Ukraine corresponded to the expansion of Cucuteni-Tropolye settlements that occurred during the Late Atlantic – Early Subboreal periods in an environment of high temperatures and precipitation highly appropriate for early farming. The early Tripolye settlements encompassed a vast area of western forest-steppe from the Prut to the middle stretches of the Southern Bug. As show the archeobotanical studies (Pashkevich 2000, 2003; Pashkevich and Videiko 2005) the assortment of early Tripolye cultigens remained fairly uniform throughout all three major stages of the Tripolye Culture. The dominant species of cereals were hulled wheats: emmer (*Triticum dicoccum* Schrank,) which prevailed, einkorn (*T. monococcum* L.) and spelt (*T. spelta* L.*)*, supplemented by naked six-row barley (*Hordeum vulgare* L.) and hulled barley (*Hordeum vulgare* L.). Bread wheat/club wheat formed small admixtures to other cereals. Broomcorn millet (*Panicum miliaceum* L.) was less common. The minor variations are observable only in relative importance of these plants.

The settlements of Gumelnitsa Culture were found in the steppe areas Odessa Oblast and the neighbouring Moldavia. Their age is estimated based on radiocarbon dates obtained for the site of Vulcanesti III in southern Moldavia: MO-417: 5810 ± 150 years BP (4896-4503 years BC cal.) and LE-640: 5300 ± 60 years BP (4235-4006 years BC cal.). The pollen data indicate the wetter climate as compared to the present-day conditions. The subsistence was predominantly based on animal rearing, and included the cattle, sheet/goat, pig and horse. Agriculture was apparently less important. Yanushevich (1976) has identified the impressions of emmer (most common cereal), einkorn and spelt; hulled and naked barley, and also oats, millet and blackthorn.

During the Subboreal period, in an environment of growing aridity, several cultural entities arose along the margins of Tripolye Culture in the forest-steppe area, from the Danube to Molochnaya River including the Dereivka, Lower Mikhailovka and Pivikhian. As demonstrate the archeobotanical evidence (Pashkevich 2000, 2003), agriculture was of minor importance for the livelihood of all these cultures. Amongst the studied 2,461 pot sherds of Lower Mikhailovka sites only nine revealed imprints of cultigens, which included *Triticum dicoccon* (4 impressions), *Hordeum vulgare* (also 4), *Panicum miliaceum* (1) and *Vicia sp.*(1). At Molukhov Bugor site (the Dereivka Culture) only eight imprints (out of 372 studied samples) have been identified, they included emmer, einkorn, millet and hulled barley. Two imprints belonged to wild Gramineae. The ethnobotanic records at Dereivka site included a single imprint of rye (*Secale sp.*), imprints of emmer and hulled barley (two of each), and single imprints of naked barley, as well as those of weeds *Setaria sp.* (1) and *Echinocloa crus galli* (1). Lysaya Gora and Prisya sites which belong to the Pivikhian Culture in the Middle Dniepr area yielded but a few pot sherds with imprints, which included: *Triticum dicoccon* – (1), *Pisum sativum* – (1), *Vicia ervilia?* – (1), *Panicum miliaceum* – (2), and *Bromus sp.* – (1).

In the second half of the 3rd millennium BC, predominantly stock-breeding Usatovo groups appeared in the western steppe area (Zbenovich 1971). The ethnobotanical records indicate the agricultural component in their subsistence. The studies of pot sherds of Bol'shoi Kuyalnik and Mayaki sites near Odessa, identified the imprints of *Triticum monococcum, Triticum dicoccon, Triticum aestivo-compactum* and seeds of peas *Pisum sativum* as well as straw fragments resulting from cereals thrashing. Imprints of millet were most frequent on the pottery and were also found on ritual figurines (Kuz'minova & Petrenko 1989).

The pollen data indicate the growing aridity of climate in the steppe and forest-steppe Ukraine starting with the final 3rd millennium BC, at the beginning of the Middle Subboreal zone. The Kardashinsky bog pollen sequence on the Lower Dniepr stretches shows the maximum abundance of broad-leaved arboreal species (particularly, the oak) in an interval of 4.5 – 4.2 ky (Kremenetsky 1991).This was accompanied by the reduction of forests on river terraces and the expansion of shrubs including hazelnut, buckthorn, sallow thorn, and elder. The time-span of 4.2 – 3.7 ky saw the further reduction of valley forests, with the diminished abundance of elm, hornbeam and grape-vine. The Middle Subboreal spectra of the Orgeyev (Orhei) lake show the total disappearance of forests and the spread of steppe grassland with an elevated participation of Compositae, Criciferae and Plumbaginaceae.

The Middle Subboreal dry episode is equally acknowledgeable in eastern Ukraine's steppe, in the Donetsk basin and Azov Sea coastal area. The spectra obtained for Bronze Age sites: Bezymennoe I and II, Kamyshevataya XIV, XIX, Glubokoye Ozero 2 and Rogalik 12, ^{14}C dated to: 3720±90, 3505±100, 3460±100 indicate an abrupt reduction of both arboreal species and mesophytic forbs (Gerasimenko 1997). Bunchgrass steppe with an abundance of wormwood became the dominant vegetation type in the Donetsk basin, and wormwood-bunchgrass steppe, in Azov Sea coastal area. The Ukraine south-east became quasi-totally treeless, broad-leaved trees (oak, lime and ash-trees) surviving only inside the ravines. The floodplains were drained and their vegetation acquired xerophytic character.

Special geobotanic studies (Osichnyuk 1973) show that the 'pastoral digression' under the impact of grazing results in an increased xerophytisation of the vegetation cover. In the case of forbs-fescue-feathergrass steppe, this lead to a decreased abundance of feathergrass, and the change in the composition of forbs. The intensive grazing resulted in the emergence of numerous annual ruderals, such as knotgrass, Tartar orache, as well as perennials: Austrian wormwood , prostrate summer cypress and some others.

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Multiple Sources for Neolithic European Agriculture: Geographical Origins of Early Domesticates in Moldova and Ukraine

Giedre Motuzaite-Matuzeviciute,[1] Harriet V. Hunt[2] and Martin K. Jones[1]

[1]*Department of Archaeology, University of Cambridge, Downing Street, Cambridge CB2 3DZ, UK*
[2]*McDonald Institute for Archaeological Research, University of Cambridge, Downing Street, Cambridge CB2 3ER, UK*

Introduction

Discussion of the spread of agriculture into Europe has concentrated almost exclusively on the west and centre of the continent, spanning the longitudes from the Atlantic seaboard to the western edge of the Black Sea. In this respect, two routes have been well documented, both from ultimate origins in the Near East: a coastal route, marked out by the presence of shell-impressed (Cardium) pottery, and an inland route, along the Danube Basin, and marked out from Hungary onwards by Linear Bandkeramik (LBK) pottery. However, geographical Europe extends eastward to the Ural Mountains. The spread of agriculture across the eastern half of the continent has been less intensively studied (cf. Milisauskas, 1986, Whittle, 1996, Gronenborn, 2003, Dolukhanov *et al.*, 2005), even though this region constitutes a potential 'crossroads' of interaction between Europe, the Near East, and Asia. To address this balance, we focus in this paper on Ukraine and Moldova, and review the archaeobotanical evidence for domesticated crops before 5000 BC.

Agriculture is usually assumed to have spread into this region from an eastward branch of the Danubian route. Through consideration of the domesticated plants, we explore the possible influence of two other areas on the adoption of farming in Moldova and Ukraine: the east Caspian basin/Caucasus corridor, and north-central Asia. The implications of such possible influences go beyond the region in question, and contribute to our understanding of the spread of agriculture across Europe as a whole.

The study area

In recent times, much of the study area has been under intensive agriculture. In the pre-5000 BC period, the archaeobotanical evidence currently available derives predominantly from the west of the region. The inferred climatic climax vegetation follows a north-west to south-east cline, from deciduous forest, through forest steppe to full steppe, along a gradient of increasing summer temperatures and transpiration/precipitation ratios. While the boundaries between these zones are not fixed in space and time, there may well be a broad correlation between the highest density of pre-5000 BC crop records and the inferred region of forest steppe. To the east, similar clines from forest, through forest steppe to steppe continue intermittently towards northern China. To the southeast, they connect with a 'Caucasus Corridor', a region of varied topography between the Black and Caspian Seas. To the northwest of the region, as the patterns of seasonality and biological productivity shift, woodland predominates in the climax vegetation. To the southwest, the Carpathian Mountains fall away into the Danube Basin.

Early agriculture in Ukraine and Moldova

Archaeology has not been the only source of evidence contributing to our understanding of agriculture in this region. At least as influential has been the evidence from historical linguistics, and a close analysis of Indo-European word stems. These have been interpreted as emphasizing horse-riding and pastoralism, at the expense of agriculture and fishing, reference to which has seemed absent from the proto-Indo-European lexicon (cf. Gimbutas, 1952, Mallory, 1989). This analysis has been questioned by reference to the archaeological record (Renfrew, 1987), and scientific analyses have provided direct evidence of both agriculture (Rassamakin, 1999, Pashkevich, 2003) and fishing (Lillie and Richards, 2000, O'Connell *et al.*, 2003, Lillie and Jacobs, 2006). The absence of linguistic reference to farming and fishing has moreover been queried (Jones, 2002).

A current synthesis of material cultural and scientific evidence points towards a mixed agricultural economy in the Neolithic, under a predominantly western influence, a consequence of the spread of LBK farmers along the valleys to the north of the Carpathian Mountains and the formation of the Cucuteni-Tripolye Culture under the influence of farmers in the Balkan-Danube region (Danilenko, 1969, Zvelebil and Lillie, 2000, Davison *et al.*, 2006, Zbenovich, 1996). Meanwhile, some researchers suggest a much earlier origin of agriculture in Moldova and Ukraine, beginning in the Southern Bug - Dniester River basins by the end of the 7th millennium BC, influenced by Körös-Criş farmer communities (Tovkailo, 2005, Markevich, 1974, Danilenko, 1969, Zaliznyak, 1998, Dergachev et al., 1991). The Neolithization of this region has normally been considered in terms of pottery typology, in keeping with Soviet-influenced definitions of the Neolithic. Relatively little archaeobotanical and zooarchaeological investigation has been carried out in this region to date, and the direct evidence for domesticated plants and animals is accordingly rather patchy compared to more westerly regions of Europe.

The evidence for agriculture in Ukraine and Moldova comes mostly from grain impressions in pottery. Our current knowledge of the specific taxa of domesticated plants in use in Ukraine and Moldova includes evidence of einkorn (*Triticum monococcum*), emmer wheat (*Triticum dicoccum*), spelt wheat (*Triticum spelta*), bread wheat (*Triticum aestivum*), hulled and naked barley (*Hordeum vulgare* and *Hordeum vulgare* var. *nudum*), millet (specifically proso millet, *Panicum miliaceum*), flax (*Linum usitatissimum*), pea (*Pisum sativum*), bitter vetch (*Vicia ervilia*) and hemp (*Cannabis sativa*) (Yanushevich, 1989, Pashkevich, 2003). The earliest crop records are reported from the Bug-Dniester Culture (c.6400-5300 BC) in the form of impressions of barley, millet and flax in pottery ascribed to the end of the 7th millennium BC (eg. Pashkevich, 2003).

Among all Neolithic records of domesticated plants from the region, the earliest and most numerous are of barley (Yanushevich, 1989, Pashkevich, 2003). The oldest imprints of barley in pottery were found in Ukraine at Sokoltsy 2 (c.6400-6000 BC), Sokoltsy 6 (6400-5300 BC), Bazkov Ostriv (5600-5500 BC), and Shumilovo (5900-5300 BC) (Kotova, 2003, Pashkevich, 2003). In Moldova one imprint from the Bug-Dniester culture site Soroki (c.6300-5400 BC) was tentatively ascribed to barley. All other barley records from Moldova come from LBK sites (see Table 1).

A crop frequently found together with barley at Ukrainian Neolithic sites is proso millet (Pashkevich, 2003). This crop has been reported from Neolithic cultures of various parts of Europe: the LBK, Vinça, Körös, Starčevo, Criş, Bug-Dniester, Volyn, Kiev-Cherkasy, Donetsk, Sesklo/Proto Sesklo and Tripolye cultures (Hopf, 1962, Kroll, 1981, Comşa, 1996, Kotova, 2003, Larina, 1999, Pashkevich, 2003, Kreuz *et al.*, 2005, Greenfield & Jongsma, 2008). For the period under consideration here, millet records from central and southern Europe remain rare, and the majority of records are from Ukraine and Moldova. As with other Neolithic crop records in Moldova and Ukraine, the dating of proso millet records is usually on the basis of pottery typology. For example, of the six Neolithic sites in Ukraine at which *Panicum miliaceum* was identified, radiocarbon dates are available only for the Bug-Dniester culture site of Sokoltsy 2. Here, the cultural layer of the pottery containing a millet imprint was dated to 6300-6250 BC (Kotova, 2003, Pashkevich, 2003). The most numerous records of proso millet come from two LBK sites in Moldova. 59 imprints were identified in Denchen 1, and 97 imprints in Sakarovka 1, both attributed by Larina to the 2nd half of the 6th millennium BC (Yanushevich, 1986, Larina, 1999).

These early records form a prelude to a long and significant history of millet cultivation in this region. It becomes a predominant component of Chalcolithic assemblages of the 5th and 4th millennia BC (Yanushevich, 1976, 1980, Zohary and Hopf, 2000, Pashkevich, 2003). In the Mayaki site (2nd half of the 4th millennium BC) impressions of proso millet have been found on 70 cult clay statuettes, suggesting a special significance for millet among the inhabitants of this site (Kuzminova and Petrenko, 1989). On the basis of both macrofossils and impressions, Pashkevich (1984, 2003) concludes that proso millet, barley, and wheat were major crops among the Bronze and Iron Age cultures of the steppe region.

Another early cereal in the region under consideration is spelt wheat, *Triticum spelta*. It is recorded from the Bug-Dniester, Criş and LBK cultures in the period 6300-5300 BC (Wasylikowa *et al.*, 1991, Shnirelman, 1992, Larina, 1999). In Ukraine it has only been reported from one Bug-Dniester Culture site, Shimanovskoye, whereas in Moldova it is known from eight sites belonging to both the LBK and Bug-Dniester Cultures (Yanushevich, 1976, 1980, Kotova, 2003, Pashkevich, 2003).

Seed impressions of hemp (*Cannabis sativa*) have been identified in pottery from Denchen 1 in Moldova and the Zimne site in Ukraine (Larina, 1999, Pashkevich, 2003).

There are some notable correlations between crops and cultures. For example, rye, oats and hemp are only recorded from LBK sites, and these crops, together with bitter vetch and peas, are all absent from the Bug-Dniester culture. Flax is only reported from the Bug-Dniester Culture.

Evidence for early farming in southeastern Ukraine comes from sites dated to the end of the 7th - beginning of the 6th millennium BC along the northern Azov Sea coast belonging to the Surskaya and Azov-Dnieper Cultures (Kotova, 2003). The data consist of domestic animal bone finds and palynological records. In most of the excavated sites in this region the animal bones - bovines, equines and ovicaprines - were identified as domestic (Kotova, 2003). Pollen attributed to domesticated cereal has been identified from a cultural layer dated to 8020-7030 BP from the Chepaevka settlement situated on the Molochnaya River, north-west of the Azov Sea (Bezusko *et al.*, 2000). (Table 1. Fig. 1).

Adjacent to our study area in modern-day Russia, archaeological sites in the northern Azov Sea and lower Don River valley regions with a range of 7th millennium BC dates, have yielded domesticated animal bones, reaping knives, pestles, horn mattocks, grinding stones and cereal pollen (Belanovskaya, 1995, Kotova, 1998, 2003). The pollen evidence includes "20 large grass pollen grains", presumed to be cereal type, from the Neolithic level (attributed to c.6350 BC) at the Matveev Kurgan 1 site on the north west Azov Sea

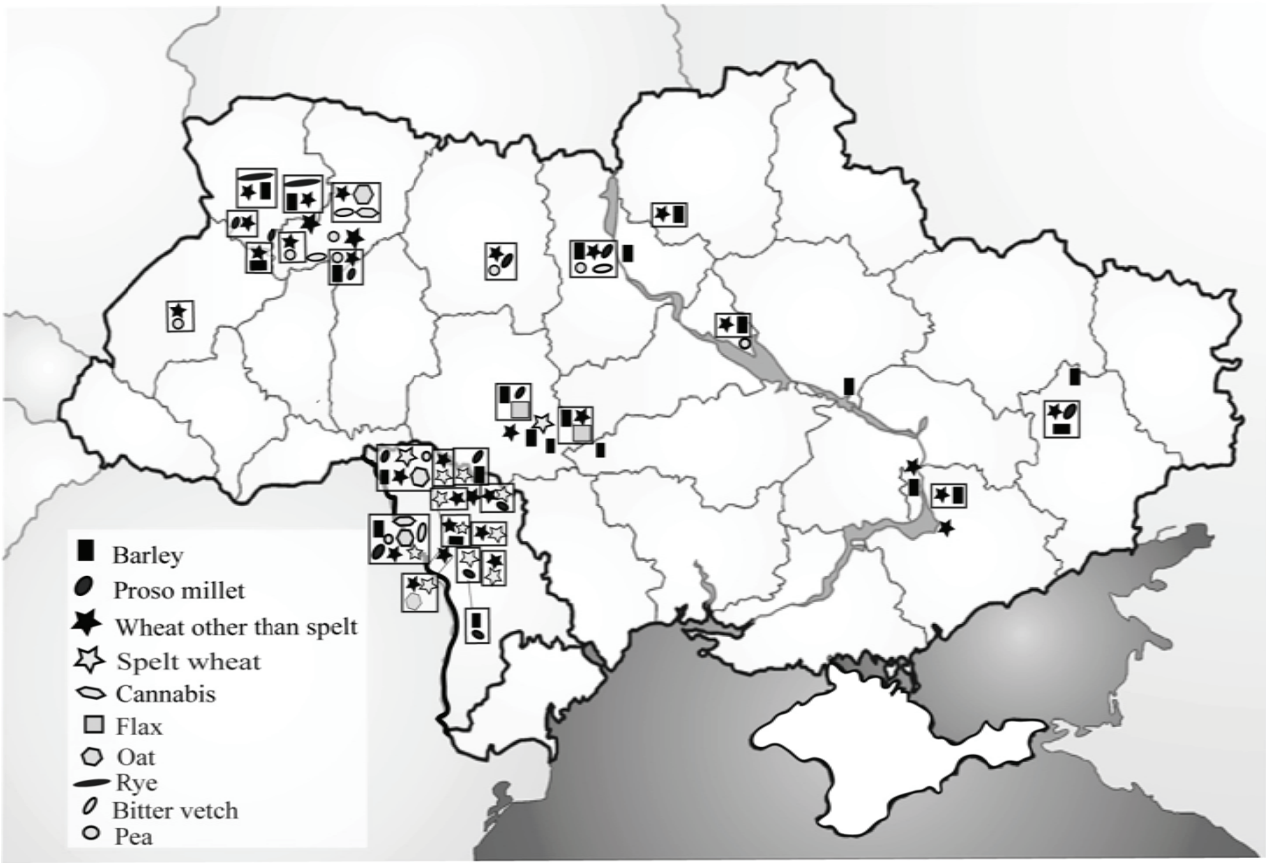

Fig. 1. Sites with records of seed/grain crops in Moldova and Ukraine prior to 5000 BC.

coast (Krizhevskaya, 1992). From a time lag potentially indicated in the above dates, Kotova (2003) has argued for an east west movement of early agriculture across Ukraine.

The arrival of agriculture in Moldova and Ukraine has generally been discussed in terms of an eastward 'front' of the Neolithic spread to central Europe ultimately deriving from the Danubian route. However, on the basis of the evidence listed above, Kotova (2003) suggested that agriculture in the Bug-Dniester Culture in Ukraine developed under the influence of the Lower Don and northern Azov Sea cultures to the south and east. The archaeobotanical records considered above include taxa not associated with early Danubian agriculture, particularly *Panicum* and *Cannabis*, lending support to the idea of alternative corridors of entry into the region. In the following sections we consider the archaeobotanical and genetic evidence for these two alternative 'corridors' into Europe.

The Caucasus corridor

An early spread of domesticates into Europe from or via the Caucasus has been postulated by several researchers (e.g. Telegin, 1977, Dolukhanov, 1982, Yanushevich, 1984, Shnirelman, 1989, 1992, Jacobs, 1993, Jacobs *et al.*, 1996), stemming from the identification of the Caucasus as a centre of early farming, and possible locus for independent domestications (Vavilov, 1940). Both archaeobotanical and archaeozoological links between the Caucasus and the steppe regions to the north have been noted. For example, Wasylikowa *et al.* (1991) argued that agriculture in Moldova and Ukraine, including the Crimea, developed under the influence of the Caucasus region. Shnirelman (1992) and Kotova (2003) have argued that the origin of early Neolithic BC sheep and goat remains, found in the settlements along the northern Azov Sea coast and in the lower valley of the Don River, are also linked with a Caucasus route.

Both naked and hulled six-row barley have been found among the earliest domesticated plants in the northern Caucasus settlement of Chokh in Dagestan, dated through cultural association to the 7th-6th millennia BC (Amirkhanov, 1987). Other sites sharing a similar archaeological inventory are known from the northern Caucasus region. These include the Rugudjin and Sosruko cave sites in Kabardino Balkharia, which yield artifacts resembling those from Chokh, but which have not yet been studied in detail (Kotovich, 1964). The oldest domesticated plants, including naked barley, from the southern Caucasus are from the end of the 7-6th millennia BC, at the Armenian Neolithic sites of Aratashen and Aknashen (Hovsepyan, 2004, Hovsepyan and Willcox, 2008.

Recent genetic studies on the origins of domestic barley lend support to the idea of an additional, east Caspian basin/Caucasus, route of its introduction to Europe from the east, in parallel with the established Danubian and Mediterranean coastal routes. There is evidence that domestic barley had two independent origins: one in the southern part of the Fertile Crescent and the other further east in central Asia, at the eastern edge of the Iranian plateau (Morrell and Clegg, 2007). These authors have suggested that this second domestication contributed to most of the genetic diversity in barleys from central Asia to the Far East. However, research by Jones *et al.* (2008) on allele distribution in the photoperiod response gene Ppd-H1 suggests that *Hordeum vulgare* landraces in northern, central and eastern Europe today may also have drawn on a gene pool located some way to the east of the Fertile Crescent. These landraces have a high frequency of the mutant allele *ppd-H1*, which makes the plants unresponsive to long days and thus delays flowering, allowing the plants to be better adapted to the longer growing season and reduction in aridity in non-Mediterranean climates (Cockram *et al.*, 2007). The discovery of a wild barley population in Iran with the *ppd-H1* mutation suggests a possible geographic origin for this genotype, with possible spread into Europe via the east Caspian basin/Caucasus/steppe route, away from Mediterranean latitudes favouring the photoperiod-responsive type *Ppd-H1* (Jones *et al.*, 2008).

Another possible candidate for westward movement into Europe from north of the Black Sea is spelt wheat. Two possible evolutionary scenarios have been proposed for the origins of this taxon (Dvorak *et al.*, 1998, Nesbitt, 2001). The first derives the hexaploid spelt wheat from a cross between a domesticated tetraploid wheat, and the wild diploid goat grass *Aegilops squarrosa*. The second derives hexaploid spelt wheat from introgressive hybridisation between two distinct domesticated wheats: hexaploid bread wheat (*Triticum aestivum*) and tetraploid emmer wheat (in the source publications variously called *Triticum turgidum* subsp. *dicoccon* and *Triticum dicoccum).* The first of these scenarios would imply an origin in the southern Caspian basin, where the range of wild *Aegilops squarrosa* overlaps with that of tetraploid AABB-genome wheats. The archaeobotanical evidence is consistent with the hypothesis of a southern Caspian origin of spelt and its spread to Europe via the Caucasus and Black Sea regions: the earliest archeobotanical records of spelt wheat to date are from the Bug-Dniester sites in Moldova and Ukraine, dated between 6300-5300 BC (Yanushevich, 1976, 1986, Larina, 1999, Kotova, 2003, Pashkevich, 2003) and from Georgia, found in Arukhlo and Imiris-Gora at 5800-4800 BC (Yanushevich, 1976, Kiguradze, 1986). However, analysis of genetic diversity at the *GluDy* locus is more consistent with a central or western European origin for spelt by the second evolutionary scenario (Giles and Brown, 2006). Further work is needed to reconcile the archaeobotanical and genetic data.

An eastern corridor from central Asia and China

Crop evidence prior to 5000 BC

Panicum miliaceum is not known from the Fertile Crescent before the 1st millennium BC (Nesbitt and Summers, 1988). Its geographical origin may thus be presumed to lie elsewhere. However, its wild ancestor has not been conclusively identified. A weedy subspecies, *Panicum miliaceum* subsp. *ruderale*, which could represent an ancestral form. grows between the Aralo-Caspian Seas basin and northern China (Kitagawa, 1937), leading Zohary and Hopf (2000) to suggest a dual domestication, with one origin in northern China, the other as far west as the Aralo-Caspian basin.

The earliest carbonized proso millet remains are known from China, dated to the late 7th – early 6th millennium BC (Cohen, 2002, Zhao, 2005, Crawford, 2006). Jones (2004) has suggested that a Chinese domestication substantially predating these finds, followed by spread westward to Europe, might be possible. The earliest proso millet record in the territory between China and the Ural mountains is relatively late, coming from the Chalcolithic Sokolniki site (3200-2500 BC) in the southern Tumen region, western Siberia (Shnirelman, 1992). However, this region is not well explored archaeobotanically.

Hemp (*Cannabis sativa*) grows in a presumed wild state across a broad region of central Asia, running from the Caspian Sea to the Himalayas (Zohary and Hopf, 2000). While its genetics and archaeological history could benefit from further study, it had clearly traveled from central Asia westward into Ukraine and Moldova by the 6th millennium BC (Larina, 1999, Pashkevich, 2003).

Later crops involving possible east-west contacts

The idea that the Neolithic of eastern Europe was influenced by contact with central and eastern Asia is consistent with the presence in Europe of a number of crops which arrived somewhat later than the period under examination here. Another millet, foxtail millet (*Setaria italica*), appears in the archaeobotanical record in a number of 6th and 7th millennium BC sites in the Yellow River valley and other regions of north China. The genetic evidence suggests this crop was probably domesticated independently in this region and in Afghanistan/northwestern Pakistan; European landraces have the same nuclear ribotype as those from eastern Asia (Li *et al.*, 1995, Fukunaga *et al.*, 2006), suggesting they originated in this region. Foxtail appeared first in the Danube Valley and the Caucasus around the 5th-4th millennia BC. It has not been recorded from the intervening central Asian region until the mid-2nd millennium BC (Zohary and Hopf, 2000, Jones, 2004).

Konishi *et al.* (2005) inferred the Sanjiang area of southeastern China as the geographical origin of buckwheat on the basis of genetic similarity of domesticated buckwheat to local populations of its wild ancestor *Fagopyrum esculentum* subsp. *ancestrale*. However, the earliest evidence of Chinese buckwheat cultivation comes from pollen sequences in the north, identifying buckwheat cultivation circa 5400 BP (Li *et al.*, 2006). Janik (2002) speculates on the basis of early European records of buckwheat that it traveled through the northerly route of the Central Asian Steppes to Europe.

In this general context, it is interesting to note another Asian domesticate, the apple, whose wild progenitor is the central Asian species *Malus sieversii* (Harris *et al.*, 2002). Currently, the majority of earlier archaeobotanical identifications are not taken further than the generic level, and a great number of *Malus* sp. records may well be of *Malus sylvestris*, a wild apple species widely distributed throughout Europe. As the record improves, it will be interesting to see how far back in time taxa with a central Asian ancestry appear in Europe.

Conclusions

Ukraine and Moldova together occupy a large area toward Europe's eastern fringes, surrounded by the Carpathian Mountains, Danubian Basin and North European Plain to the west, the Black Sea and Azov Sea to the south, and the Caucasus Mountains, Don River and Russian steppe- and forest-steppe zones to the east. The coming of agriculture to this region has been under-studied, but was undoubtedly shaped by these varied geographic features. Two routes of early Neolithic influence are well-attested and discussed in the literature on Europe, a coastal (Mediterranean) and an inland (Danubian) route. In this paper we have explored two further potential routes of interaction. Neolithic interaction between Europe and eastern Asia has been noted by Li *et al.* (2007) with regard to the presence of wheat in northwestern China. Contrary to these authors' conclusions, however, early trans-Asian crop movement was bidirectional, as indicated initially by the cross-continental distribution of broomcorn millet in the 6th millennium BC, and subsequently by the eastern Asian distribution of barley, and European distributions of foxtail millet, buckwheat, hemp and apple. Bidirectional movement of crops may also have occurred along the Caucasus corridor, with possible southward movement of broomcorn millet in the Late Neolithic, concurrently with northward movement of barley and spelt wheat, although further genetic and/or archaeobotanical work on all these crops is needed to substantiate this speculation.

Overall, the assemblage of crops in Ukraine and Moldova suggests this region may have been a Neolithic 'melting pot' influenced from multiple directions. This region could have acted as a 'back door' for movement into Europe of a significant minority of crops, which subsequently became more widespread in the continent.

Table 1. Records of seed/grain crops in Moldova and Ukraine prior to 5000 BC.

Location	Culture	Site name	Date	Details	Reference
Ukraine (W-central)	Bug-Dniester	Sokoltsy 2	6440-6090 BC[1] (2 dates)	*Hordeum vulgare* 1 (PI) (1^{st} period)	Kotova, 2003, Pashkevich, 2003, Telegin et al., 2003
Ukraine (W-central)	Bug-Dniester	Sokoltsy 6	6400-5300 BC[4]	*Hordeum vulgare* 1 (PI) (1st or 2nd period)	Kotova, 2003
Ukraine (SW)	Bug-Dniester	Mikolina Broyaka	5439 +/-75 BC[2]	*Hordeum vulgare* 2 (PI) (2nd period)	Pashkevich, 2003, Tovkailo, 2005
Ukraine (SW)	Bug-Dniester	Shumilovo	5900-5300 BC[4]	*Hordeum vulgare* 1 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (SW)	Bug-Dniester	Bazkov Ostrov	5581-5498 BC[1] (2 dates)	*Hordeum vulgare* 3 (PI)	Pashkevich, 2003
Moldova (N)	Bug-Dniester	Soroki 1	6300-5400 BC[5]	cf. *Hordeum vulgare*	Yanushevich, 1976
Ukraine (S-central)	Azov-Dnieper	Nikolskoe cemetery	5308-5099 BC[1] (3 dates)	*Hordeum vulgare* var. *nudum* 1 (PI) (2nd period)	Telegin et al., 2002, Kotova, 2003
Ukraine (central)	Dnieper-Donets: Kiev-Cherkasy	Uspenka	5700-5150 BC[4]	*Hordeum vulgare* var. nudum 1, *H. vulgare* 1 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (central)	Dnieper-Donets: Kiev-Cherkasy	Buzki	5700-5150 BC[4]	*Hordeum vulgare* 3 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (central)	Dnieper-Donets: Kiev-Cherkasy	Vita Litovskaya	5200-4250 BC[4]	*Hordeum vulgare* 2 (PI) (2nd period)	Kotova, 2003
Ukraine (E)	Donets	Serebryanskoe	5350-5050 BC[4]	*Hordeum vulgare* 1 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NE)	Dnieper-Donets: Kiev-Cherkasy	Kamenka	5200-4250 BC[4]	*Hordeum vulgare* 1 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (central)	Dnieper-Donets: Kiev-Cherkasy	Grini	5200-4250 BC[4]	*Hordeum vulgare* 1 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NE)	Dnieper-Donets	Pustynka	5500-3500 BC[7]	*Hordeum vulgare* (PI)	Zvelebil and Lillie, 2000, Pashkevich, 2003
Ukraine (W)	LBK	Rovno	5550-5150 BC[4]	*Hordeum vulgare* var. *nudum* 9, *Hordeum vulgare* 2 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W)	LBK	Golyshev	5450-5050 BC[4]	*Hordeum vulgare* var. *nudum* 4, *Hordeum vulgare* 2 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W)	LBK	Girka Polonka	5450-5050 BC[4]	*Hordeum vulgare* var. *nudum* 2, *Hordeum vulgare* 3 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W)	LBK	Gnidava	5050-4650 BC[4]	*Hordeum vulgare* 1, *Hordeum* vulgare var. nudum 2 (PI) (3rd period)	Pashkevich, 2003
Moldova (central)	LBK	Denchen 1	End of the 6^{th} millennium BC[6]	*Hordeum vulgare* 7 (PI)	Larina 1999
Moldova (central)	LBK	Durlesht 1	Late 6^{th}-early 5^{th} millennium BC[6]	*cf. Hordeum vulgare* 1 (PI)	Larina 1999
Moldova (central)	LBK	Rogozhen 2	Late 6^{th}-early 5^{th} millennium BC[6]	*Hordeum vulgare* var. nudum (PI)	Larina 1999
Moldova (central)	Criş	Sakarovka 1	5644-5486 BC[3]	*Hordeum vulgare* var. *nudum*, *H. Hordeum. vulgare* (charred seeds)	Yanushevich, 1986, Larina, 1999

Ukraine (S-central)	Mariupol-Azov-Dnieper	Vovnigi	5200-4750 BC[4]	*Hordeum vulgare* cf. *nudum* -1 (PI) (2nd period)	Kotova, 2003
Moldova (NE)	Bug-Dniester/Criş	Ruptura	5976-5560 BC[3]	cf. *Panicum miliaceum* 1 (PI)	Yanushevich, 1989
Moldova (NE)	Bug-Dniester	Soroki 1	6300-5400 BC[5]	cf. *Panicum miliaceum* 1 (PI)	Yanushevich, 1976
Moldova (central)	LBK	Durlesht 1	Late 6th-early 5th millennium BC[6]	*Panicum miliaceum* 1 (PI)	Larina 1999
Moldova (central)	Criş	Sakarovka 1	5644-5486 BC[3]	*Panicum miliaceum* 97 (PI)	Larina, 1999
Moldova (E-central)	LBK	Braneshty 1	Late 6th-early 5th millennium BC[6]	*Panicum miliaceum* 1	Yanushevich, 1976
Moldova (central)	LBK	Denchen 1	End of the 6th millennium BC[6]	*Panicum miliaceum* 60 (PI)	Larina 1999
Ukraine (central)	Kiev-Cherkasy	Grini	5200-4250 BC[4]	*Panicum miliaceum* 3 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NW)	Dnieper-Donets: Volyn	Krushniki	5100-3850 BC[4]	*Panicum miliaceum* 2 (PI) (2nd period)	Kotova, 2003
Ukraine (NW)	Dnieper-Donets: Volyn	Mala Osnitsa	5450-5100 BC[4]	*Panicum miliaceum* 1 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NW)	Dnieper-Donets: Volyn	Obolon	5450-5100 BC[4]	*Panicum miliaceum* 1 (PI) (1st period)	Kotova, 2003
Ukraine (NE)	Dnieper-Donets	Pustynka	5500-3500 BC[4]	*Panicum miliaceum* (PI)	Zvelebil and Lillie, 2000, Pashkevich, 2003
Ukraine (W)	LBK	Rovno	5550-5150 BC[4]	*Panicum miliaceum* 2 (PI) (1st period)	Kotova, 2003
Ukraine (W-central)	Bug-Dniester	Sokoltsy 2	6440-6090 BC[1] (2 dates)	*Panicum miliaceum* 1 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003, Telegin et al., 2003
Ukraine (SW)	Bug-Dniester	Shimanovskoye	5900-5300 BC	*Triticum spelta* 1 (PI) (2nd period)	Kotova, 2003
Moldova (NE)	Bug-Dniester/Criş	Ruptura	5976-5560 BC[3]	*Triticum monococcum*, *T. dicoccum*, *T. spelta* (PI)	Yanushevich, 1989
Moldova (N)	Bug-Dniester	Soroki 2	6435-6096 BC[3]	*Triticum monococcum*, *T. dicoccum*,	Yanushevich, 1976, Quitta&Kohl, 1969
Moldova (N)	Bug-Dniester	Soroki 3	5841-5487 BC[3]	*Triticum monococcum*, *T. dicoccum*, *T. spelta* (PI)	Yanushevich, 1976, Yanushevich, 1989
Moldova (N)	Bug-Dniester	Soroki 1	6300-5400 BC[5]	*Triticum spelta* (PI)	Yanushevich, 1976
Moldova (N)	Bug-Dniester	Soroki 5	5631-5232 BC[3]	*Triticum monococcum*, *T. dicoccum*, *T. spelta* (PI)	Yanushevich, 1976, Quitta&Kohl, 1969
Moldova (central)	LBK	Denchen 1	End of the 6th millennium BC[6]	*Triticum spelta* 1, *T. dicoccum* 48, *T. monococcum* 58, *T. aestivum* 9 (charred grains)	Larina 1999 Yanushevich, 1989
Moldova (central)	LBK	Durlesht 1	Late 6th-early 5th millennium BC[6]	*Triticum dicoccum* 1 (PI)	Larina 1999
Moldova (central)	LBK	Floresht 1	Late 6th-early 5th millennia BC[6]	*Triticum monococcum* 7 (charred grains)	Larina 1999
Moldova (central)	LBK	Rogozhen 2	Late 6th-early 5th millennium BC[6]	*Triticum monococcum*, *T. dicoccum*, *T. spelta* (PI)	Larina 1999
Moldova (central)	LBK	Novye Ruseshty 1	4685-4233 BC[3]	*Triticum dicoccum*, *T. spelta* (PI)	Yanushevich, 1976, Quitta&Kohl,

					1969
Moldova (central)	LBK	Novye Ruseshty 2	Late 6^{th}-early 5^{th} millennium BC[6]	*Triticum dicoccum*, *T. spelta* (PI)	Yanushevich, 1976
Moldova (central)	LBK	Braneshty 1	Late 6^{th}-early 5^{th} millennia BC[6]	*Triticum spelta* 4 (PI)	Yanushevich, 1976
Moldova (N)	LBK	Gura-Kamenka	Late 6^{th}-early 5^{th} millennium BC[6]	*Triticum dicoccum* 2, cf. *T. spelta* (PI)	Yanushevich, 1976
Moldova (central)	Criş	Sakarovka 1	5644-5486 BC[3]	*Triticum spelta* (PI and charred grains), *T. dicoccum* (PI)	Yanushevich, 1986, Larina, 1999
Ukraine (SW)	Bug-Dniester	Bazkov Ostrov	5581-5498 BC[1] (2 dates)	*Triticum dicoccum* 1, *T. monococcum* 3 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W)	LBK	Nezvisko	5550-4650 BC[4]	*Triticum dicoccum* (charred grains)	Chernysh, 1962 as cited in Pashkevich, 1997
Ukraine (S-central)	Mariupol-Azov-Dnieper	Strilcha Skelya	5200-4750 BC[4]	*Triticum dicoccum* -1 (PI) (2nd period)	Kotova, 2003
Ukraine (S-central)	Mariupol-Azov-Dnieper	Vovnigi	5750-5300 BC[4]	*Triticum dicoccum* -1 (PI) (period 1b)	Kotova, 2003
Ukraine (S-central)	Mariupol-Azov-Dnieper	Lysaya Gora cemetery	5200-4750 BC[4]	*Triticum* cf. *monococcum* 2, *T. dicoccum* 1 (PI) (2nd period)	Kotova, 2003
Ukraine (central)	Dnieper-Donets: Volyn	Mala Osnitsa	5450-5100 BC[4]	*Triticum dicoccum* 1 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (central)	Dnieper-Donets: Volyn	Roznychi	5450-5100 BC[4]	*Triticum monococcum* 1 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NW)	Dnieper-Donets: Volyn	Krushniki	5100-3850 BC[4]	*Triticum dicoccum* 1 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NW)	Dnieper-Donets: Volyn	Novoselki	5450-3850 BC[4]	*Triticum aestivum* 1 (PI)	Pashkevich, 2003
Ukraine (central)	Dnieper-Donets: Kiev-Cherkasy	Buzki	5700-5150 BC[4]	*Triticum monococcum* 1 (PI) (1st period)	Kotova, 2003
Ukraine (central)	Bug-Dniest	Zankovtsy	5900-5300 BC[4]	*Triticum dicoccum* (ear imprint) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NE)	Dnieper-Donets: Kiev-Cherkasy	Kamenka	5200-4250 BC[4]	*Triticum dicoccum* (2 ear imprints), *T. monococcum* 1 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NE)	Dnieper-Donets	Pustynka	5500-3500 BC	*Triticum dicoccum* (1 ears), cf. *T. monococcum* 1 (PI)	Zvelebil and Lillie, 2000, Pashkevich, 2003
Ukraine (central)	Dnieper-Donets: Kiev-Cherkasy	Grini	5200-4250 BC[4]	*Triticum dicoccum*, cf. *T. aestivum* l (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W-central)	LBK	Rovno	5550-5150 BC[4]	*Triticum dicoccum* 5; *T. aestivum* 1 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W-central)	LBK	Golovna	5550-4650 BC[4]	*Triticum monococcum* (PI)	Pashkevich, 2003
Ukraine (W)	LBK	Golyshev	5450-5050 BC[4]	*Triticum dicoccum* 1 *T. monococcum* 2 *T. aestivum* 1 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W)	LBK	Girka Polonka	5450-5050 BC[4]	*Triticum dicoccum* 1 (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W)	LBK	Gnidava	5050-4650 BC[4]	*Triticum dicoccum* 1, *T. aestivum* 1 (PI) (3rd period)	Kotova, 2003, Pashkevich, 2003

Ukraine (W)	LBK	Zimne	5550-4650 BC[4]	*Triticum dicoccum* 2 (PI)	Pashkevich, 2003
Moldova (central)	LBK	Denchen 1	End of the 6^{th} millennium BC[6]	*Cannabis sativa* 9 (PI)	Larina 1999
Ukraine (W)	LBK	Zimne	5550-4650 BC[4]	*Cannabis* sp. 1 (PI)	Pashkevich, 2003
Ukraine (W-central)	Bug-Dniester	Sokoltsy 2	6440-6090 BC[1] (2 dates)	cf. *Linum usitatissimum* 2 (PI) (1st period)	Kotova, 2003, Telegin et al., 2003
Ukraine (SW)	Bug-Dniester	Bazkov Ostrov	6400-5300 BC[4]	*Linum usitatissimum* 1 (PI)	Pashkevich, 2003
Ukraine (W)	LBK	Girka Polonka	5550-4650 BC[4]	*Secale sp.* (PI)	Pashkevich, 2003
Ukraine (W)	LBK	Gnidava	5550-4650 BC[4]	*Secale sp.* (PI)	Pashkevich, 2003
Moldova (central)	Criş	Sakarovka 1	5644-5486 BC[3]	*Avena sp.* (PI)	Yanushevich, 1986, Larina, 1999
Ukraine (W-central)	LBK	Zimne	5550-4650 BC[4]	*Avena sp.* (PI)	Pashkevich, 2003
Moldova (central)	LBK	Novye Ruseshty 2	Late 6^{th}-early 5^{th} millennium BC[6]	cf. *Avena sp.* (PI)	Yanushevich, 1976
Moldova (central)	LBK	Denchen 1	End of the 6^{th} millennium BC[6]	*Avena sativa*	Larina 1999
Ukraine (NW)	Dnieper-Donets: Volyn	Krushniki	5450-5100 BC[4]	*Pisum sativum* 1 (PI)	Pashkevich, 2003
Ukraine (NW)	Dnieper-Donets: Volyn	Konik	5100-3850 BC[4]	*Vicia ervilia* (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (NW)	Dnieper-Donets: Volyn	Novoselki	5450-3850 BC[4]	*Pisum sativum* (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (central)	Dnieper-Donets: Kiev-Cherkasy	Pischiki	5200-4250 BC[4]	*Pisum sativum* (PI) (2nd period)	Kotova, 2003
Ukraine (central)	Dnieper-Donets: Kiev-Cherkasy	Grini	5200-4250 BC[4]	cf. *Pisum sativum* *Vicia ervilia* (PI) (2nd period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W-central)	LBK	Rovno	5550-5150 BC[4]	*Pisum sativum* 3 (PI) (1st period)	Kotova, 2003, Pashkevich, 2003
Ukraine (W-central)	LBK	Litovii	5550-4650 BC[4]	*Pisum sativum* 1 (PI)	Pashkevich, 2003
Ukraine (W)	LBK	Nezvisko	5550-4650 BC[4]	*Pisum sativum* (charred pulses)	Chernysh, 1962 as cited in Pashkevich, 1997
Ukraine (W-central)	LBK	Zimne	5550-4650 BC[4]	*Vicia ervilia* 1 (PI)	Pashkevich, 2003
Moldova (central)	Criş	Sakarovka 1	5644-5486 BC[3]	*Pisum sp.* (PI)	Yanushevich, 1986, Larina, 1999
Moldova (central)	LBK	Denchen 1	End of the 6^{th} millennium BC[6]	*Pisum sativum* 10 (charred grains)	Larina 1999
Moldova (central)	LBK	Denchen 1	Late 6^{th}-early 5^{th} millennium BC[6]	*Vicia ervilia* 6 (charred grains)	Larina 1999

Note. In the case of pottery impressions (PI) the number of records is indicated when available in the source text.
Chronological sources: [1]Range of dates published in source text. [2]Date and estimate from source text. [3]OxCal4 date range (95.4%) of published uncalibrated date. [4]Date range after Kotova (2003). [5]Date range after Tovkailo (2005). [6]Periodization following Larina (1999). [7]Date range after Zvelebil & Lillie (2000). All dates are calibrated years BC.

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Late Quaternary Environments of the North Caspian Lowland

P.M. Dolukhanov,[1] A.L. Chepalyga,[2] and N.V. Lavrentyev[2]

[1]*School of Historical Studies, Newcastle University, UK*
[2]*Institute of Geography, Russian academy of Sciences, Moscow, Russia*

The Caspian Sea is the world's largest lake of inner drainage, with no outlet to the ocean The sea extends over 1000 km from the north to the south, and consists of three basins, which are different both by their depth and geologic histories: the northern (80,000 km^2, an average depth of 5–6 m and a maximum depth of 15–20 m); the middle (138,000 km^2, an average depth of 175 m and a maximum depth of 788 m), and the southern one (168,000 km^2, an average depth of 325 m and a maximum depth of 1025 m). The Caspian drainage basin covers more than 3 million sq km, and includes the Volga, Europe's largest river, which contributes more than 80% of the total river inflow, as well as several smaller rivers.

The Caspian Sea lays in the collision zone of Eurasian and Afro-Arabian tectonic plates [1]. Jointly with the Black, and Aral Seas, the Caspian Sea is a relic of the huge Tethys basin, which attained its maximum extension in Jurassic, ca. 150 million years (Ma) ago. During the Oligocene (30-10 Ma) the Afro-Arabian plate moving to the north formed a zone of subduction, and separated the Tethys' northern periphery, the Parathesys. During the Middle Miocene (15-14 Ma) the large-scale mountain-building split up the Parathesys into several minor basins, the South Caspian basin being one of them. At a later stage, the subsidence in the northern Caucasus and the adjacent Scythian-Turanian platform formed the Middle Caspian basin. Still later the Caspian basin jointed its northern extension, which had been part of a huge marine basin that had existed since the Devonian period. By the end of Miocene, ca 5.3 Ma, the advance of the Arabian Plate further to the north caused the massive uplift of the Caucasus which eventually separated the Caspian from the Black Sea. In Early Pliocene (5-3 Ma) the Northern and Middle Caspian basins became dry land, and the Palaeo-Volga carried its water directly into the South Caspian basin. The remaining marine basin was filled in with sands and clays and formed the main Caspian hydrocarbon reservoir.

The North Caspian Lowland corresponds to a tectonically heterogeneous structure, the Caspian syneclise. The Karpinsky Ridge rift system formed in mid-Devonian crosses it from the Donetsk in the north-east to the Mangyshlak Peninsula in the south-east. The Terek trough, a part of the Caucasian foredeep lies south of it, extending up to the Uralian Mountains. The Lowland includes several major anticlines and synclines generally directed from the north-west to the south-east. Impressive salt domes reaching the altitude of 100-150 m form a particular feature of the North Caspian setting.

Its present-day outlook was mostly shaped in the course of Late Pleistocene, when sizeable Khvalynian transgressions that covered its entire area (Fig. 1). Two areas are distinguishable. The northern one, which lies predominantly at the altitude ranging from 50 to 0 m, was formed by the 'chocolate' loams and silt deposited by the Early Khvalynian transgressions. Its outer rim reaches the altitude 100 m, being separated by an abrupt scrap from the Syrt Upland further north. The surface relief was subsequently cut apart by numerous lakes of inner drainage which are now taken up by salt basins or saline soils. They include 'suffusion' lakes resulting from the solution and dislocation of soil. One equally notes numerous 'limans' or estuaries as well as numerous deltas of the Volga and smaller rivers. Several generations of Volga's deltaic sediments reflect its displacements that followed the Caspian sea-level fluctuations (Kroonenerg et al.1997).

The southern area which lies below 0 m absolute was formed during the Late Khvalynian transgression. Its surface with several barrier beaches is tilted to the south, reaching the altitude of 10-12 m below the mean ocean level. It contains numerous water channels, estuaries, minor lakes and coastal barriers that were subsequently transformed by wind erosion. This led to the formation of *sors* (dry lakes) some of which are 3-5 m deep. A particular feature of North Caspian landscape constitutes elongated hills up to 20 m high and locally up to 20 km long (the 'Bear knolls'), which are viewed either as longitudinal dunes or coastal landforms (Svitoch and Yanina 1994).

Still further to the south lies the 'Neocaspian' coastal area of Holocene age, equally tilted to the south. At least three levels are distinguishable: the early (20-22 m below the ocean); the middle (22-25 m below the ocean) and the Late Neocaspian (25-28 (29) m below the ocean). The maritime areas were affected by repeated transgressions which repeatedly occurred throughout Holocene, yet never exceeded 20 m below the ocean level. The North Caspian Plain is crossed by river valleys of the Volga-Akhtuba, Ural and Emba and several minor rivers.

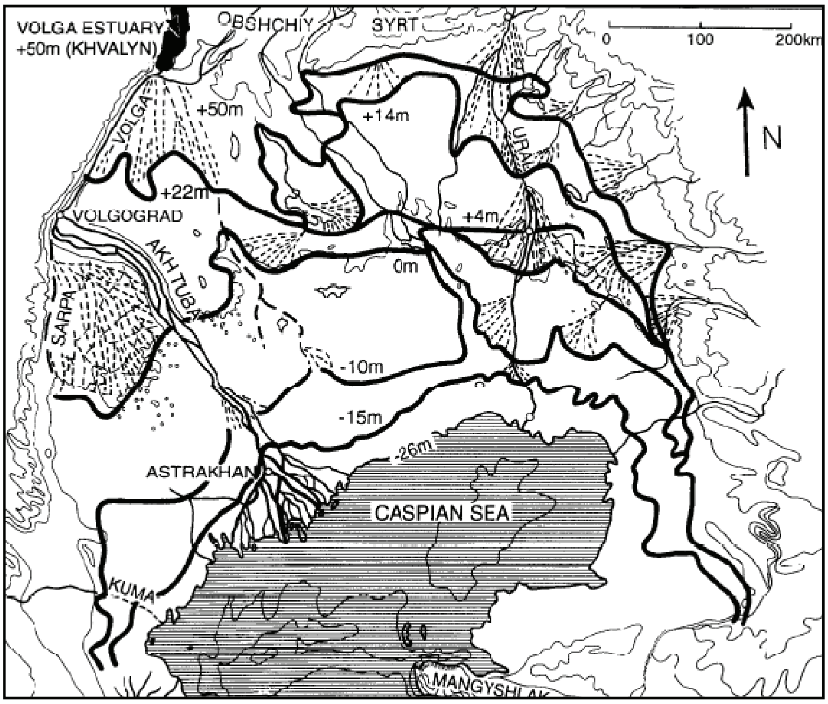

Fig. 1. Khavalynian shore-lines and ancient river deltas on North Caspian Lowland (after Kroonenberg, at al. 2007)

The present-day climate of North Caspian Lowland is continental and dry. The winter is harsh (mean January temperature -14C) with rare snow falls, the summer is hot (20-25 in July). The annual precipitation is less than 200 mm. The vegetation of the Caspian Lowland belongs to the Kazakho–Dsungarian desert belt up to 48°N, and a semi-desert up to 50°N. The Volga delta is dominated by freshwater wetlands with a *Phragmites* and *Typha* cover, with small wood patches consisting of tamarisk, willow, poplar and elm.

The peculiarity of the Caspian Sea consists in repeatedly occurring oscillations of its level. Presently the sea-level stands at 27 m below the ocean's level. Only 30 years ago, in 1977, its level was 2.5 m lower, reaching an all-time low of -29.01 m. Before that, since the 1930s, the Caspian sea-level continuously dropped to the total value of more than 3 m. In the course of late 19th century (when regular observations started) and in early 20th century the Caspian level remained at 25.5 – 26.0 m below the ocean, with a downward trend. Much greater changes of the Caspian sea-level are recorded in its geologic past.

The first major Cainozoic transgression of the Caspian Sea, the Akchagylian, started at ca 3.3 Ma. During its latest stage, which lasted until ca 1.2 Ma, the Caspian waters submerged all low-lying areas of the Caucasus, Turkmenistan and the greater part of the Volga catchment. The next major Caspian Sea transgression, the Apsheronian, began at ca 1.6 Ma and lasted until 0.96 Ma (Kroonenberg et al. 1997). Its sediments, which show a reversed polarity (Trubikhin 1997), are found at 300 m absolute height (in meters above the ocean level). At that time, the Caspian became connected with the Black Sea via a strait in the Kuma–Manych depression, north of the Caucasus Mts. All subsequent Caspian deposits show the normal magnetic polarity (except minor excursions), meaning that they correspond to Brunhes magnetic epoch (< 780 ka) (Rychagov 1997a). During the course of the Baku transgression (500-400 ka) a connection with the Black Sea was re-established through the 'Kumo-Manych' strait, and a large basin fed by the Caspian waters emerged in the place of the Azov Sea and the lower Don River.

The next episodes in the Caspian Sea history that occurred during the Late Pleistocene and Holocene were roughly coeval with the marine oxygen isotope (MIS) stages 5 -1. Two major Caspian Sea transgressions are acknowledgeable at that time. The Khazarian, the earlier one, had been first identified in the early 20th century predominantly on the mollusc evidence. The Khazarian terraces on the Caucasian coast are encountered at the altitudes ranging from 170 to 80 m. The later, Khvalynian transgression was identified mainly based on geomorphic criteria, and two its major stages were recognised. The coastal landforms and corresponding deposits situated above 0 m absolute height are classified as the Early Khvalynian, whereas those between 0 and -17 m absolute height are viewed as the Late Khvalynian (Svitoch 1991). Presently nine Khvalynian terraces are identified on the Caspian coasts: +48m, +35m, +22m, +6m, -5m ±0, -2m; -12m and -16m (Leontyev et al. 1997; Rychagov 1997).

The Khvalynian mollusc fauna consists of Caspian endemics, belonging to the Limnocardiidae family, and typically, *Didacna* Eichwald genus. Presently exclusively restricted to the Caspian basin, this fauna had a wider distribution in the Azov-Black Sea during the Pleistocene, including its Karangatian stage (Chepalyga 2007). The diagnostic fossils of Early Khavalynian mollusc assemblage include *Didacna cristata* Bog., *D. ebersini* Fed., *D. zhukovi* Fed., *D. parallella* Bog. and *D. protracta* Eichw (Fedorov 1957). These molluscs are distinctive by their small size (2-3 time smaller than the present-day varieties), and thin walls. The less varied Late Khavalynian mollusc assemblage consists predominantly of *Didacna praetrigonoides* Nal., *D. parallella, D. protracta* and, more rarely, *D. subcatillus* Andr. These species are of a greater size and feature a massive abundance (Mayev and Chepalyga 2002).

Recently available radiometric data (Dolukhanov et al. 2009) strongly suggest that the peak of the Khvalynian transgression occurred in a vary limnited time-span of 16.0–11.8 thousand years ago, basically coeval with the Neo-Euxinian transgression of the Black Sea (Fig. 2). As show the analysis of 'stable' oxygen isotopes, during the Early Khvalynian transgression maximum the summer temperatures were close to the present-day values. The spring and summer seawater temperatures further increased in the Late Khvalynian Basin, by 2-3° as compared to the Early Khvalynian regression phase; the spring and summer salinity in the western part of the Northern Caspian becoming almost identical to the recent one.

Based on the available radiometric evidence, one may ascertain that the early Khvalynian transgression was basically coeval with the mild Late Glacial intervals in the higher latitudes. Temperature reconstructions for Western Europe based on the fossil Coleoptera suggest a rapid temperature rise at the rate of 7°C per century, reaching the values above the present-day level (Coope 1997).

During the course of Khvalynian transgression the volume of the Caspian basin increasing 6.5 fold, as compared to that of the preceding Atelian one. The transgression supposedly proceeded in a quick alteration of successive sea-level fluctuations and in some cases had a catastrophic character. The lower stretches of the Volga and Ural rivers formed impressive estuaries. The sea submerged the greater part of the Kura valley in the Caucasus, western part of the Mangyshlak Peninsula and the entire Western Turkmenian Lowland. The Late Khvalynian basin stood close to the mean ocean level. Its area is estimated as 699.700 km^2 with the length of the coastline of 6,844 km.During the peak of the Khvalynian transgression, its excessive water was discharged into the Black Sea via a Manych-Kerch strait north of the Cascasus (Fig. 2) (Chepalyga 2007).

Based on the detailed investigations of barriers and incised valley fills along the Dagestan up to 5 transgression phases have been identified. The 14C dates suggest their age as around 8000, 7000, 6000, 3000 and 200 years BP. The maximal absolute height of the Caspian sea reached during these transgressions is around -22 m. (Fig. 4) (Rychagov (1997b).

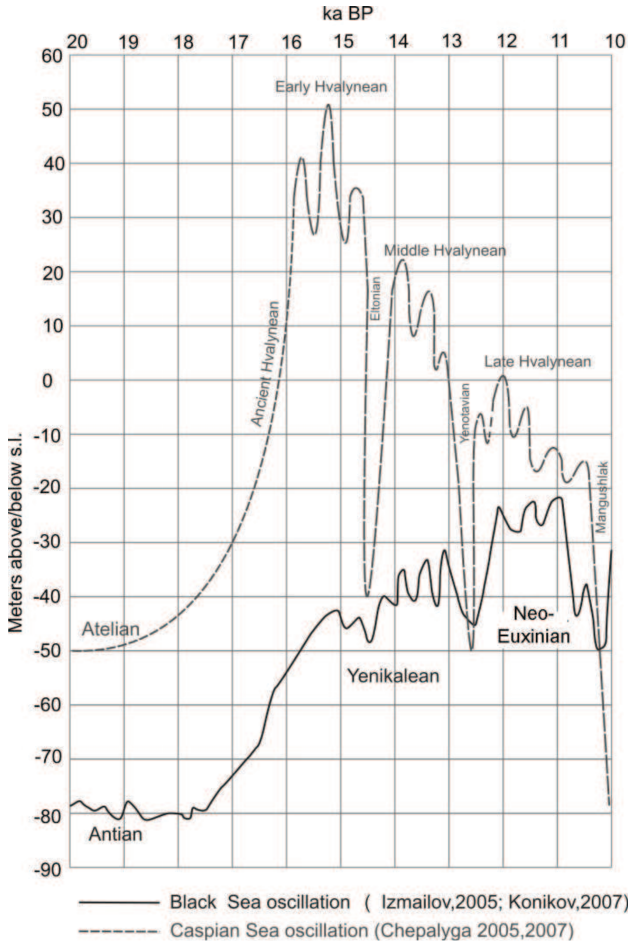

Figure 2. The Caspian and Black Sea levels fluctuations in Late Pleistocene.

The Holocene vegetation of the North Caspian Lowland is restored based on the several radiocarbon-dates pollen profiles obtained for bow-lake deposits on the Volga-Akhtuba flood-plian (Bolikhovskaya 1990) (Fig. 5).

The earliest deposits dated to 9500±60 BP, show the prevalence of coniferous forests domiunated by spruce; the non-arboreal pollen consisting mainly of xerophytic grasses: Chepopodiaceae, *Artemisia* and *Ephdra*. The landscape is seen as the forest-steppe mwith a cool, continental and moderately wet climate.

The next stage, dated to 8500±100 BP features the decline of arboreal pollen with the rise of grasses dominated by Chepopodiaceae and *Artemisia*. This suggests a cool and dry climate, supposedly coeval with the Mangyshlak regression of the Caspian Sea.

The studied profiles reveal a prolonged stage of warm and wet

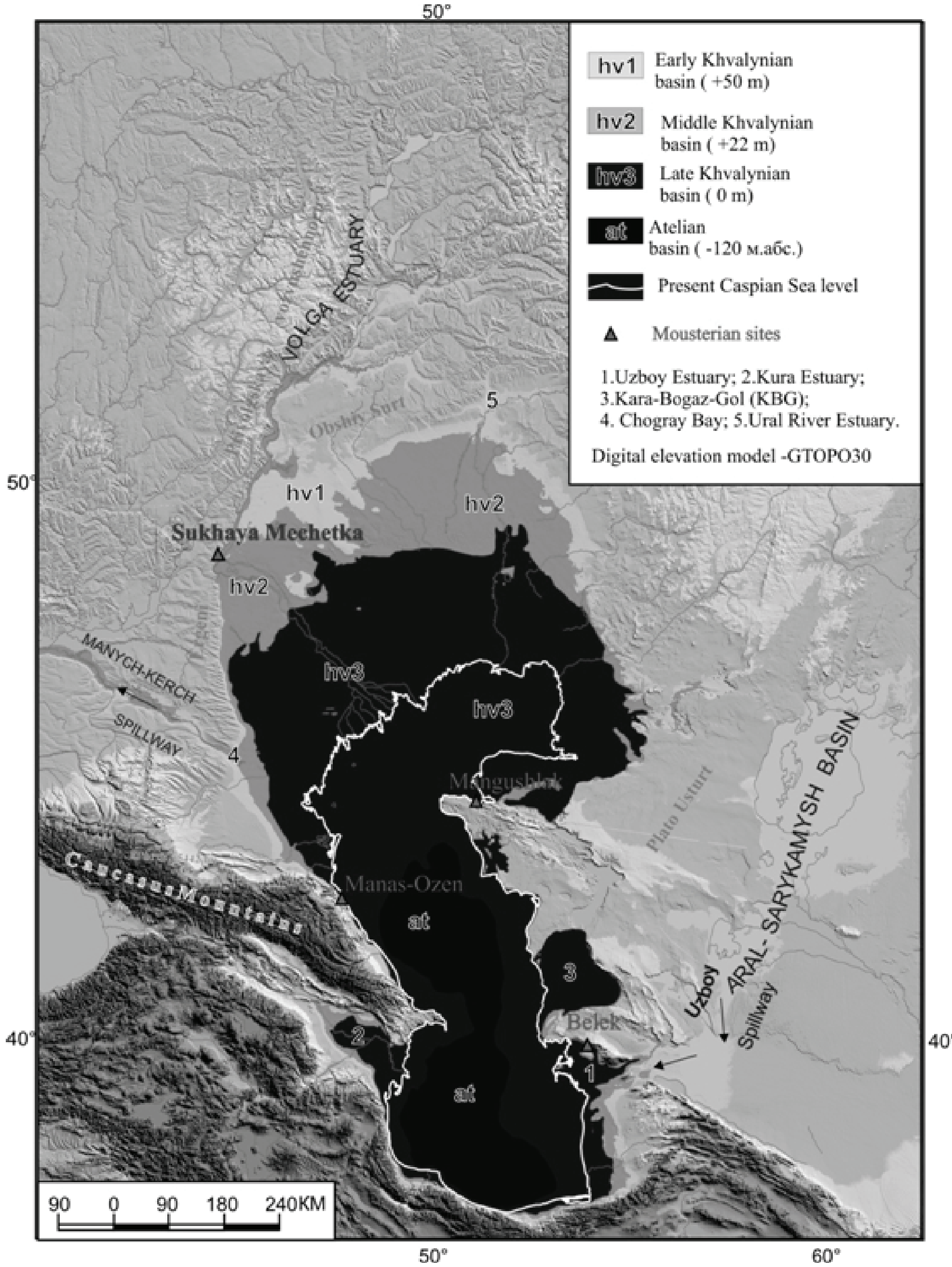

Figure 3. The Caspian Sea during the peak of the Khvalynian transgression

climate lasting from c 8500 until 7500 BP. It features the maximum expansion of broad-leave forest dominated by oak and elm. The steppe consisted predominantly of Gramineae and forbs communities. This stage was apparently coeval with the maximum rise of the Caspian Sea level.

At about 7500 BP one notes the sharp rise of xerophytic grasses (dominated by Chepopodiaceae and *Artemisia*) combined with the relatively high rate of broad-leave arboreal species (elk, lime). The maximum expansion of mixed broad-leave forest (with several species of oak, elm and lime) is recorded at the levels dated 6100-5000 BP. These forests became dominant in the Lower Volga-Akhtuba valleys. At the same time pine and birch forests wee spread in the inner lakes, small river deltas and estuaries.

Lavrushin et al. (1984) based on the pollen analysis and radiocarbon dates for palaeosoils at several Neolithic sites in the northern Caspian area suggest a strong aridisation of climate between 8 and 7 ky BP., basically coeval with '8200 yr BP event' (Alley et al. 1997).

Starting with c 5000 BP one notes the restriction of the forests with the simultaneous expansion of xerophytic steppe communities, in an environment of increasingly dry climate, which is typical for the entire arid zone of the Old World (Boqiang et al. 1991)

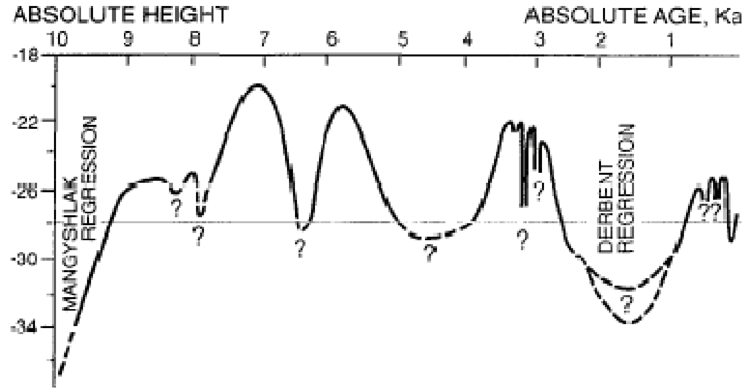

Figure 4. Fluctuations of the Caspian sea-level in the Holocene (after Rychagov 1993).

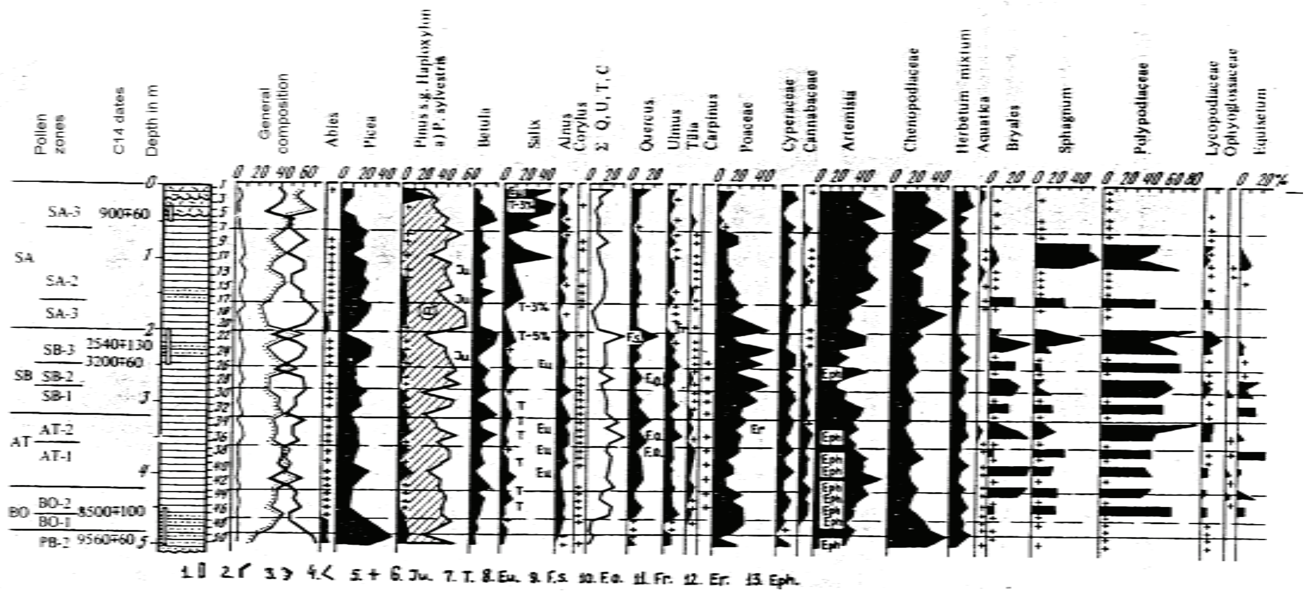

Figure 5. . The pollen diagram of the Solenoye Zaimishche sequence, the Lower Volga (after Bolikhovskaya 1990). Key: 1 – C-14 samples; 2 – arboreal pollen; 3 – non-arbpreal pollen; 4 – spores; 5 - <5%; 6 – *Juniperus*; 7 – *Tamarix*; 8 – *Euonymus*; 9 - *Fagus sylvatica*; 10 - *Fagus orientalis*; 11 – *Fraxinus*; 12 – Ericaceae; 13 - *Ephedra*.

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The Middle Volga Neolithic

A.Vyborbnov,[1] P. Dolukhanov,[2] A. Aleksandrovsky,[3] N.N. Kovalyukh,[4] V.V. Skripkin,[4] T.V. Sapelko,[5] G.I. Zaitseva[5] and A. Shukurov[6]

[1]Samara State Pedagogical University, Russia
[2]School of Historical Studies, Newcastle University, UK
[3]Institute of Geography, Russian Academy of Sciences, Moscow, Russia
[4]Institute of the Geochemistry of Environment, National Academy of Sciences of Ukraine, Kiev, Ukraine
[4]Institute of Limnology, Russian Academy of Sciences St. Petersburg, Russia
[5]Institute for History of Material Culture, Russian Academy of Sciences St. Petersburg, Russia
[6]School of Mathematics and Statistics, Newcastle University, UK

Map 1. Sites in Middle Volga, Northern Caspian Lowland and Lower Don

Key: 1- Racushechnyi Yar, 2. -Matveyev Kurgan, 3- Kairshak I-III, 4- Kugat IV, 5- Tektensor I, III, 6- Burovaya, 7- Varfolomeyevka, 8- Lebyazhinka, 9- Elshanka groups sites, 10-Chekalino IV, 11- Maksimovka, 12- Ivanovskoe, 13- Jangar, 14- Il'inka

Intensive field studies conducted in the middle stretches of the Volga River in the 1970s, brought to light several sites with 'Yelshanian-type' pottery, which was deemed as the earliest ceramic ware ever to be found on East European Plain (Vasil'ev and Penin 1977). Since then the Yelshanian related wares been identified at several sites: Staraya Yelshanka I, II, Maksimovo, Chekalino, Lower Orlyanka, Ivanovka, Lugovoye III, Lebyazh'ye I, Bol'she-Rakopvskaya, Il'ynskaya, Krasnyi Gorodok, Zakhar-Kolma, Vilovatovskaya (Mamonov, 1999; Lastovsky 2006). Amongst these sites, the 'pure Yelshanian element' has beren recognized only in two cases, the lower strata of Chekalino IV and Lower Orlyanka II.

As the microscopical studies have shown (Mamonov 1995)., the Yelshanian pottery was manufactured from the local sandy clay which included the natural admixture of organic matter and small fragments of mollusc shells. In rare cases one notes the tempering by chamotte or old crumbled pottery sherds. The vessels were made from clay lumps more than 5

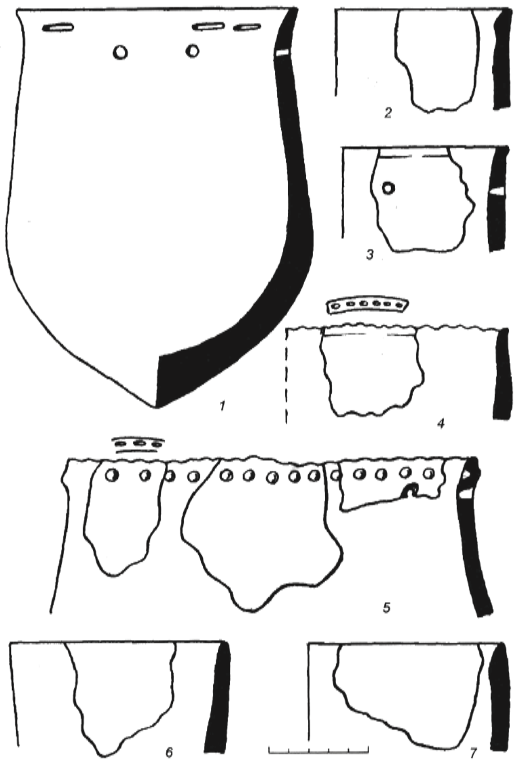

Fig. 2. Yelshanian pottery (Staro-Yelshanskaya site)

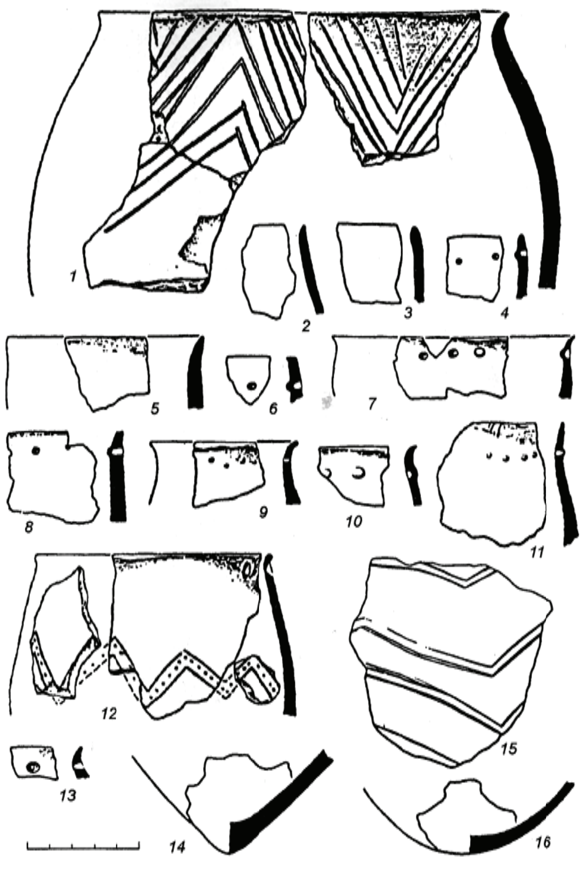

Fig. 3. Yelshanian pottery (Chekalino 4 site)

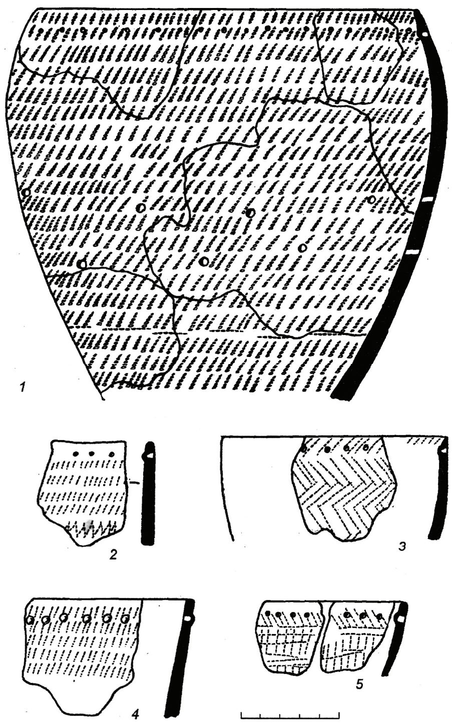

Fig. 4. Yelshanian pottery. Vilovatovskaya site.

cm in diameter which were fixed on a solid model. The outer surface was smoothed apparently by flat pebbles. The rugged inner surface was supposedly flattened by soft wooden knives. The vessels were fired in open hearths at the temperature not exceeding 450°C.

Judging from the pot shards the vessels had round or pointed bottoms, straight rims with either flat, or round or pointed edges, transforming into S-profiled rims. The vessels' mouths were usually narrowed, and in a few cases, wide opened. The walls are usually 0.4 -0.6 cm thick.

The majority of pottery vessels were not ornamented. In rare cases one notes the incised lines, pit impressions, or short notches, forming zigzag patterns. Several vessels were decorated by a belt beneath the rim consisting of pits and 'pearl' impressions (Fig. 2).

A different variety of pottery, recognized at several sites and notably, Volovatovskaya, was decorated by a stroked pattern. Thin- and usually strait walled either flat-bottomed or conic vessels were made of clay tampered with sand and, rarely, vegetable matter. Either oval or sub-squared strokes formed horizontal or tilted rows, horizontal or vertical zigzags, meanders or skewed networks (Fig 3).

Still another group consists of comb- and-tooth-decorated vessels. Thin-walled and predominantly flat-bottomed pots, made of clay tempered with sand, crushed pottery or vegetable matter were decorated by comb impressions forming horizontal rows, zigzags, 'retreating spatula' patterns, and skewed networks (Fig. 4).

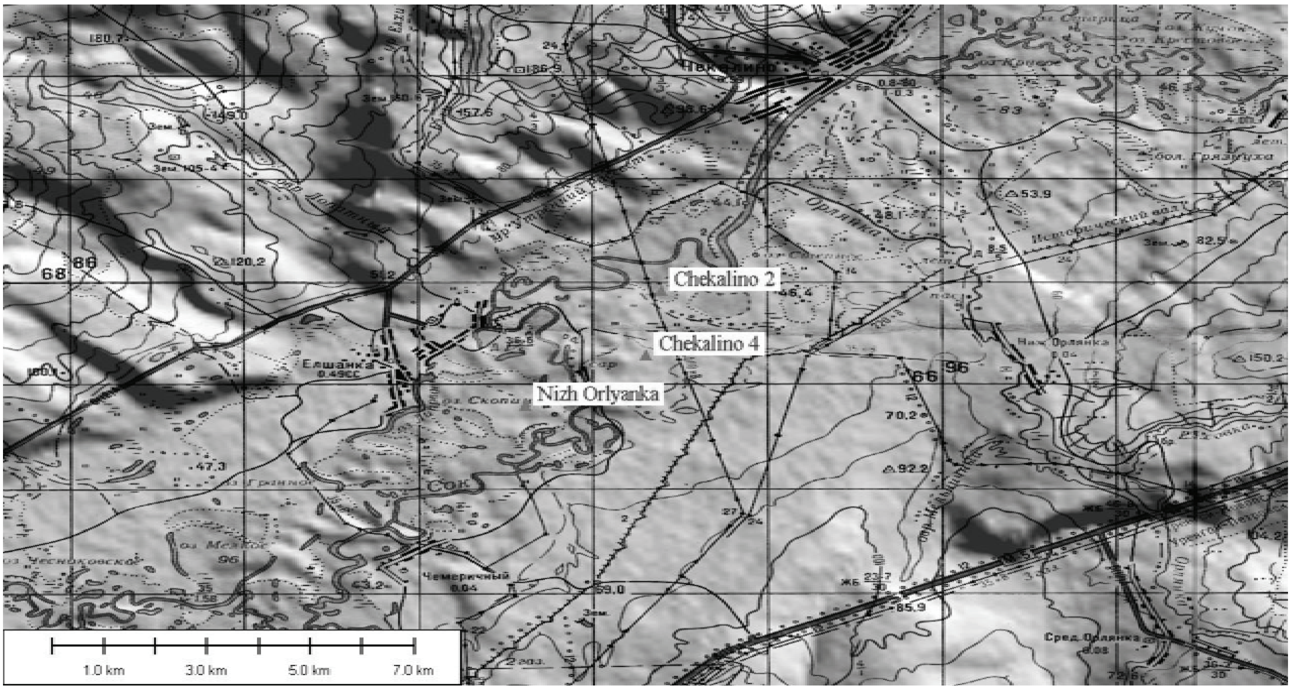

Fig. 5. Sok River and the location of Yelshanian sites.

It has been remarked that the point-bottom, S-profiled and poorly ornamented pottery deemed as the archaic one, was encountered jointly with two different types, namely, straight-walled, flat-bottomed stroke-ornamented, and vessels of a similar shape ornamented by comb impressions. The latter two varieties were deemed as forming separate cultural entities: The Volga-Uralian (Morgunova 1984), or the Middle Volga Culture (Vasil'ev and Vybornov 1988).

Morgunova (1984) considered the Volga-Uralian as consisting of two successive stages: Yelshanian and that of stroked pottery. The Yelshanian pottery was viewed as having common features with Central Asia (Darya-Sai), on the one hand, and the Lower Don Neolithic (Rakushechnyi Yar) on the other. Later the Yelshanian-related sites have been identified further afield, in the forested Middle Volga area, along the rivers Moksha and Sviyaga (Vybornov 2008). As about the stroked ornamented pottery, Vybornov (2008) views its origins in the Karshaik-type sites of the Northern Caspian area.

Vybornov (2000) views the Middle Volga pottery as including several stylistic components, namely, the stroked, toothed-comb, unornamented with pit-pearl belts, stroked and lined varieties. All these elements were detectable in varying proportions at all early pottery sites in the Middle Volga area.

The stone industry was based on both flake and blade blanks, with a considerable amount of thin and long unretouched blades. Amongst the cores one note the pyramidal both double- and single-platform varieties with the indices of secondary flaking. The inventory includes the secondary trimmed blades, both retouched ones and burins on blade truncations. A series of scraping tools includes the end-scrapers on flakes, end-lateral, sub–rectangular, and circular varieties, and those on the truncated flakes. Several end-scrapers on blades have been found. One notes owls on elongated flakes, abruptly retouched along the working edges. Several axe-like tools with rounded butts and narrow edges were supposedly used for timber working. A series of points includes both tanged and blade-based varieties. One notes similarities with the points of Post-Swiderian and Reindeer Island types in Central Europe and Northern Russia.

The most important Yelshanian sites lie on the flood-plain levels of the River Sok (Fig. 5), the left tributary of the Volga River in its middle courses. The Sok River valley emerged resulting from the Lower Khvalynian transgression of the Caspian Sea, which formed its upper terraces. The flood-plain levels, as well as numerous meanders and ox-bows which are conspicuous in the present-day relief, were related to the Holocene development of the Volga River.

The flood-plain of the River Sok is located within the forest-steppe belt of East European Plain. It features the vast spaces of meadow grassland, alternating with broad-leaved forests. The present-day animal world includes boar, beaver, antelope-saiga, as well as a variety of steppe birds.

The setting of *Chekalino 4* sites is typical of Yelshanian sites in the Sol River valley. The excavations divulged the following sequence of archaeological deposits (Fig. 6).

Fig. 6. Chekalino 4 site.

The Chalcolithic deposits appear directly beneath the turf, and comprise the upper 0.70 – 0.80 m. The uppermost 20-30 cm include predominantly small-size stone tools, supposedly resulting from the displacement by soil animals.

The lower 20-30 cm above the 'virgin soil' includes the Yelshanian materials.

At the contact of Chalcolithic and Yelshanian deposits, the samples of 'comb-decorated pottery' has been encountered, which is attributed to the Late Neolithic.

The sequence of the western watt of the Grid 6 of the excavation site.

0.0 – 0.10m: turf; greyish to black sandy loam, loose, with numerous roots; includes the archaeological materials of Late Bronze Age;
0.10-0.35m: soil A1 horizon; dark compact loam, high carbonate content;
0.35-0.60m: soil AB horizon; grey-brownish compact loam, high pH content (basic);
0.60-0.90m: soil AB horizon; grey-brownish compact loam, high carbonate content, numerous *krotovinas* (soil animal burrows);
0.60-0.80m: finds of Chalcolithic age (stone tools and large fragments of pottery);
0.80-0.90m: finds of comb-ornamented pottery (Late Neolithic);
0.90-1.00m: soil AB horizon; greyish compact loam high carbonate content; numerous *krotovinas*; finds of Yelshanian pottery;
1.00-1.20m: soil BA horizon; yellowish compact loam, high carbonate content, numerous *krotovinas*; finds of Yelshanian pottery;
1.20-1.70m (exposed thickness) soil BCa horizon; light yellowish compact loam very high pH content (ultra basic), numerous *krotovinas*; without archaeological materials, gradually transforming into alluvial (flood-plain) loam.

Gradual transitions between the horizons suggest a continuous soil formation interrupted by short-lived seasonal flush-floods. Numerous *krotovinas* imply a possibility of transportation of archaeological materials through the activity of soil animals.

Excavations of Chekalino 4 sites revealed five hearths in the form of charcoal concentrations 10-12 cm in diameter and 10-12 cm deep, well as eight hollows and an area of *Unio* shell compact concentrations. One of the hollows included 450 pieces of flint, predominantly chips and small flakes. Another follow contained numerous small fish bones.

That site also included a human burial. The skeleton at the bottom of archaeological deposits was found in a contracted posture, with bent knees, the hands beneath the head, directed to the north-west. No remains of a grave were found, a flint blade near the head was the only implement. The diseased belonged to a large-headed dolichocran anthropological type.

Sequence of Chekalino 2 site has shown the following sequence:

0.0 – 0.10 m: turf; loam dark-greyish to black, loose, patchy, with numerous roots, gradual transition to the underlying level; lesser amount of roots,
0.10 – 0.40 (0.50) m: loam dark-greyish to black, more compact and structured, gradual transition to the underlying level;

0.40 (0.50) – 0.70 m: loam brownish-grey, patchy, compact, with white carbonate veins, gradual transition to the underlying level;

0.70 – 0.90 m: loam dark brownish-grey, slightly humified compact, with clearly visible vertical white carbonate veins, this level reportedly contained Mesolithic implements; gradual transition to the underlying level;

0.90 – 1.40 m (exposed thickness): brownish loam, greyish in its upper portion, compact, with a large amount of oval carbonate concretions.

The following sequence has been identified at *Nizhnyaya Orlyanka* site**:**

0.0– 0.50m: AI soil horizon, the uppermost level with numerous plant routs; dark grey silt – clayey loam, loose; archaeological remains of Late Bronze Age;
0.50-0.70/0.80m: yellowish-brownish compact silt with numerous *krotovinas*, contains Yelshanian archaeological materials;
0.70/0.80-1.40m: yellowish-brownish compact silt with numerous *krotovinas*, no archaeological finds;
1.40-1.50m: white silt-calayey loam with numerous carbonates;
1.50-1.70m (exposed thickness): laminated silt-loam, each bedding 5-6 cm thick; loam beddings, rich in carbonates.

In contrast to Chekalino 4, the soil in this case was formed on sandy silt, underlain by laminated silt-loam, the latter rich in carbonates. These deposits are usually formed in the steppe under the alternating drier and moister climate. The deep penetration of soil animal burrows is typical for the steppe with low-laying water table.

The grain size distribution shows an increased rate of coarse-grained fractions (notably that of medium-grain sand) down the sequence; other variations are insignificant.

Table 1 Grain-size analysis of Chekalino 4 sequence

Soil horizons, depth (in m)	**Fractions (mm) per cent.**						
	1.0-0.25	**0.25-0.05**	**0.05-0.01**	**0.01-0.00**	**0.0050.001**	**<0.001**	***<0.01***
ABca 0.45	1.85	47.2	2.8	4.7	10.0	14.45	*29.1*
ABca 0.87	3.7	48.9	15.9	6.6	8.1	16.8	*31.5*
Bca 1.40	2.6	34.9	17.6	8.1	13.5	23.2	*44.8*

Note: 1.0-0.25 mm – medium-grain sand; 0.25-0.05mm – fine-grain sand; 0.05-0.01 – coarse dust; 0.01-0.005 – medium dust; 0.005-0.001 – fine dust; <0.001 – silt; <0.01 – 'physical' clay.

Table 2. Chemical composition of Chekalino 4 sequence

Depth (in m)	Soil horizons; archaeological layers	pH $_{H2O}$	C %	Humus, %	P_2O_5, %	CO_2, %	$CaCO_3$, %
0.05	$A1_1$	7.85	**6.99***	**12.1**	0.38	2.79	**6.3**
0.20	$A1_2$	-	**5.07**	**8.8**	0.37	**6.62**	**15.0**
0.45	AB	8.6	2.31	4.0	**0.43**	**8.78**	**19.9**
0.60-0.65	Calcolithic	-	2.11	3.6	**0.40**	**9.31**	**21.1**
0.75	Late Neolithic	-	1.83	3.2	**0.44**	**9.52**	**21.6**
0.85	Late Neolithic	-	1.65	2.9	**0.59**	**10.06**	**22.8**
0.85-0.90	Yelshanian	8.85	1.37	2.4	0.33	**10.23**	**23.2**
0.90-0.95	AB Yelshanian	-	1.25	2.2	0.31	**10.18**	**23.1**
1.00	BA	-	1.03	1.8	0.26	**10.39**	**23.6**
1.10	BA	-	0.83	1.44	0.20	**10.03**	**22.8**
1.40	Bca	-	0.40	0.69	0.11	**13.61**	**30.9**
1.60	Bca	9.15	0.28	0.48	0.09	**11.55**	**26.2**

* Higher concentrations are shown in bold face.

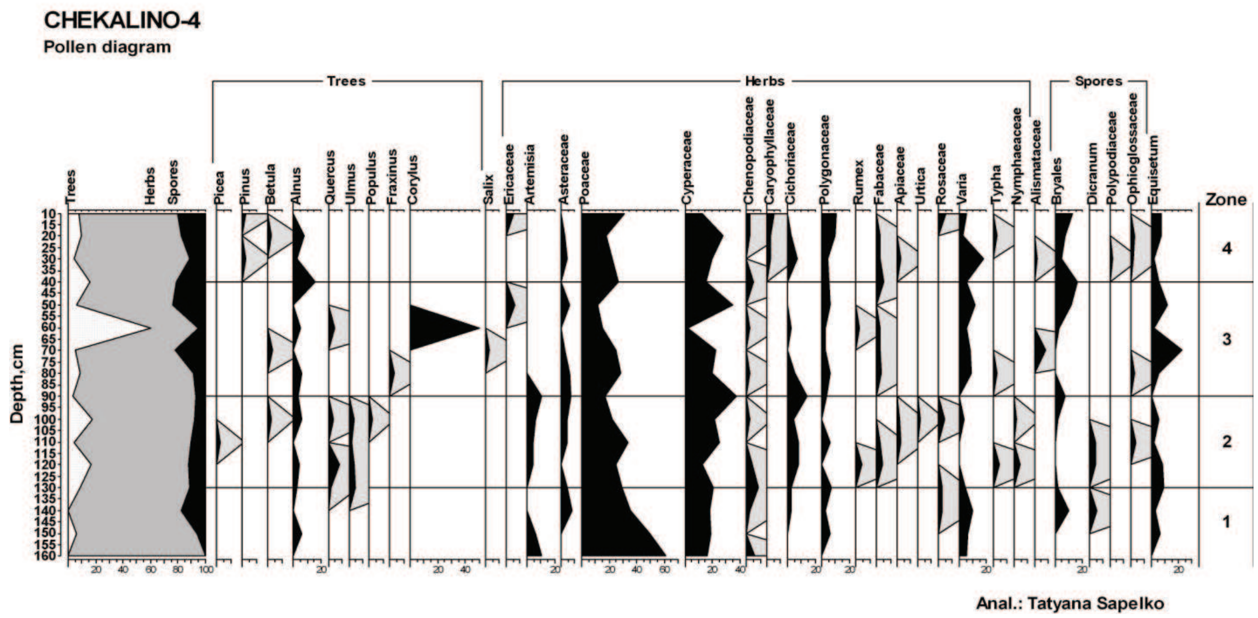

Fig. 7. Pollen diagram of Chekalino 4 site sequence.

The entire sequence is rich in carbonates. Although lime nodules are perceptible only in the lowermost stratum, the high content of dissolved carbonates is noted all along the profile, except the uppermost A1 horizon. Apparently due to the high concentrations of carbonates and other salts, high pH values are recorded in all levels, alkalinity notably increasing down the profile.

The humus content which highest values are recorded in the upper horizons decreases downwards, attaining the lowest figures in the bottom level. Remarkably, one notes elevated values of phosphorus, reaching the highest figures in the middle part of the profile, corresponding to the Chalcolithic and Late Neolithic levels.

Based on the pollen analysis of Chekalino 4 sequence (Fig. 7) several vegetation phases were identified.

The lower part of the sequence, (1.30-1.70 m) shows the maximum content of grasses dominated by Gramineae and a great variety of xerophytic forbs. The vegetation cover was predominantly formed by Gramineae steppe. Mesophytic flood-plain meadows in the wetter habitats along the river course included horse-tails. No evidence of forests were. The climate may be defined as very warm and arid.

The middle part of the sequence (0.90-1.30 m), which includes the Yelshanian archaeological deposits, corresponds to the wetter climate. The pollen spectra show the spread of broad-leave forests. The pollen spectra indicate a sufficiently high frequency of arboreal species, of which elm and oak are the most common, with the total absence of connivers. The rate of herbs remains high. The herbs are dominated by Gramineae, with the increased rate of wormwood (Artemisia) and goosefoot (Chenopodiaceae). One notes the appearance of aquatic plants. This suggests the climate becoming wetter and cooler, which favoured the local spread of forests, with the continued occurrence of goosefoot-wormwood and Gramineae steppe communities farther afield. This phase may be seen as corresponding to the Holocene climatic optimum (the Atlantic phase of Altithermal) in other parts of East European Plain.

The next phase (0.40-0.90 m) saw the restriction of forests and the change in their composition. The broad-leave species nearly totally disappear with the spread of birch and alder in much smaller quantities. The highest rate of arboreal pollen identifiable in the middle pat of this phase was due to an abnormally high content of hazel, recorded in a single sample. The grasses dominate the pollen spectra, suggesting the Gramineae and forbs-dominated steppe vegetation covering the large forest-free areas. Rare aquatic plants were identified. Based on the pollen evidence one may suggest a warm and moderately wet climate.

The youngest phase (0.0-0.40 m) reflects the further rise of temperature and dryness. A limited amount of arboreal pollen consists of pine, birch and alder. The grasses include Gramoineae, Cyperaceae, and Compositae. One may suggest the dominance of Gramineae-forbs steppe communities in the vegetation cover.

Presently about 200 radiocarbon dates for early pottery sites are available for the Middle and Lower Volga area (Vybornov 2008; Table 3). Aiming at the statistical analysis, we selected a set of dates stemming from an area in the Middle Volga basin, ranging from the Kama River in the north to the Sok River in the south. Following the Vybornov's classification we have chosen the following the stylistical classification of the sites (based on the most frequent pottery ornamental patterns):

1. Yelshanian (Y);
2. Stroked (S);
3. Lined (L);
4. Toothed (T);
5. Comb (C);
6. Unornamented (UO).

The totality of radiocarbon dates shows the mean value of 5310 cal BC with standard deviation of 627 years. At the same time, the frequency distribution shows at least three distinct peaks, which proved to be statistically valid. The range of the first peak was 7.2 – 6.4; the second one, 6.0 – 5.6, and the third, 3.2 – 4.5 ky BC (Fig. 8). As show, the separate analyses of the frequencies of ornamental patterns (Figs. 9-13), the older peak corresponded exclusively to Yelshanian-type pottery, which also was frequent at the middle peak. Stroked and linear patterns were common at the middle peak, while the comb-decorated pottery became common only at the latest peak.

Table 3. Radiocarbon dates of Middle Volga sites

Site	Index	Age BP	Sigma	Age BCcal min	Age BCcal max	Pottery
Lebyazhinka IV	Ki-14081	5930	90			Y
Lebyazhinka IV	Ki-14120	5880	90			Y
Lebyazhinka IV	Ki-14083	5690	80	5040	4550	S
Lebyazhinka IV	KI-14122	5590	80	4950	4490	S
Lebyazhinka IV	Ki-14082	5420	80	4720	4350	T
Lebyazhinka IV		5360	90	4620	4250	T
Lebyazhinka IV	Ki-14468	5970	80	4450	4040	C
Yelshanka	Ki-14569	6760	80	4350	3980	C
Yelshanka	Ki-14570	6480	80	5100	4600	Y
Lebyazhinka IV	Ki-14081	5930	90	5800	5510	Y
Lebyazhinka IV	Ki-14120	5880	90	5560	5300	Y
Lebyazhinka IV	Ki-14083	5690	80	5040	4550	S
Lebyazhinka IV	KI-14122	5590	80	4950	4490	S
Lebyazhinka IV	Ki-14082	5420	80	4720	4350	T
Chekalino IV		5910	90	5000	4540	Y
Chekalino IV		5870	80	4940	4530	Y
Maksimovka 2	Ki-14411	6420	80	5540	5210	UO
Maksimovka 2	Ki-14412	6470	80	5560	5300	UO
Ivanovka	Le-2343	8020	90	8550	7800	Y
Ivanovka	Ki-14658	7930	80	7060	6630	Y
Ivanovka	Ki-14567	7150	90	6220	5830	Y
Ivanovka	Ki-14568	7680	90	6700	6440	Y
Ivanovka	Ki– 14568	7930	90	7080	6590	Y
Ivanovka	Ki– 14567	7680	90	6700	6340	Y
Ivanovka	Ki– 14631	7780	90	7050	6400	Y
Ivanovka	Ki-14118	7060	100	6090	5720	S
Ivanovka	Ki-14079	6980	80	6010	5710	S
Ivanovka	Ki-14119	6930	90	5990	5660	S
Ivanovka	Ki-14080	6840	90	5010	5550	S
Staroyelshanka II	Ki-14569	6760	80	5800	5510	Y
Staroyelshanka II	Ki-14570	6480	80	5620	5300	Y
Staroyelshanka II	Ki-14413	6820	80	5880	5610	Y
Il'inka	Ki-14096	6940	90	5990	5660	L
Il'inka	Ki-14111	6740	70	5740	5480	UO
Il'inka	Ki-14145	6680	70	5720	5480	UO
Il'inka	Ki-14619	6760	90	5810	5510	L

Il'inka	Ki-14464	6640	100	5730	5370	L
Il'inka	Ki-14147	6770	90	5810	5510	S
Il'inka	Ki-14113	6670	100	5740	5460	S
Il'inka	Ki-14112	5620	80	4680	4330	T
Il'inka	Ki-14146	5730	80	4780	4360	T
Kras Gorodok	Ki14117	6550	130	5800	5470	UO
Kras Gorodok	Ki14117	6550	130	5800	5470	UP
Kras Gorodok	Ki-14078	6730	100	5730	5280	UO
Krasny Yar VII	Ki-14580	6540	80	5630	5360	UO
Krasny Yar VII	Ki-14586	6280	90	5470	4990	UO
Krasny Yar VII	Ki-14462	5780	100	4990	4350	S
Maksimov II	Ki-14411	6420	80	5540	5210	UO
Maksimov II	Ki-14412	6470	80	5610	5300	UO
Maksimov II	Ki-14412	6470	80	5610	5300	UO
Bol'sherak II	Ki-14835	6310	90	5480	5050	UO
Bol'sherak II	Ki-14829	5770	90	4810	4390	UO
Bol'sherak II	Ki-14830	5610	90	4960	4250	UO
Vilovatov	Ki14058	5840	100	4940	4450	S
Vilovatov	Ki14124	5910	80	4960	4540	S
Vilovatov	Ki-14086	5840	90	4910	4490	S
Vilovatov	Ki-14125	6020	90	5250	4650	S
Vilovatov	Ki-14087	6010	80	5210	4710	T
Vilovatov	Ki-14833	5920	90	5030	4540	T
Vilovatov	Ki-14833	5920	90	5030	4540	T
Vilovatov	Ki-14126	5880	90	4950	4490	T
Vilovatov	Ki-14088	6160	100	5350	4800	T
Vilovatov	Ki-14127	5980	100	5250	4600	T
Vilovatov	Ki-14089	5960	90	5100	4550	T
Vilovatov	Ki-14089A	5755	80	4800	4400	T
Vilovatov	Ki-14090	6320	90	5480	5050	S
Shcherbet II	Ki-14530	6090	90	5260	4780	S
Shcherbet II	Ki-14098	6530	90	5630	5320	S
Shcherbet II	Ki-14134	6620	90	5720	5370	S
Shcherbet II	Ki-14531	6270	90	5740	5470	S
Tetyush IV	Ki-14452	6170	90	5320	4850	S

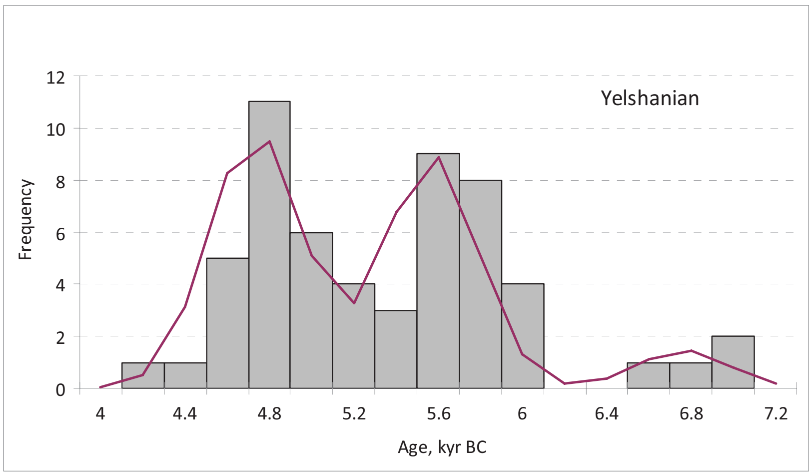

Fig. 8. Frequencies of radiocarbon dates for Yelshanian sites.

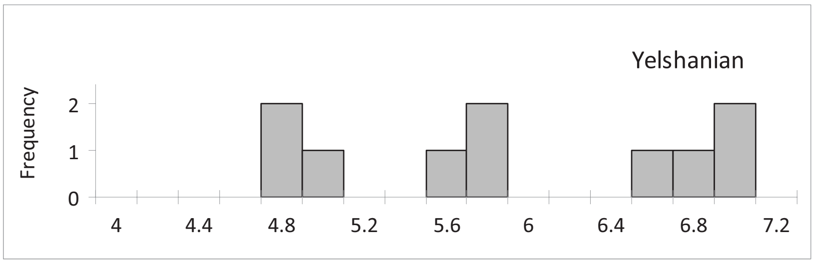

Fig. 9. Frequencies of radiocarbon dates for sites with 'Yelshanian' ornaments.

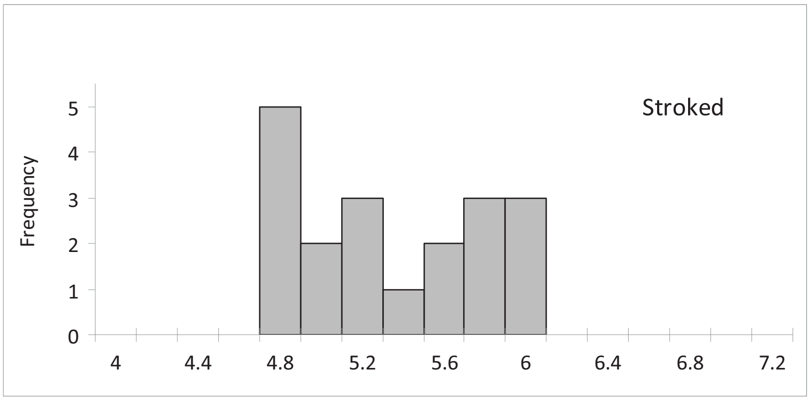

Fig. 10. Frequencies of radiocarbon dates for sites with 'stroked ornaments.

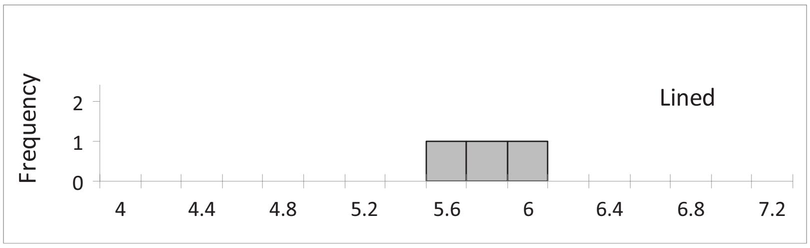

Fig. 11. Frequencies of radiocarbon dates for sites with 'incised lines ornaments.

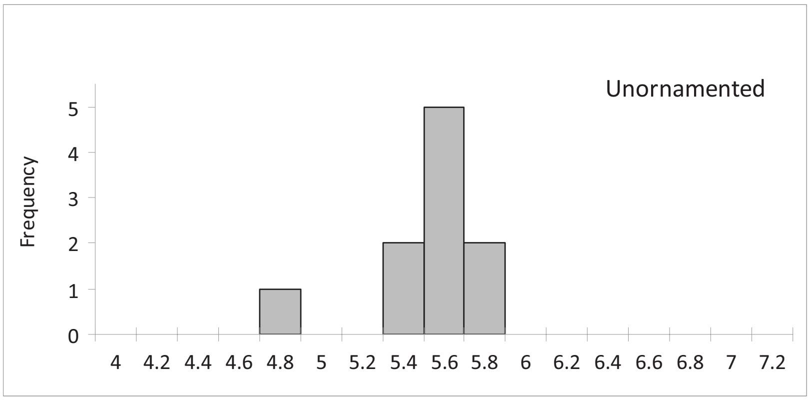

Fig. 12. Frequencies of radiocarbon dates for sites with unornamented pottery.

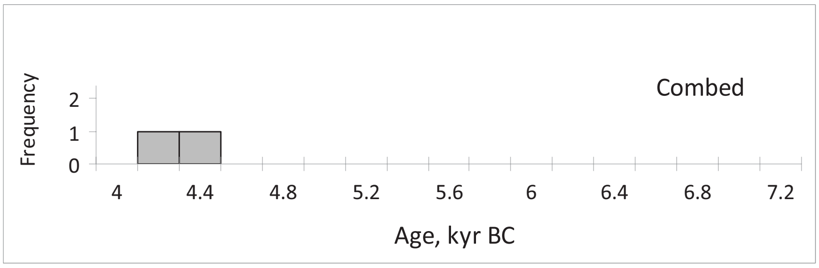

Fig. 13. Frequencies of radiocarbon dates for sites with comb-ornamented pottery.

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The North Caspian Mesolithic and Neolithic

A.Vyborbnov,[1] P. Dolukhanov,[2] N.N. Kovalyukh,[3] V.V. Skripkin,[3] G.I. Zaitseva[4] and A. Shukurov[5]

[1]*Samara State Pedagogical University, Russia*
[2]*School of Historical Studies, Newcastle University, UK*
[3]*Institute of the Geochemistry of Environment, National Academy of Sciences of Ukraine, Kiev, Ukraine*
[4]*Institute for History of Material Culture, Russian Academy of Sciences St. Petersburg, Russia*
[5]*School of Mathematics and Statistics, Newcastle University, UK*

The Mesolithic sites in the Northern Caspian Lowland were first discovered by A.N. Melentyev (1977) and classified by him as belonging to Seroglazovian Culture. These sites werev usually found linked to the former hydrological network, which included extinct water channesl, lakes, and in some cases dried salt lakes (*sory*). The Mesolithic inventory is dominated by the microblade technique with the common occurrence of geometrics: crescents, trapezes, rectangles and triangles (Fig. 6).

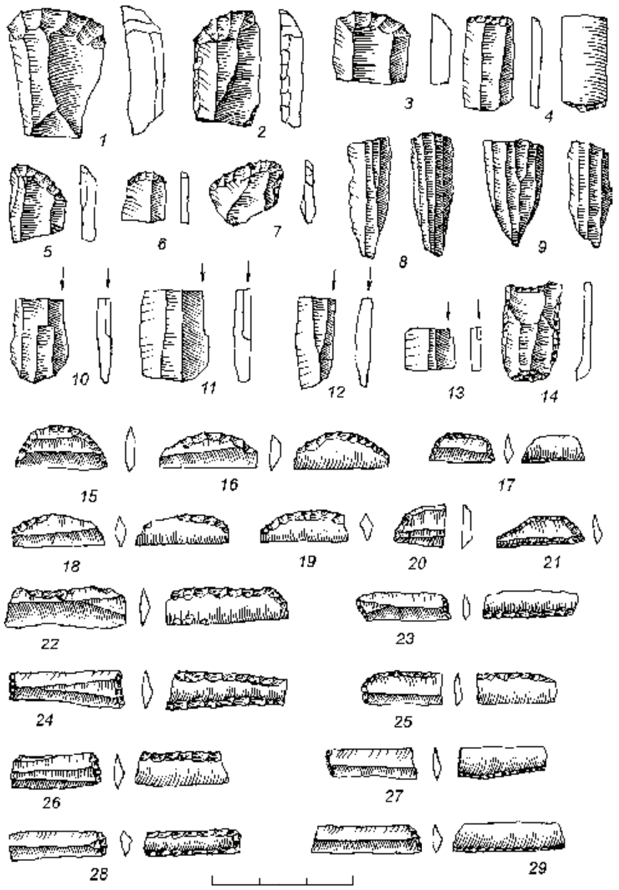

Fig. 1. The North Caspian Mesolithic. Flint tools.

Large Neolithic sites in the Caspian Lowland and the Lower Volga were first discovered only in the 1980s intensive surveys resulted in the discovery of several sites with clear archaeological deposits: Kairshak III and Tenkeskor in the Northern Caspian Lowland, Jabgar in the North-Western Caspian area, and Varfolomeyevka on the Lower Volga (Fig. 7).

The Neolithic sites likewise the Mesolithic ones, are usually bound to former water channels and dried salt lakes (*sory*). In typical cases the sites are found in deflation hollows within large desert dunes (*barkhans*) (Fig.3).

The Middle and Neolithic sites on the Volga's left bank (Kairshak III, and II) include exclusively remains of wild animals: onager (*Equus hemionus),* 50-70%, red deer, 16-17, antelope-saiga, 8-13%. Teneksor I (Late Neolithic), in addition to the same species, includes wild horse. In Varfolomeyevka, lower level, wild horse malkes up 36%, with 30% of antelope-saiga, 18% of aurochs and 5% of red deer. The animal assemblage of the layer 2B of the same site includes 34% of antelope-saiga, 31% of onager, 20% of wild horse, 9% of aurochs, and 3% of wild boar. The animal remains identified in the 3rd (lowermost layer) of Jangar included 2 individuals pf wild horse, 6, of onager, and 3 of anrelope-saiga. In addition to the same species, several individuals of red deer were identified in the middle and upper laters of the same site.

Koltsov (2004, 135) recently reported the occurrence of remains of domestic animals (sheep/goat, cattle and supposedly domesticated horse) in Jangar's upper layer. A single bone of sheep/goat has been encoutered in the layer 2A of Varfolomayevka. Yet in the latter case, this level included the finds of copper plaque, macehead, and figurines of apparently Chalcolithic age. Hence one cannot rule out the penetration of later materials (including the bones of domesticates) also in nther case of Jangar.

Following Vasil'yev and Vybornov (1988), two cultural groups the *Kairshak-Tenteksorian* and *Jangar-Varfolomeyvian* or *Jangar*ian (Vybornov 2008) are distinguishable in the North Caspian Neolithic which form together the Lower Volga cultural entity. Each group each comprises several chronological stages. One notes considerable similarities in

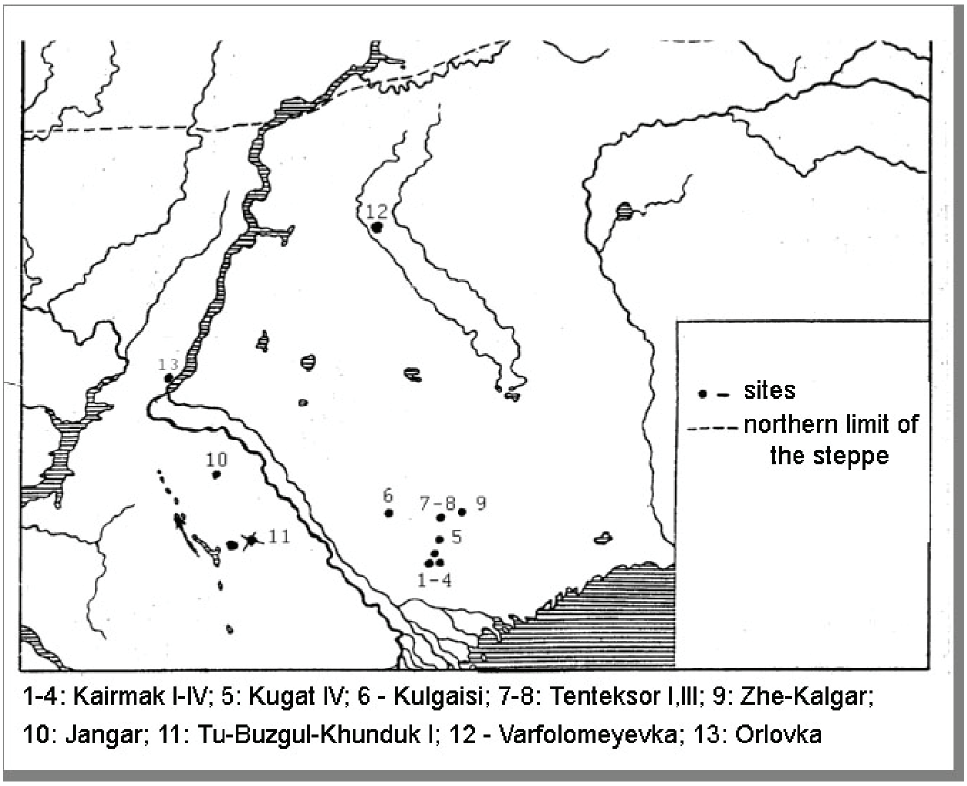

Fig. 2. Location of North Caspian Neolithic sites.

Fig. 3. North Caspian landscape (desert dunes and salt lakes)

the material culture between the both entities on which basis Yudin (2002) classifies them to a single Lower Volga 'cultural area'.

The Kasirshak-Tenteksorian culture is now viewed (Vybornov 2008) as consisting of two chronologically successive stages, Kasirshaian and Tenteksorian. The former had apparently developed on the local Mesolithic substratum, which is evident in the Mesolithic character of its lithic industry. Its pottery for which so far no direct analogies were found, was manufactured from the clay which included crashed shells, fish scales and vertebra and plant remains identified as blue-green algae.

The earlier stage of *Kairshak-Tenteksorian* culture is exemplified by Kugat IV and Kulagaisi sites. At Kurgat IV archaeological materials were collected inside a deflation hollow of a huge desert dune (*barkhan).* The stone inventory of all these sites retained a Mesolithic character and was dominated by the blade reduction technique, with unretouched blades being the most common. Geometric microliths are most numerous among the products of secondary trimming; they consist of crescents, rectangles and triangles. Lithic tools also include end-scrapers, points and truncated bladlets (Fig. 4). The fragments of straight-walled vessels with round bases were manufactured from the clay with crushed shells and plant remains. The ornament consists of incised lines and oval impressions (Fig. 5).

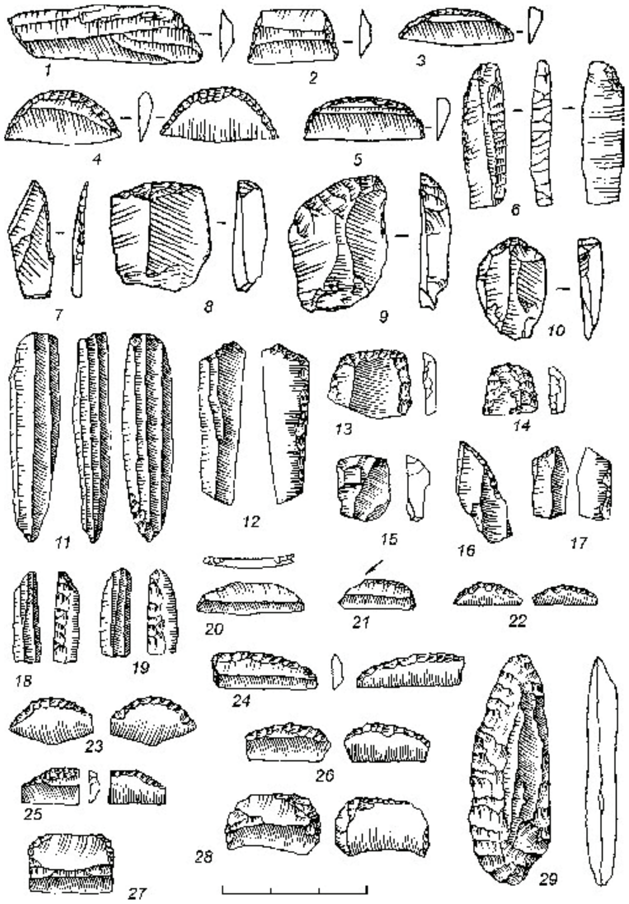

Fig. 4. Kulgat IV. Flint tools

The sites Kairshak I, II and III belong to the second stage. Archaeological materials were found inside a deflation hollow of a large sand dune. A system of dry salt lakes (*sor*) was located directly to the north-west of the dune. Archaeological layers at Kairshak III formed several dark-coloured lenses 3 by 3 m with charcoal paricles. These lenses included animal bones and pot sherds A reddish spot (0.5 by 0.5 m) found nearby, included the hind limbs of a kulan found in an anatomical order, a piece of sandstone with particles of red ochre, and several red coloured flint implements.

Circular, straight and oblique end-scrapers are the most numerous types of lithic tools. The geometrics include the

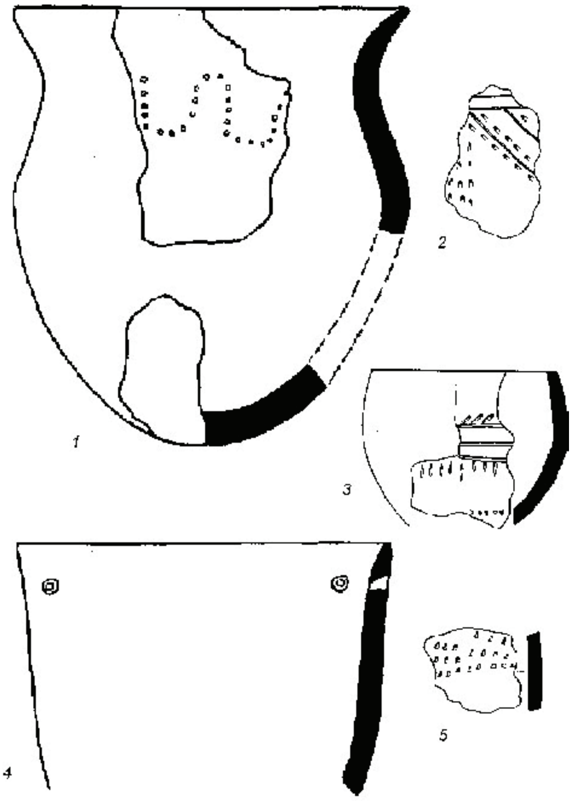

Fig. 5. Kulgat IV. Pottery

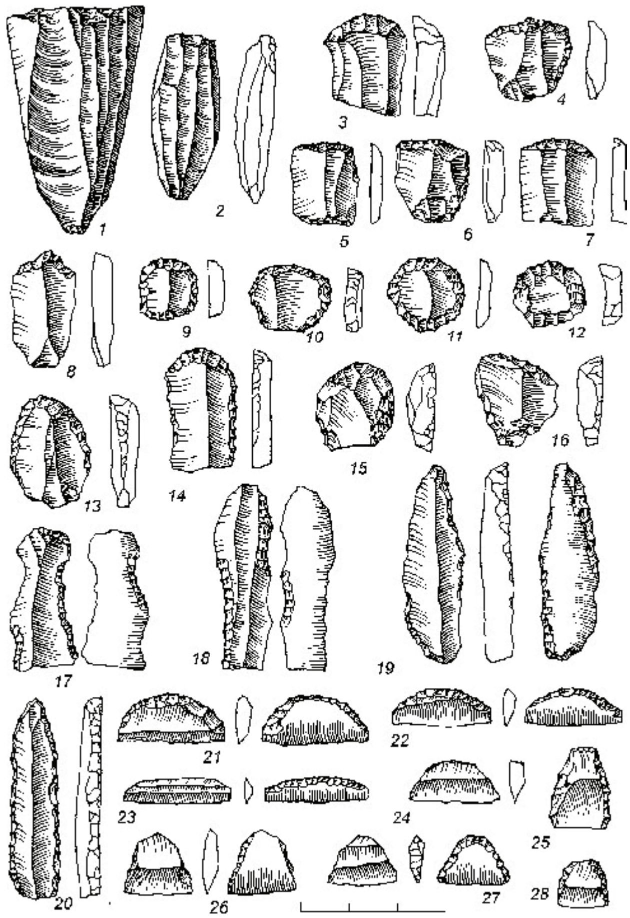

Fig. 6. Kairshak III. Flint tools

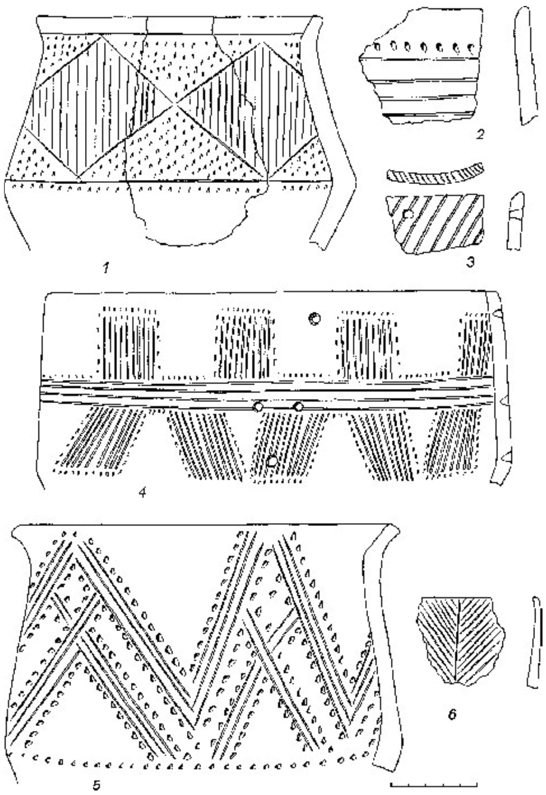

Fig. 7a. Karshak III. Pottery.

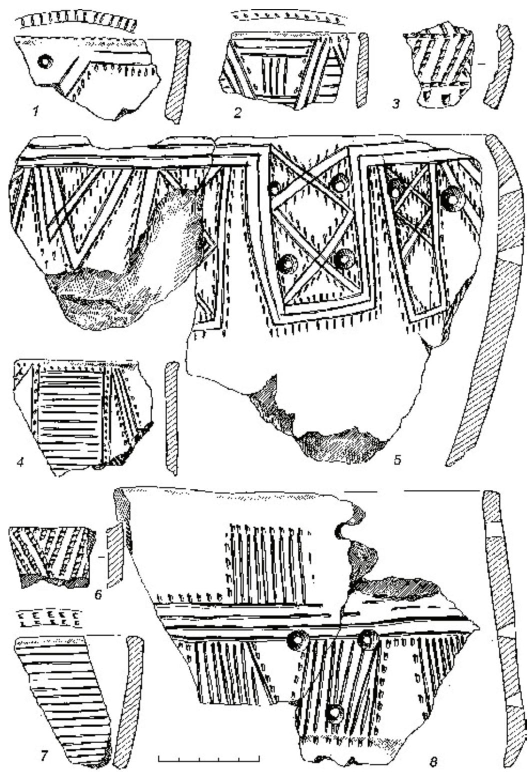

Fig. 7b. Karshak III. Pottery

crescents, trapezes and triangles. The inventory includes bladlet-points, notched scraping tool and a burin (Fig. 6).

Numerous ceramics include profiled flat-bottomed pots manufactured from clay tempered with crushed shells and vegetable matter. 60% of vessels were ornamented with incised lines or oval impressions, forming horizontal lines or, rarely, geometric designs: rhombi, meanders or zigzags (Figs 7a, 7b).

The third stage is exemplified by the sites Tenteksor, Zhekolgan and Kachkarstau. The Tenteksor site occupied an area of about 300 sq m and included remains of a surface dwelling. The fragments of more than 170 vessels found at the site belonged to both profiled and unprofiled flat-based pots with either rounded or flat rims. They were made of clay tempered with crushed shells and vegetable matter. The ornament restricted to the upper portion of the vessels consisted of receding oval or square impressions forming horizontal rows, rhombi, meanders, zigzags, triangles and rectangles. The flint inventory is not numerous and includes blades and flakes in an equal proportion. End-scrapers on large blades and flakes predominate; symmetrical bladlets-points are the second by importance. A series of trapezes with removed dorsal surface is remarkable.

The sites belonging to the *Jangar-Varfolomeyevian* cultural entity are found both on the right and left banks of the lower stretches of the River. Malyi Uzen'. Its common features include the prevalence of the blade technique in the stone inventory, with a high proportion of tools, particularly, various types of end-scrapers, with common occurrence of geometrics and arrowheads. The pottery was usually manufactured from the clay with crushed shells, the flat-based pots with strait or S-shaped walls were decorated in the upper portions by strokes and incised lines forming simple geometric patterns.

Three stages are distinguishable. The earlier stage is represented by Tu-Buzgu-Khuduk I and similar sites. The blade dominated stone industry obviously retains Mesolithic features. It includes numerous circular, double and lancet-like end-scrapers. A series of elongated symmetrical or truncated points was found. A small series of arrowheads included a tanged and notched varieties. Geometrics, few in number, included symmetrical trapezes and a crescent (Fig. 8).

The pottery was manufactured from clay tempered with sand and plant remains. The vessels with either rounded or flat bases, straight walls and closed mouths were ornamented in the upper part by either triangular or oval impressions forming horizontal rows or zigzags (Fig. 9).

The second stage is typified by the layers 3 and 2 of Jangar and the lower stratum of Varfolomeyevka site, located in the land- locked valley of Malyi Uzen' River.

The rich stone inventory has less archaic character being dominated by unretouched blades. The various types of end-scrapers formed the majority among the tools. The points

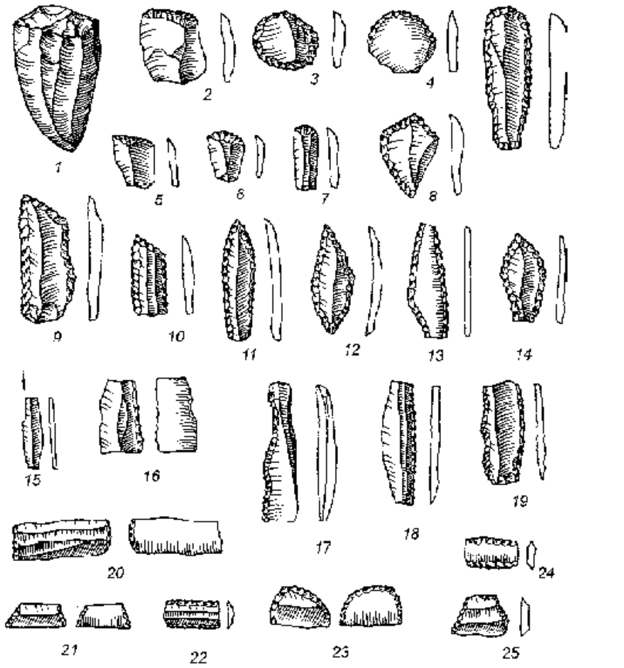

Fig. 8. Tu-Buzgu-Khuduk I. Flint tools.

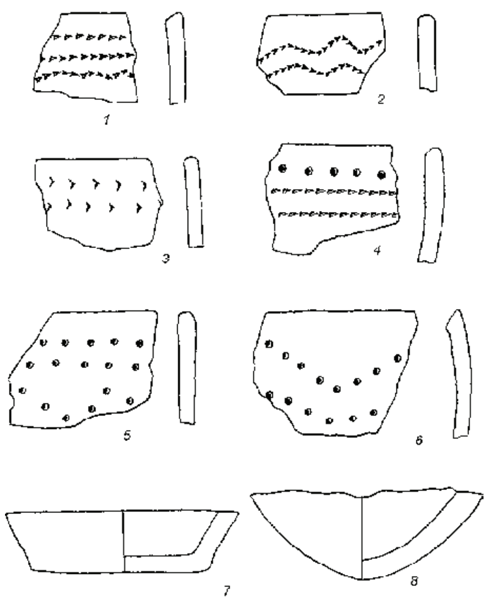

Fig. 9. Tu-Buzgu-Khuduk I. Pottery.

were slightly less numerous and included elongated and symmetrical varieties with the retouch either along the edge, or ventral, or dorsal surfaces. Side-scrapers comprised the notched category. A large series of knives made of elongated blades is noted. Geometrics consist of symmetrical trapezes and segments. Arrowheads consisted exclusively of tanged types (Fig. 10).

The solidly baked pottery was made from the clay with crushed shells. Straight-walled, close-mouthed and S-shaped varieties are distinguishable. The bases were almost exclusively flat. The ornament always restricted to the vessels'

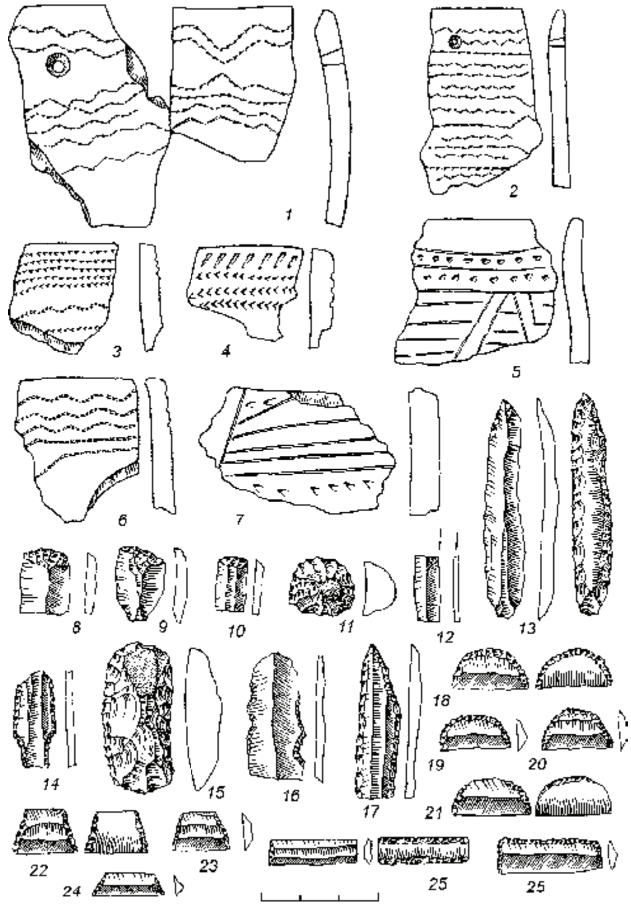

Fig. 10. Jangar, layer 3. Pottery and flint tools.

upper portion consisted of receding triangular, square and oval impressions and incised lines forming horizontal and undulating bands, the combination of horizontal and inclined rows, triangles and rectangles. In several cases the vessels of Varfolomeyevka have bulges on the inner side of the rims (Fig. 12).

The age of the initial Neolithic in the North Caspian area may be estimated based on the radiocarbon date obtained from Late Mesolithic site, Kairshak Va: 7255±95 BP.

Two dates are available for the later stage of Kairshak-Tenteksorian culture at Karshak-type sites, culturally related to Kugat-type sites: 6950±190; 6720±80 BP.

The subsequent Jangar-Varfolomeyevian stage is exemplified by the layers 2 and 3 of Jangar and layer 3 of Varfolomeyevka (Fig. 12). This layer yielded a radiocarbon date: 6980±20, coeval with the corresponding stage of Kairshak-Tenteksorian, which pottery assemblages show common elements.

The age of the Late Neolithic Jangar-Varfolomeyevian stage may be assessed based radiocarbon dates available for layer 2B of Varfolomeyevka (6400±230 and 6090±160) and that for layer 2 of Jangar (6100±70 BP). Although no radiocarbon dates for Kasirshak-Tenteksorian latest stages are currently

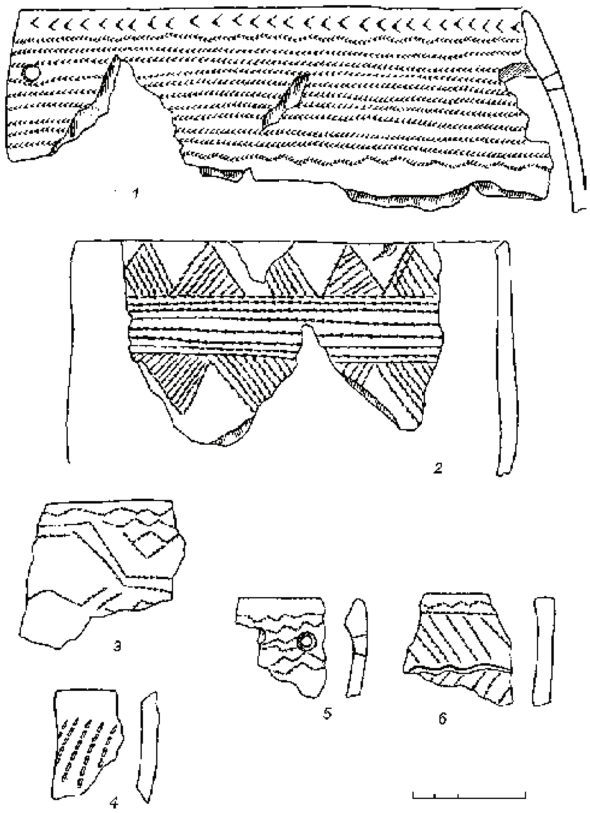

Fig. 11. Jangar, layer 1, pottery.

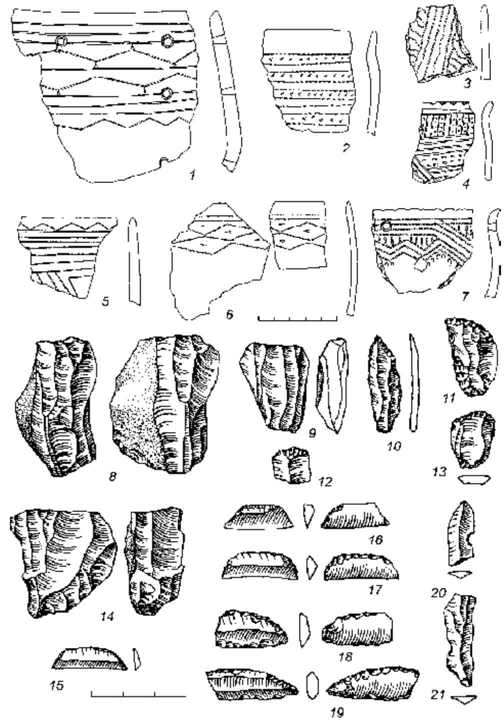

Fig. 12. Varfolomeyevka. Layer 3. Pottery and flint tools

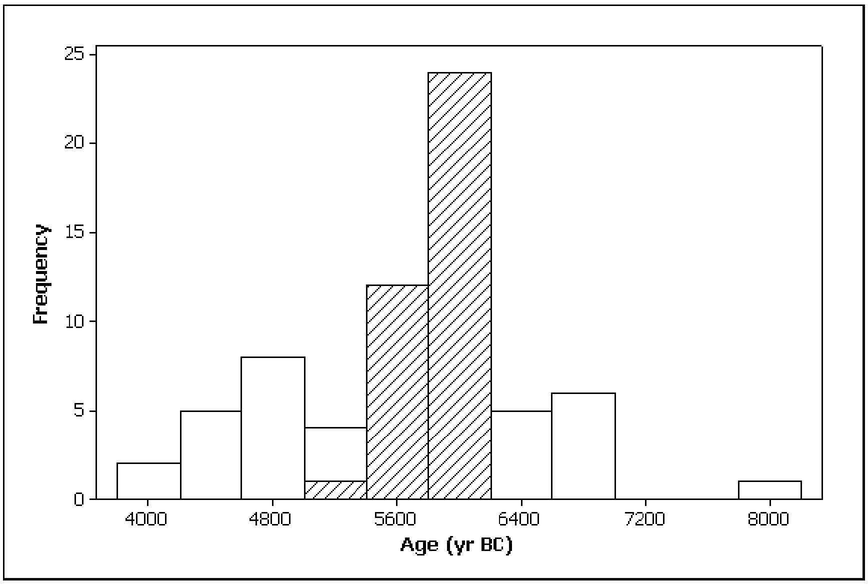

Fig. 13 . Frequencies of radiocarbon dates for North Caspian Neolithic sites.

available, the occurrence of Kasirshak-type pottery in Jangar, layer 2, implies its survival until that time.

The latest Neolithic stage on the Volga's left bank at the Tenteksor site is radiocarbon dated to 5500±150BP. This date was obtained for a soil sample and might be too young. The second phase of the Late Neolithic Jangar-Varfolomeyevian stage is estimated by the age obtained for Jangar's upper stratum, and Varfolomeyevka's layer 2A: 4214-3991 cal BC.

65 radiocarbon dates are available for North Caspian sites (Table 1) The coeval sample test reveal $T = 5859 \pm 236$ with $\sigma_c = 192$. Significantly, there is a considerable number of dates falling beyond the subsample and showing the age in the range of 8000-6500 BC (Fig. 13).

Table 1. Radiocarbon date-list

Site	BP uncal	Lab Index
Kairshak I	7230±90	Ki - 14094
Kairshak I	7180±90	Ki - 14132
Kairshak III	6950±190	GIN - 5905
Kairshak III	6720±80	GIN - 5927
Kairshak III	6100±100	GIN
Kairshak III	7950±90	Ki - 14133
Kairshak III	7890±90	Ki - 14097
Kairshak III	7780±90	Ki - 14471
Kairshak III	7740±70	Ki - 14095
Kairshak III	7680±90	Ki - 14096
Kairshak III	7530±90	Ki – 14632
Kairshak III (bone)	7190±80	Ki – 14633
Kairshak III (bone)	7010±80	Ki – 14634
Tenteksor I	6640±80	Ki - 14101
Tenteksor I	6630±80	Ki - 14137
Tenteksor III	7005±90	Ki - 14445
Kugat IV	7680±80	Ki - 14501
Kugat IV	7560±90	Ki - 14500
Kairshak IV	7105±90	Ki - 14440
Kairshak IV	6960±80	Ki - 14440
Burovaya 42	6920±90	Ki - 14444
Kachkarstau	6730±80	Ki - 14461
Kyzylakh	6400±90	Ki - 14443
Kyzylakh	5905±100	Ki – 14443
Jangar, layer 1	5890±70	LE - 2901
Jangar, layer 1	5480±80	Ki – 14643
Jangar, layer 2	6100±70	LE - 2564
Jangar, layer 2	6780±90	Ki – 14641
Jangar, layer 2	6680±90	Ki – 14642
Jangar, layer 3	5500±150	GIN - 6177
Jangar, layer 3	7080±90	Ki - 14639
Jangar, layer 3	6990±90	Ki - 14640
Varfolomeyevka 2A	5430±60	Ki - 3589
Varfolomeyevka 2A	5390±60	Ki - 3595
Varfolomeyevka 2A	5270±50	Ki - 3590
Varfolomeyevka 2A	5220±50	Ki - 3596
Varfolomeyevka 2A	7100±80	Ki – 14372
Varfolomeyevka 2A	6970±80	Ki – 14375
Varfolomeyevka 2A	6890±80	Ki - 14371
Varfolomeyevka 2A	6860±90	Ki – 14373
Varfolomeyevka 2A	6040±80	Ki – 14637
Varfolomeyevka 2A	5870±80	Ki – 14614
Varfolomeyevka 2B	6400±230	Lu - 2642
Varfolomeyevka 2B	6040±160	Lu - 2620
Varfolomeyevka 2B	8650±80	Ki- 14635
Varfolomeyevka 2B	7590±100	Ki-14636
Varfolomeyevka 2B	7280±100	Ki – 14374
Varfolomeyevka 2B	7230±90	Ki – 14368
Varfolomeyevka 2B	7070±90	Ki – 14370
Varfolomeyevka 2B	6980±90	Ki – 14369
Varfolomeyevka, layer 3	6980±200	GIN - 6546
Varfolomeyevka, layer 3	7760±100	Ki - 14108
Varfolomeyevka, layer 3	7620±100	Ki - 14142
Varfolomeyevka, layer 3	7250±80	Ki - 14109
Varfolomeyevka, layer 3	7170±90	Ki - 14143
Varfolomeyevka, layer 3	7080±80	Ki -14110
Varfolomeyevka, layer 3	7120±90	Ki - 14144

The majority of these dates has been obtained by means of direct dating of organic matter in the pottery (Zaitseva et al. 2009). Although in most cases these dates show a coherent pattern, one may observe considerable discrepancies in the measurements of the samples from the same sites, of apparently limited life-span. This suggests that some of the dated materials were affected by processes, which sufficiently affected the age. To test this hypothesis and to identify the possible sources of age distortions we conducted the multiple analysis of pot fragments from the site of Tenteksor. Microscopically visible plant remains and *Valvata* shells particles were extracted from the pottery mass and separately dated on AMS installations at the Laboratory of Uppsala University (Sweden). The measured age of the shells was 7235±45 BP with 13C= -13.3‰ (Ua-35226). That of the charcoal after the acid treatment was found to be 6695±40 BP with 13C= - 27.7 ‰. The pottery sherds were consequently separated into an inner ('the 'terra-cotta' red coloured portion) and an outer parts (the dark one), the both parts were treated by HCl and HF, and the remaining black carbon fraction mainly originated from the outer part has been measured. The obtained 14C age was 6695±40 BP with 13C= - 27.7 ‰ (Ua-35227). This age is practically equal to that obtained at the Kiev Laboratory with the use of liquid scintillation facilities: 6630±80 BP (Ki-14137). The difference in age between the dates for shells and charcoal, obtained for the same pottery fragment of 550 years which may be considered as an estimation of the reservoir effect. On the other hand, one may reasonably suggest that the charcoal penetrated the pottery matrix in the process of firing in a hearth and hence may be deemed as a reliable estimation of the pottery age.

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The Lower Don Neolithic

A.L. Aleksandrovsky,[1] T.D. Belanovskaya,[2] P.M. Dolukhanov,[3] V. Ya. Kiyashko,[4] K.V. Kremenetsky,[5] N.V. Lavrentiev,[1] A.M. Shukurov,[6] A.V. Tsybriy,[4] V.V. Tsybriy,[4] N. N. Kovalyukh,[7] V.V. Skripkin[7] and G.I. Zaitseva[8]

[1]Institute of Geography, Russian Academy of Sciences, Moscow, Russia
[2]Department of Archaeology, St. Petersburg University, Russia
[3]School of Historical Studies, Newcastle University, UK
[4]Department of Archaeology, Southern Federal University, Rostov-on-Don, Russia
[5]Department of Geography, UCLA, USA
[6]School of Mathematics and statistics, Newcastle University, UK
[7]Institute of the Geochemistry of Environment, National Academy of Sciences of Ukraine, [8]Institute for History of Material Culture, Russian Academy of Sciences St. Petersburg, Russia

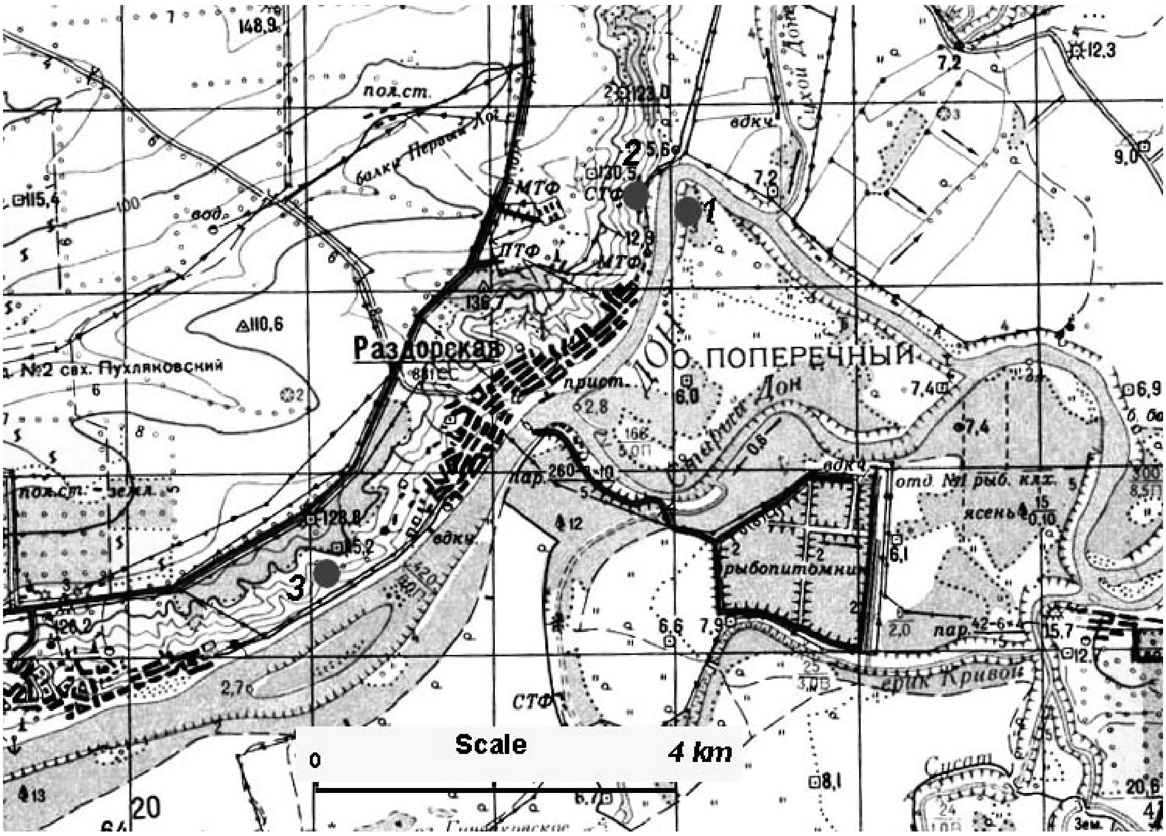

Fig. 1. Mesolithic and Neolithic sites on the Lolwer Don.
Key: 1 – Rakushechnyi Yar; 2 – Razdorskoye 1; 3 – Razdorskoye 2.

The low stretches of the River Don include several clearly stratified sites which are of key importance for understanding early Neolithic developments in the East European steppe area (Fig. 1).

One of these sites, *Rakushechnyi Yar*, is located in the north-western coastal area of a small island (Porechnyi) off Razdorskaya village, 100 km upstream from the city of Rostov (Fig. 1, *1*). The excavations conducted in the 1950s and 1960s exposed an area of over 1,200 square meters (Belanovskaya 1995). The site lies on the flood-plain terrace of the River Don, at the altitude ranging from 6.0 to 7.2 m above the river (2.8 – 2.9 m above the sea-level) (Fig. 2). The uneven surface consists of sub-latitudinal ridges 1 – 1.5 m high, separated by inter-ridge depressions. A beach barrier overlaying the ridges is apparently of a more recent age, being formed as a result of the change of the river course and accompanied by a steep meandering.

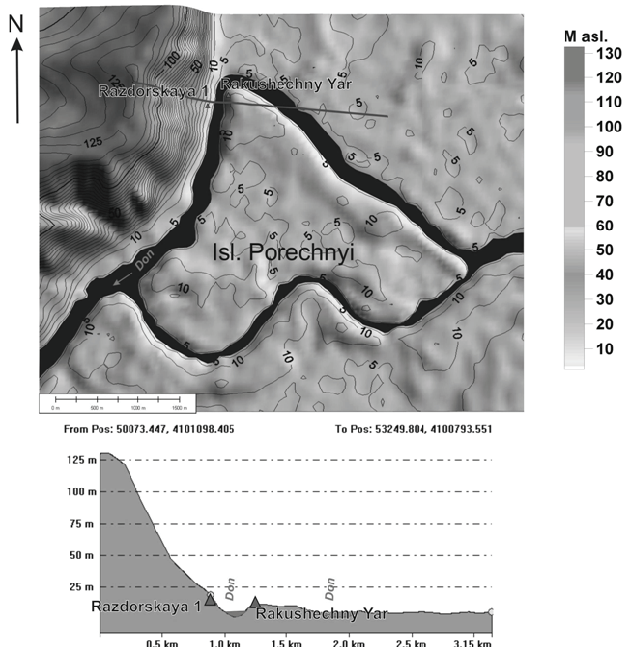

Fig. 2. Location of Rakushechnyi Yar site.

Belanovskaya in her original publication (Belanovskaya 1995) distinguished 23 archaeological layers, of which the lower 19 were attributed to the Neolithic, and the upper three to the Chalcolithic. The thickness of layers varied between 2 and 5 cm, and in most cases they were separated by sterile deposits. A different stratigraphical division has been suggested by Telegin (1981) who distinguished only six archaeological units, of which the upper three were considered as belonging to Bronze Age and Chalcolithic, and the lower three,. to various Neolithic stages.

Aiming at verifying the stratigraphy of the site and collecting additional samples, in August-September 2008 we dug the 6-meter deep test-pit, adjacent to Belanovskaya's excavation site (Fig. 2). Our observations indicated two series of deposits. The upper one (0.0 – 3.5 m) consisted of flood-plain alluvium interbedded by palaeosoils. The lower series (3.5 – 6.0 m) included shell-middens interstratified with fluvial deposits and a single poorly developed soil. The following sequence has been established (Fig. 3).

0 – 0.08 m (A1[1]): grey-brownish loam, loose, lumpy, with numerous rootlets; gradual transition to the underlying level;

0.08 – 0.22 m (BC): light grey-brownish loam, loose with unstable lumps, with numerous rootlets; sharp boundary with the underlying level;

0.22 –0.35 m (A1): grey to dark brown loam; lumpy, weakly compact, with rare rootlets; sharp transition to the underlying level;

0.35 – 0.45 m (A1) loam dark grey-brown loam, fine and lumpy, compact, with rare rootlets, gradual transition to the underlying level;

0.45-0.65m (AB) grey-brownish loam, with large charcoal particles, loamy, ribbed, clear transition to the underlying level;

0.65-0.90m ($A1_1$) dark-grey loam and sandy loam, compact, weakly lumpy, rare rootlets and charcoal particles along the krotovinas (mole burrows); gradual transition to the underlying level;

0.90-1.15m ($A1_2$): grey-brownish sandy loam, becoming lighter downwards; gradual transition to the underlying level;

1.15-1.55m (AB): light grey sandy loam, with a thin layer of weathered concretions at the bottom; clear transition to the underlying level;

1.55-1.73m (AB/BA): grey-yellowish sandy loam, amorphous, consolidated; clear transition to the underlying level;

1.73-1.80m (BA/D): sandy loam and sand alluvium; light spots against the darkish background; clear transition brownish grey to the underlying level;

1.80-1.83m (A1'): noncalcerous sandy loam, visibly lumpy, compact, clear transition to the underlying level;

1.83-2.0m (A1ca): greyish loam with white calcareous concretions along worm burrows, decomposed rootlets, clear transition to the underlying level;

2.0-1.20m (A1ca); dark grey loam, visibly lumpy, compact, calcareous concretions along worm burrows; gradual transition to the underlying level;

2.20-2.37m (ABca): grey-brownish loam, visibly lumpy, compact, solid denticulate calcareous concretions; clear transition to the underlying level;

2.37-2.46m (D): light loam and sand loam alluvium; rapid transition to the underlying level;

2.46-2.64m (A1ca): dark grey loam, visibly lumpy, compact with calcareous concretions; gradual transition to the underlying level;

2.64-2.8m (ABca): grey-brownish loam visibly lumpy, very compact, clear transition to the underlying level;

2.80-3.35m: three superimposed palaeosoils:

2.80-2.9m (A1ca): dark-grey loam visibly lumpy, compact with numerous light calcareous concretions; gradual transition to the underlying level;

2.9-3.07m (A1ca): darker loam of the same character;

3.07-3.3m (A1ca): lighter loam of the same character;

3.3-3.35m (ABca): grey-brownish loam, less calcareous; clear transition to the underlying level;

3.35-3.46m (D): sand-loam-sand alluvium, noncalcerous, rapid transition to the underlying level;

3.46-3.65m (A1ca): dark-grey loam, very compact, visibly lumpy, calcareous, *Viviparus diluvianus* shells appear in the bottom part; gradual transition to the underlying level;

3.65-4.35m (Neolithic archaeological layer) shell midden level in the compact calcareous sand matrix, rapid transition to the underlying level;

[1] AI, BC etc : soil horizons.

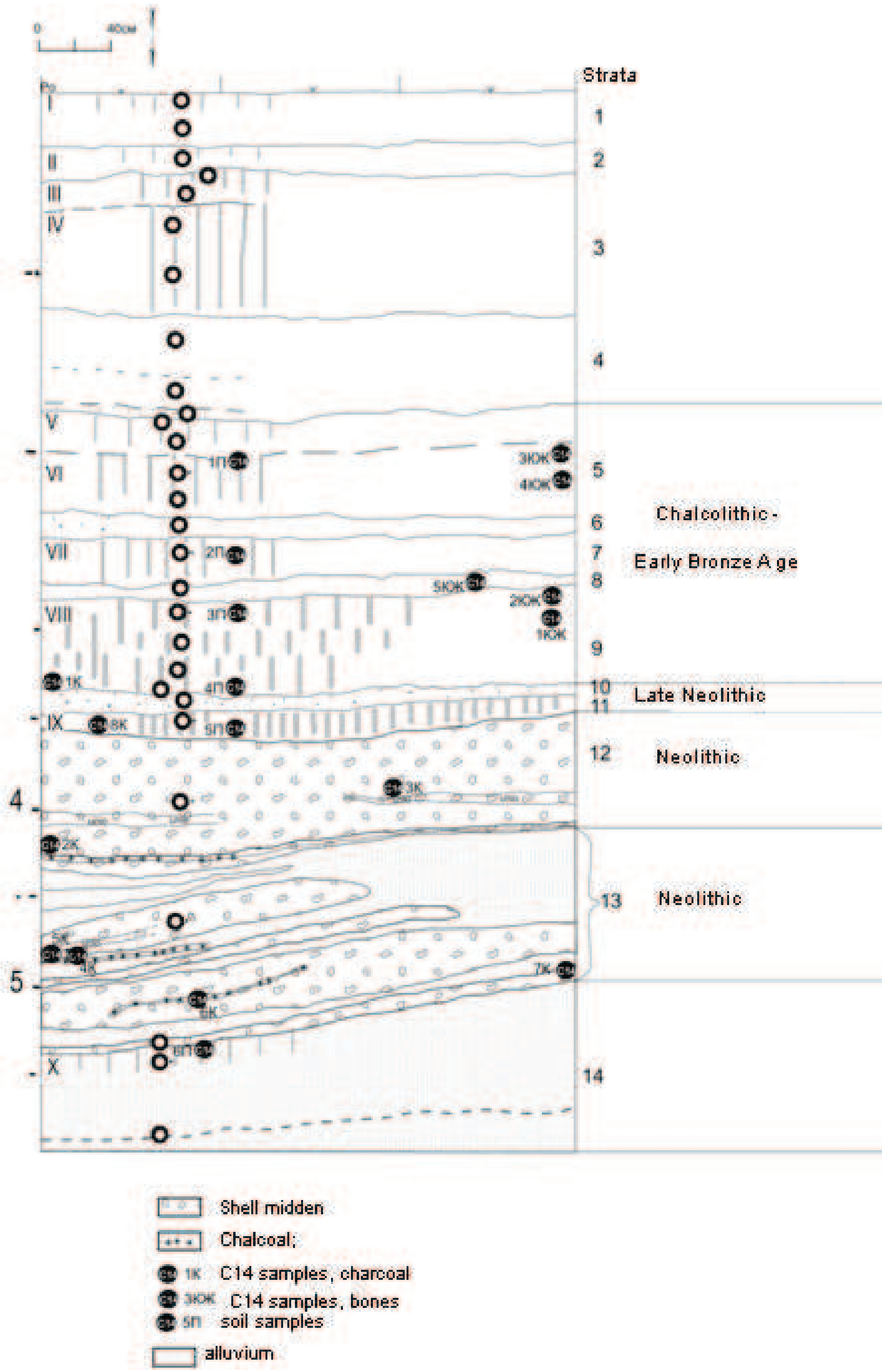

Fig. 3. Rakushechnyi Yar 2008. Stratigraphical sequence.

Note: White circles: samples for pollen analysis. Strata numbered in accordance with Telegin (1981).

4.35-4.50 (4.60)m: white fine- and middle size quarts-sand alluvium, cross-bedded, noncalcerous; rapid transition to the underlying level;

4.50 (4.60)-4.95m (Neolithic archaeological layer): shell midden level in the matrix of grey sand loam interbedded with white sand; rapid transition to the underlying level;

4.95-5.0 (5.05) m: light fine- and middle size noncalcerous sand alluvium; rapid transition to the underlying level;

5.0 (5.05)-5.4m (Neolithic archaeological layer): shell midden grey sandy loam with beds of white nonlalcerous fine grain sand; layer of fish bones and scales at 5.35m; ; rapid transition to the underlying level;

5.4-5.6m (A1): loam grey-brownish, slightly compact and cryptobedded; gradual transition to the underlying level;

5.6-6.0m (Dg): light fine- and middle size sand alluvium interbedded with brownish loam; the layer of fish bones and scales at 5.75m (Fig. 4).

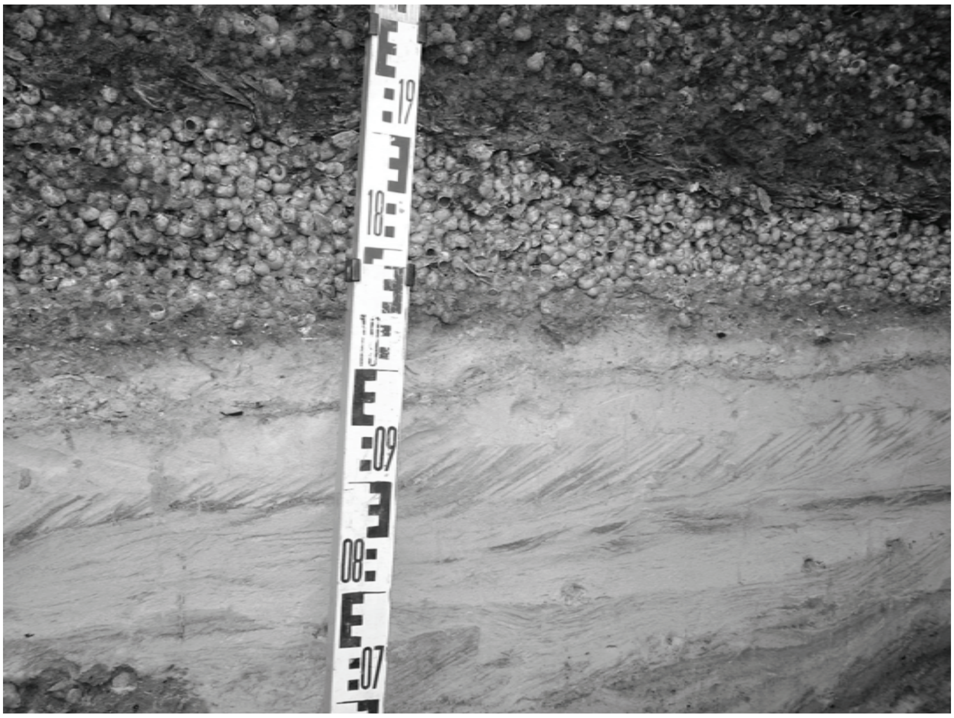

Fig. 4. Rakushechnyi Yar. Shell midden and alluvial deposits (below).

Fireplaces and the remains of surface dwelling structures have been reported by Belanovskaya (1995) from several levels. They were identifiable by occurrences of dark spots with irregular contours. In some cases the hearth hollows filled with charcoal and ashes were recognised. In several strata the writer reported pot holes up to 10 cm in diameter, visibly oriented along the river's bank. In yet other cases the writer could identify layers of burnt clay coating up to 5 cm thick, interpreted as 'house floors'. Remarkably, neither hearths nor clay coating were noted in the lower (Neolithic) levels.

The site *Razdorskoye 1* lies on the same level opposite Rakushechnyi Yar on the right bank of the River Don (Fig. 1, *2*). Archaeological deposits were found on the flood-plain level in the context of the sediments of the alluvial fan of a small stream. Previous investigations (Kiyashko 1987; Kremenetsky 1991) have established the following stratigraphy of the site:

0.0 - 0.35 m – grey sandy loam, A level, modern soil;
0.35 – 0.8 m – grey brownish loam; B level, modern soil;
0.8 – 1.0 m – darkish grey-brownish sandy loam with krotovinas; limestone fragments and shells; Scythian-Sarmatian archaeological materials;
1.0 – 1.5 m – light grey sandy loam with numerous bones and shells; Late Bronze Age archaeological materials (Timber Grave Culture);
1.5 – 1.65 m – brown-grey humified loam with bones; Bronze Age materials (Catacomb Culture);
1.65 – 1.85 m – grey-brownish loam with sandstone gruss;
1.85 – 2.05 m - grey-brownish loam with sandstone pebbles, bones and shells; Bronze Age Pit Grave Culture materials;
2.05 – 2.35 m - grey-brownish loam with sandstone detritus and shells;
2.35 – 2.65 m - grey-brownish loam with sandstone detritus, shells and charcoal; Bronze Age Konstantinovka Culture materials;
2.65 - 2.9 - grey-brownish loam with sandstone detritus and shells;
2.9 – 3.05 – grey-brownish loam with sandstone detritus, shells bones and flint tools; Bronze Age Maikop Culture materials;
3.05 – 3.20 m - grey-brownish loam with humus along burrows;
3.20 – 3.35 m - grey-brownish loam with sandstone detritus, shells bones and flint tools; Bronze Age Maikop Culture (older stage) materials;
3.35 – 3.8 m - grey-brownish loam with humus along burrows, sandstone detritus and charcoal;
3.8 – 4.1 m - grey-brownish loam with sandstone detritus, shells, and bones; Chalcolithic Khvalynian Culture materials;
4.1 – 4.3 m - grey-brownish loam with sandstone detritus;
4.3 – 4.5 m - grey-brownish loam with sandstone detritus and shells; Mariupol Culture materials;
4.5 – 4.7 m - grey-brownish loam;
4.7 – 4.9 m - grey-brownish loam with humus along burrows, sandstone detritus, shells and pottery fragments; Mariupol Culture materials;
4.9 – 5.1 m - grey-brownish loam with lenses of sandstone detritus;
5.1 – 5.3 m – dark grey-brownish loam with numerous particles of charcoal; Rakushechnyi Yar Neolithic materials.

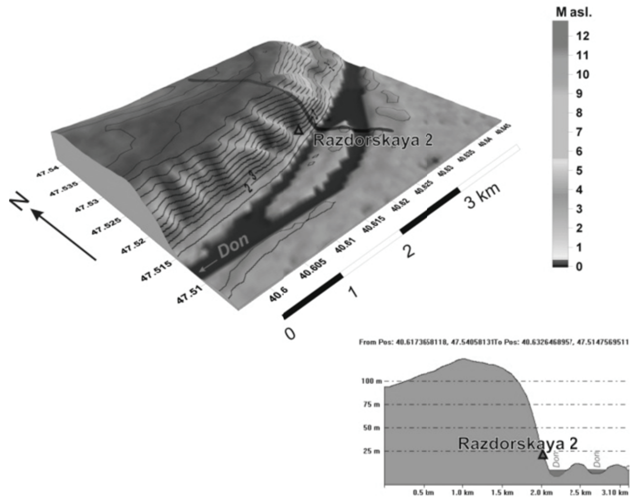

Fig. 5. Location of Razdorskoye 2 site.

Fig. 6. Razdorskoye 2 excavation site.

The site *Razdorskoye 2* lies 6 km downstream from the former (Fig. 1, *3)*, on the floodplain level (Fig. 5). The deposits, essentially similar to the lower series of Rakushechnyi Yar, were overlain by the thick alluvial fan of a small stream (Fig. 6). Our observations on the stratigraphy made in August-September 2008 are summarized below. The following sequence has been recorded on the western wall of the excavation site. All layers were inclined under 2-3°N to the north, apparently resulting from gravitational gliding. Stone Age materials have been encountered at all levels in the excavated area.

0.0-0.10 m : greyish sandy loam;
0.10 – 0.20 m: yellowish laminated middle-grain sand;
0.20 – 0.40 m: dark grey loam with shells;
0.40 – 0.80 m: light greyish compact loam with numerous shells;
0.80 – 0.90 m lens of compact shells wedging out in the northern direction;
0.90 – 1.0 m: dark grey sandy loam with numerous charcoal particles and reddish patches;
1.0 – 1.10 m: lens of compact shells wedging out in the northern direction;
1.10 – 1.30 m: reddish sandy loam with lenses of compact shells;
1.30 – 1.40 m: lens of reddish middle-grai sand;
1.40 – 1.50m: compact shells;
1.50 -1.80 m: dark grey sandy loam with numerous shells

Environments

In the geobotanical sense the investigated area lies in the province of forbs-Gramineae steppe with rare thickets of poplars and white willows on the Don's flood-plain. The pollen analysis of Razdorskoye 1 (Kremenetsky 1991) presumably on the sandy river terraces. Dense lime, oak, elm and maple forests with hazel in undergrowth covered the floodplain levels (Fig. 7).

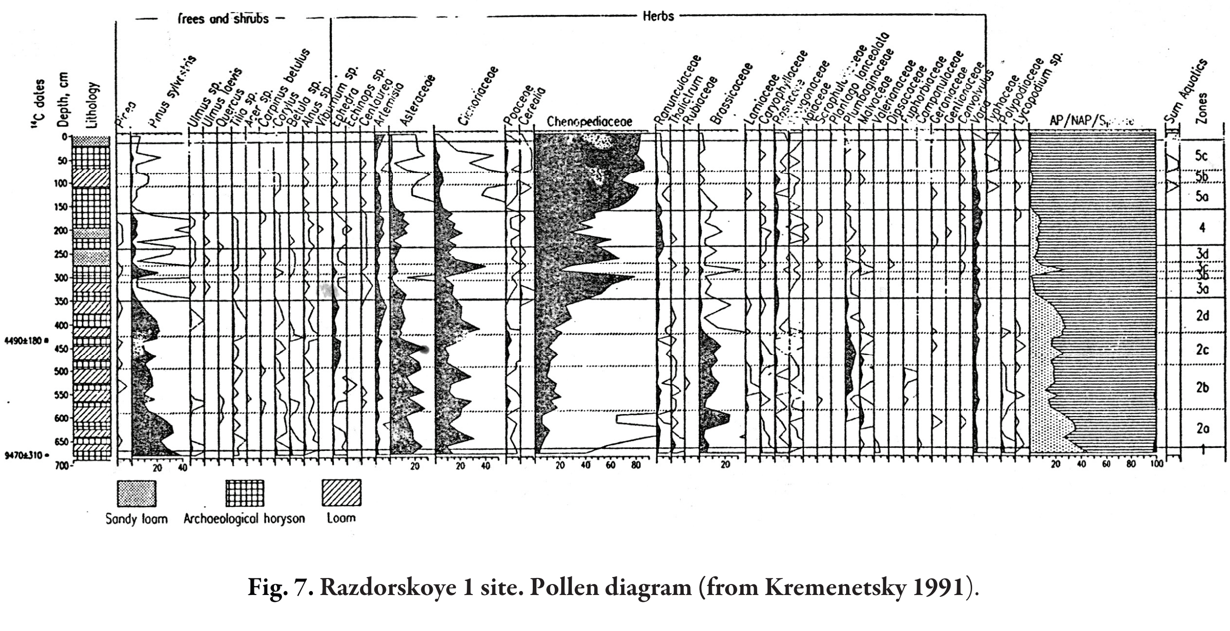

Fig. 7. Razdorskoye 1 site. Pollen diagram (from Kremenetsky 1991).

Table 1. Rakushechnyi Yar. Soil analyses

Nos	Levels, depth (cm)	$C_{organic}$, %	Humus, %	P_2O_5, %	CO_2 %	$CaCO_3$, %
1	VI A1, 200-220	0.56	0.97	0.19	3.02	6.85
2	VII A1, 246-264	0.51	0.88	0.15	2.19	4.97
3	VIII A1, 280-290	0.49	0.85	0.18	2.36	5.36
4	IX A1, 346-355	0.78	1.35	1.81	2.44	5.54
5	NAL, 399	0.30	0.52	1.40	3.16	7.17
6	NAL, 470	0.56	0.97	2.68	11.45	2.00
7	X, A1 540-565	0,23	0,40	0,18	1.85	4.20

Table 2. Razdorskoye 2. Soil analyses

Nos	Levels, lithology	$C_{organic}$, %	Humus, %	P_2O_5, %	CO_2 %	$CaCO_3$, %
8	20, light loam	0.23	0.40	0.16	4.58	10.40
9	17, upper charcoal layer	2.08	3.60	6.33	1.85	4.20
10	10, charcoal layer	0.73	1.26	1.94	0.64	1.45
11	7, light loam	0.18	0.31	0.41	2.58	5.86
12	2, charcoal layer	1,29	2.23	6.00	1.61	3.65

deposits shows that Neolithic settlements occurred in much wetter conditions with much larger spread of forest-like vegetation. These data are suggestive of pine forests

Spiridonova et al (2008) based on the pollen investigations of Razdorskoye 2 sequence arrived at essentially similar reconstruction. According to the pollen data the formation of Neolithic deposits occurred in an environment of intensively forested flood-plain (with oak, elm, hornbeam, birch and alder), and mesophytic forbs steppe on watershed areas.

The occurrence of multiple palaeosoils may be related both to the general climate change and the local relief features which favoured the intensive soil formation. The palaeosoil X, which underlies the Neolithic level, is particularly significant. This typcal 'fluvisoil' was formed under the condition of uninterrupted alluviation, which resulted in its laminated structure. Palaeosoil IV is the thickest. Its estimated period of its formation was no less than 1,000 years. All other soils were formed during shorter time-spans: soil VII – 700-900 years, and all others – 200- 500 years.

Judging from the chemical analyses (Tables 1 and 2) the humus content in palaeosoils is low. This may be due to diagenesis, the physical and chemical change that occurred immediately after the formation. The original humus content could be greater by a factor of 3.

The low humus content is also remarked in the shell-middens found in the compact calcareous sand matrix in the upper part of the Neolithic layer (399 cm). In the lower level (470 cm) the values of humus and P_2O_5 are notably higher. Their highest values are found in the palaeosoil IX within the Neolithic deposits. This may be viewed as an indication of the prolonged exposure of its surface resulting in an intensive accumulation of plant detritus (organic carbonate) and phosphates originated in living organisms. The upper palaeosoils, VI, VII, VIII (upper portion) and X, feature low humus content and extremely low phosphate values, suggestive of short-lived habitations in the post-Neolithic period.

Based on the sedimentation character, one may suggest that all three sites were originally located in the immediate vicinity of oxbow lakes of the River Don flood-plain, excessively rich in plant food, water fowl and various aquatic resources. These lakes were periodically inundated by the river and filled in by the alluvium slip slope deposits.

Archaeology

Rakushechnyi Yar

The pottery which constitutes the main element of the material culture is encountered in large quantities starting with the lowermost level of the site. The Neolithic layers include straight-walled or slightly profiled vessels with either straight or outside bent rims. The flat- bottomed vessels are most common, yet conic varieties were also found. The upper levels include only flat-bottomed ones.

By the character of clay tempering one may distinguish the varieties with crushed shells, burnt plants, sand and those without any tempering. As the spectrographic analysis shows, the pottery was subjected to firing at less 800-900˚C, and, more probably, less than 500˚C. The ceramic vessels were manufactured with the use of 'coiling technique', and the surface was subsequently smoothed either by shell rims a flat bone instrument. The majority of pottery vessels bear no ornament. The ornamented vessels constitute 10-11% in the lowermost level, their rate rising up to 47% in the upper Neolithic ones. In the ornamented vessels, the decoration was usually restricted to the upper part. These vessels were decorated by the impressions of stamps, which included the fish bones and shell rims. The most primitive ornamental patterns were found in the lowermost levels; they usually consist of isolated triangular, oval and rhomboid impressions forming parallel rows beneath the rim. Incised lines appear in thee lowermost level. In upper Ne3olithic levels the patterns include zigzag lines formed by comb impressions, still later appear herringbone patterns formed by zigzagged incised lines (Fig. 8).

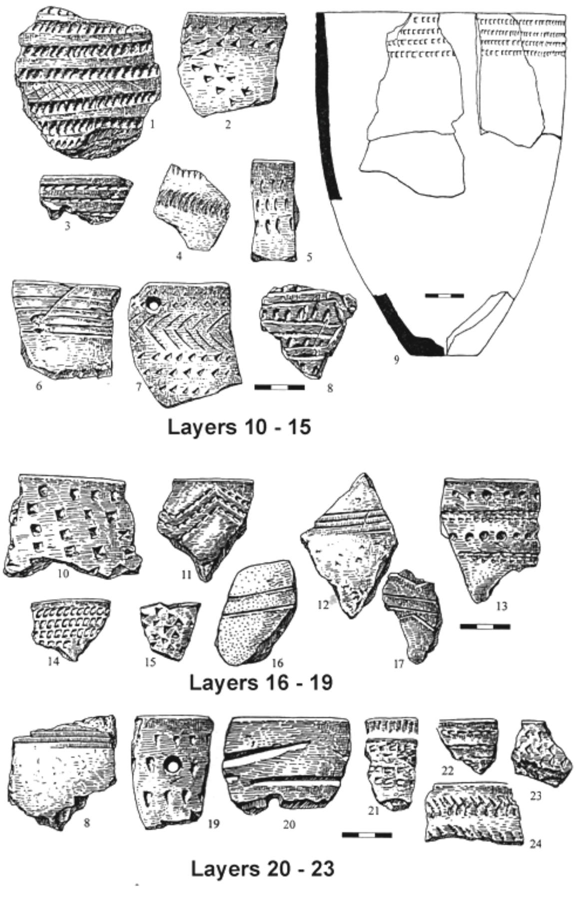

Fig. 8. Pottery from Neolithic layers of Rakushechnyi Yar (after Belanovskaya 1995).

The flint industry was dominated by the blade blanks. Retouched blades are most common amongst the secondary trimmed implements. Accomplished tools consist nearly exclusively of end-scrapers on truncated blades and semicircular varieties on flakes. Eight trimmed surface trapezes were encountered in the Neolithic layers. Axe-like tools made of clay slate include small-size either trapeze- or rectangular-shaped hatchets or adzes. Remarkably, one notes a series of perforated sinkers made of siltstone, sandstone and slate.

A rich collection of bone and antler tools includes awls, borers and various types of points. One equally notes several ornamented implements: awls, pendants and small-size axes. Among ornaments, one may distinguish incised lines and circular pits forming rhombi, networks and dotted patterns.

Razdorskoye 1

Materials originating from the Neolithic layer were not numerous they included fragments of dark brown straight-walled vessels with straight rims and flat bottoms. The clay was tempered with burnt plants, sand and crushed shells. The ornament consisted of rare oval impressions and rows of triangular stamps. The stone industry consist of prysmatic flint cores, oval and circular end-scrapers, points, and trimmed-surface trapezes. One also notes wedge-like slate axes.

Razdorskoye 2

Archaeological materials (Tsybriy 2008) consist nearly exclusively of stone, bone and antler implements, the finds of pottery are extremely rare. Among flint implements one notes a series of cores which include conic, prismatic, flat, flattened and amorphous varieties. Numerous blades and retouched blades are remarkable. Side-scrapers are frequent among accomplished tools. They were made predominantly on flakes and include lateral and oval varieties. Points are also numerous and technically may be often seen as borers. Trapezes are most common among geometrics. Axe-like tools are made usually of slate and include both typical axes and adzes. Eight slate plates were ornamented with incised simple geometric patterns.

Bone and antler industry is rich and varied. Various types of points being the most frequent. F series of bone and antler perforated tools is outstanding. Bearing complex geometric ornamentation they were of apparently ritual significance (Fig. 9).

Subsistence

Existing records suggest that the subsistence of all the sites studied in that area was essentially based on fishing and hunter-gathering with the predominant use of aquatic

Fig. 9 Bone implements from Razdorskoye 2 site.

resources. The lowermost strata of Rakushechnyi Yar site include exclusively bones of wild game (red deer, roe deer, fox, hare, and numerous birds). Sheep and goat appear starting with layer 21, and cattle, from layer 20. Horse is reported in the Bronze Age layer 15 and upwards.

The identification of bone remains from Razdorskoye 2 sites remains controversial (Tsybiy 2008). The faunal assemblage includes rare bones of red deer, roe deer, elk, boar and antelope saiga. At the same time, according to the report it contains the remains of at least three individuals of cattle. This conclusion needs further investigations.

All Neolithic levels contain numerous fish bones, often found in an anatomical order. The fish remains identified at Razdorskoye 2 sites include pikeperch (most frequent), sheatfish, carp, roach, sturgeon and pike (the latter two, less frequent). Seatfish specimen were more than 20 years old, and exceeded in length 2 meters (Sychevskaya 2008).

The mollusc shells identified in Neolithic layers of the Lower Don belong to fresh water species: the gastropod snail (*Viviparus dilluvianus* Kunth), being most common, and mussel (*Unio pictorum* Linn). Both molluscs are potentially edible.

Matveyev Kurgan 1 and 2

Two Early Neolithic sites, Matveyev Kurgan 1 and 2, are located in the valley of the Miuss River, on the littoral of the Azov Sea (Krizhevskaya 1992). Site 1 includes the remains of a surface dwelling with hearths and post-holes, as well as an open, allegedly ritual fireplace. At Site 2, open fireplaces and large stone and clay inlays were found. The animal remains of the both sites are dominated by wild species: aurochs, red deer, roe deer, beaver, wolf, wild boar, kulan and wild ass (the latter two were more typical of the Mesolithic age). The domesticates, which formed 18–20% of the total assemblage, include horse, cattle, sheep/goat, pig and dog.

Both sites contain rich lithic industries, with no less than 600 cores (both single- and double-platformed); elongated broad blades and less numerous flakes dominate the assemblage. End scrapers made from large flakes and retouched blades are found together with various tools made from blades. There are about 90 geometric microliths, mostly trapezes, in both symmetric and asymmetric varieties. Several 'bifacial' flint axes were reported, yet the number of slate polished axes is much larger. A diverse bone-and-antler industry found at the both sites includes spear- and arrowheads, awls and their fragments. Both sites have yielded slate sinkers for fishing nets. Only a handful of pottery items were found at either site: 6 fragments at the Site 1, and 21, at Site 2. The pottery fragments were unornamented and manufactured of silty clay without any apparent artificial tempering.

Chronology

12 newly available radiocarbon dates, obtained by direct dating of organic matter in the pottery from Neolithic levels of Rakushechnyi Yar have been statistically processed (Table 3).

Table 3. Radiocarbon dates for Rakushechnyi Yar site (Neolithic levels)

Samples	Index	Age BP	Sigma	BC max	BC min	Age BC	Cal 1 sigma	Error	X_i	X_i^2
Layer 20	Ki-6476	7930	140	7250	6450	6850	200	200	4.5	20.1
Layer 20	Ki-6477	7860	130	7050	6400	6725	163	163	4.7	22.5
Layer 13 (Kovaljukh)	Ki-15186	7690	90	6748	6382	6565	92	92	6.7	44.6
Layer 20	Ki-6475	7690	110	6900	6200	6550	175	175	3.4	11.6
Layer 12 (Kovaljukh)	Ki-15189	7580	90	6598	6244	6421	89	89	5.3	27.9
Layer 4 (Kovaljukh)	Ki-15190	7020	80	6026	5736	5881	73	73	-1.0	1.0
Layer 15	Ki-6480	7040	100	6050	5670	5860	95	95	-1.0	1.0
Layer 15	Ki-6478	6930	100	5960	5600	5780	90	90	-1.9	3.7
Layers 14-15	Ki-6479	6925	100	6000	5400	5700	100	100	-2.5	6.4
Layer 13 (Kovaljukh)	Ki-15187	6750	110	5876	5482	5679	99	99	-2.8	7.8
Layer 13 (Kovaljukh)	Ki-15188	6760	90	5841	5514	5678	82	82	-3.4	11.4
Layer 8	Bln-704	6070	100	5226	4727	4977	125	125	-7.8	61.4

Final mean age estimate: 5954 years calBC; standard deviation: 559 years.

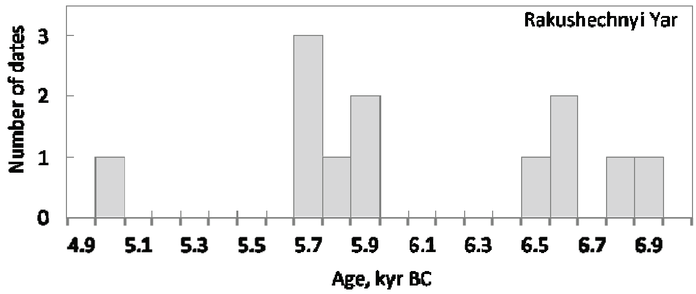

Fig. 10. Frequencies of radiocarbon dates for Rakushechnyi Yar site (Neolithic levels)

Table 4. Radiocarbon dates for Razdorskaya 2 site (coeval sample)

Samples	Index	Age BP	Sigma	BC max	BC min	Age BC	Cal 1 sigma	Error	X_i	X_i^2
#3 (hearth)	Ki-15178	8210	80	7460	7059	7259.5	100	150	1.8	3.4
#2 (hearth)	Ua-37000 (AMS)	8145	110	7480	6801	7140.5	170	170	0.9	0.8
#2 (hearth)	Le-8428b	8130	100	7515	6679	7097	139	150	0.8	0.6
#2a	Le-6952	7930	50	7035	6679	6857	89	150	-0.8	0.7
#2b (hearth)	Le-8428a	7920	110	7201	6458	6829.5	124	150	-1.0	1.1
#2c (hearth)	Ki-15179	7840	80	7051	6463	6757	98	150	-1.5	2.3

Final mean age estimate: 6984.4 years calBC; standard deviation: 202 years.

Table 5. Radiocarbon dates for Razdorskaya 2 site (beyond coeval sample)

Samples	Index	Age BP	Sigma	BC max	BC min	Age BC	Cal 1 sigma	Error	X_i	X_i^2
#A2	Le-6950	7450	100	6467	6087	6277	95	150	-2.0	4.0
#1 (hearth)	Ki-15777	7490	60	6448	6237	6342.5	53	150	-1.6	2.5
# A1	Le-6873	7640	120	6770	6232	6501	135	150	-0.5	0.3

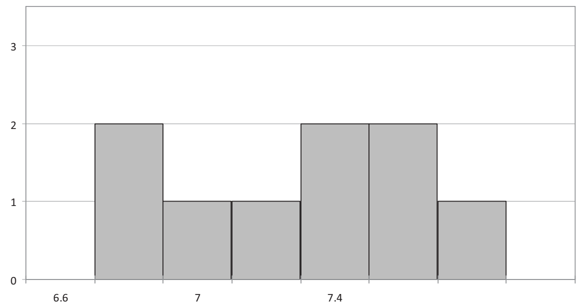

Fig. 11. Frequencies of radiocarbon dates for Razdorskaya 2 site

The projection of frequencies shows two distinct clusters of radiocarbon ages (Fig. 10). The older falls into the range of 7 – 6.5 and the younger one, 6 – 5.5 ky calBC, with one outlier.

Nine measurements were obtained for the charcoal from archaeological deposits of Razdorskaya 2 site, of which sixe were taken from the hearth. Six dates (Table 4) satisfy the criterion of the coeval sample.

Three dates show slightly younger ages (Table 5)

The projection of frequencies shows a coherent distribution of radiocarbon ages (Fig. 11).

Summing up the evidence of the radiocarbon ages for the studied sites in the Lower Don area one may suggest the following chronological sequence:

1. Razdorskaya 2: 7.2 – 7.0 cal BC;
2. Ralushechnyi Yar, older cluster, 7 – 6.5 cal BC;
3. Ralushechnyi Yar, younger cluster, 6 – 5.5 cal BC.

Significantly, the transition between the stages 1 and 2 (c. 7 cal BC) of this sequence apparently marks the initial penetration of pottery-making technology into that area. The advanced character of this technology strongly suggests the technology being introduced by experienced craftsmen from outside. On the other hand, the visible contiguity of lithic and stone-and-antler traditions rules out the probability of a major population shift.

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Early Neolithic in the South East European Plain

P.M. Dolukhanov,[1] A.M. Shukurov,[2] N. N. Kovalyukh,[3] V.V. Skripkin[3] and G .I. Zaitseva[4]

[1] *School of Historical Studies, Newcastle University, UK*
[2] *School of Mathematics and statistics, Newcastle University, UK*
[3] *Institute of the Geochemistry of Environment, National Academy of Sciences of Ukraine, Kiev, Ukraine*
[4] *Institute for History of Material Culture, Russian Academy of Sciences St. Petersburg, Russia*

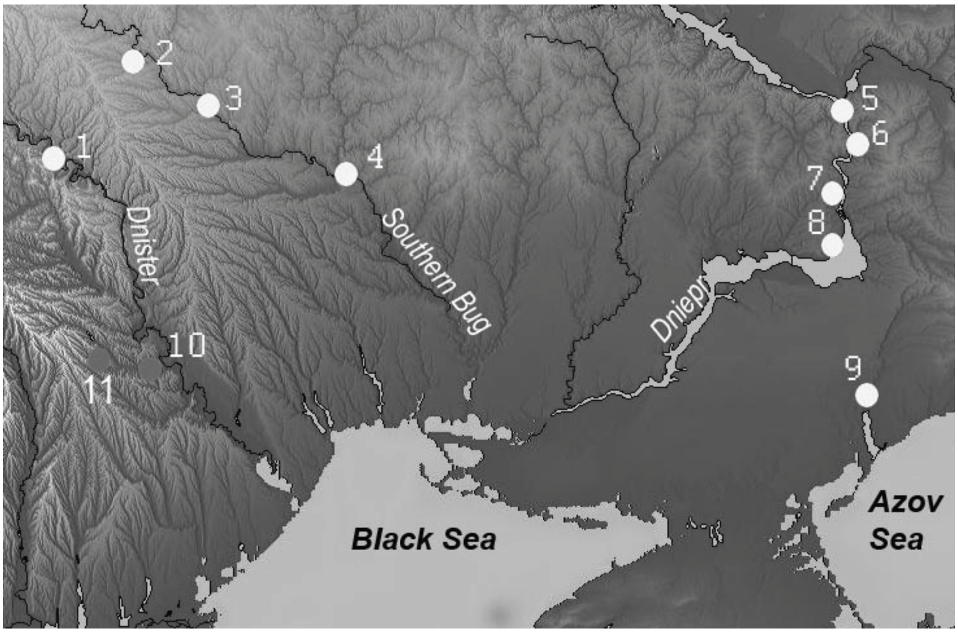
Bug-Dniestrian

The Early Neolithic in the western Ukraine and Moldova is usually associated with the sites of Bug-Dniestrian Culture (BDC) (Danilenko 1969; Markevich 1974). About 40 sites belonging to this culture are located in the valleys of middle courses of the rivers Dniester (Nistru), Southern Bug (Pyvdenyi Buh) and their tributaries (Fig. 1). The sites are usually located on the flood-plain terraces not exceeding 6 m above the river. The larger cluster of sites has been identified in the vicinity of the town of Soroki (Soroca), on the right bank of the River Dniester in the Republic of Moldova (Markevich 1974). The sites lie on a narrow, low floodplain of the Dniester River (6-8 meters above the river, 65-70 m above sea level), at the bottom of the steep slope of the upper terrace. At Soroki II site, where archaeological deposits are found in the context of clayey loam with calcareous rubble, three cultural levels were separated by sterile, and almost equally thick, beds of alluvial clayey loam. Remains of an oval-shaped semi-subterranean dwelling and a rectangular surface dwelling were identified at the near-bye Soroki 1 site.

Similar situation is observable on the Southern Bug (Pydennyi Buh) River. The site of Pechera was found on the higher flood-plain terrace (3.5 – 4 m above the present-day river level) of the right bank of the river. Archaeological deposits were found in a palaeosoil within alluvial deposits, 0.6 – 1.0 m below the surface (Dolukhanov 1978). Several sites were located on small and now submerged islets. Judging from existing records (Kotova 2002), the stratigraphy of these sites was basically similar.

Based on stratigraphic observations and typological criteria, Danilenko (1969) identified five stages in the BDC cultural evolution: Savran, Samchintsy, Pechera, Sokol'tsy and Skibentsy. This scheme has been contested by Kotova (2002), who using the revised stratigraphy and newly available radiocarbon dates for Baz'kov Isle site divided the entire BDC sequence

The older stage includes the sites on the Southern Bug River: the Baz'kov Isle, lower strata, Sokol'tsy 1, 2, 6, Pechera and several other sites. At several sites, the oval-shaped surface



Fig, 1. Neolithic sites in southern Ukraine and Moldova.

Key. 1 – Soroca; 2 – Pechera; 3 – Baz'kov Isle; 4 – Mikolina Broyarka; 5 – Sursky Isle ; 6 – Vasylievka Cemetery; 7 – Yasinovatka Cemetery; 8 – Nikolsky Cemetery; 9 - Kamennaya Mogila; 10 – Floreşti (LBK); 11 – Novye Ruseşti (LBK).

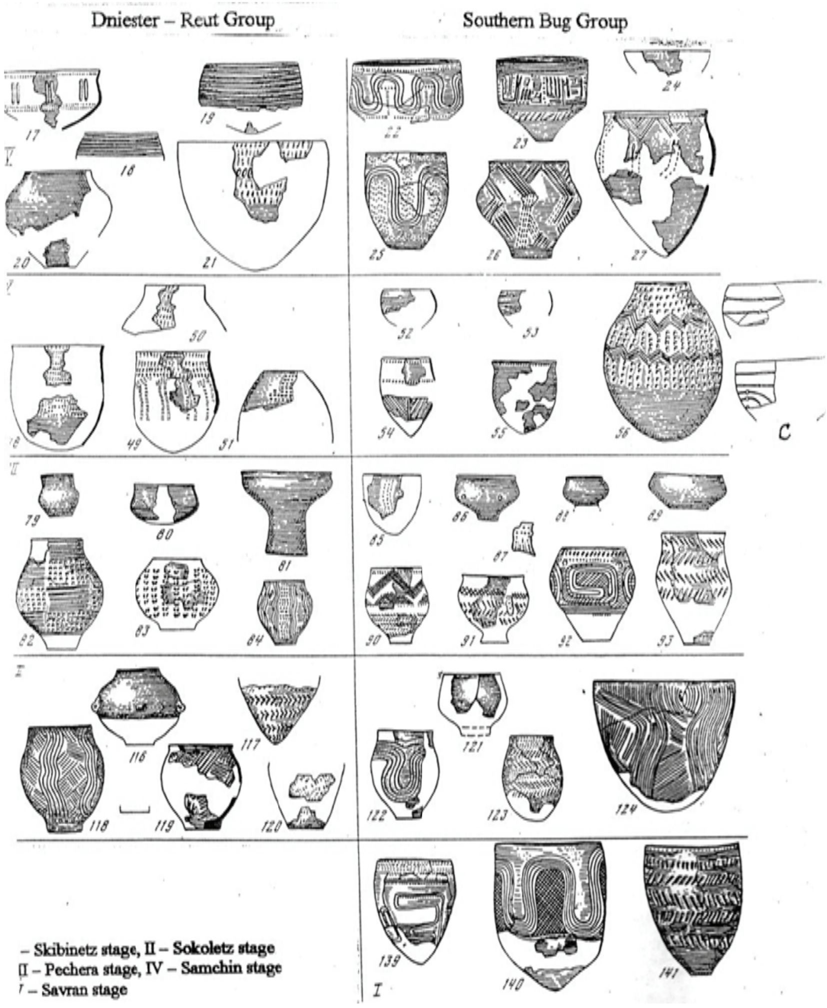


Fig.2 . The BDC pottery (after Telegin 1996)

The BDC younger stage is demonstrated by the materials from the Baz'kov Isle, upper stratum, as well as Savran', Pugach 1 and 2 and Gard 3. These sites contain surface dwellings of sub-rectangular and oval shapes, in several cases on the stone foundations. At this stage the composition of the pottery paste becomes more diversified and includes the additions of graphite, talc and mica. The pottery corpus consists of predominantly of flat-bottomed and also of conic vessels, as well as pots and bowls with high outward bent rims. The ornaments predominantly consist of comb impressions and incised lines, forming rows often separated by zigzags of comb impressions. Simple geometric patters formed by zigzags and angles are commonly encountered. The upper stratum of the Bazkov Island site, likewise the Soroki 5 site on the Dnistr River, include the 'notenkopf' variety of the Linear Pottery

The flint inventory is dominated by unretouched blades and their fragments. Semi-circular end-scrapers on flake are the most numerous among accomplished tools; burins are less common. One notes also end-scrapers, borers and combined tools on blades. Asymmetrical trapezes are most numerous varieties among the microliths. Bifacial sub-triangular points constitute a novel element in the flint industry.

dwellings with stone-laid hearths could be recognised. The pottery found at these sites was manufactured from clay tempered by sand and plant tissues, and, rarely, crushed shells. The pottery include pots, bowls and round-bellied jars. The most common ornamental elements consist of incised lines combined with oval-shaped or pit impressions. Several vessels were decorated with finger-nail impressions. In several cases the walls were decorated with circular bulges. A separate group consists of grey polished palleted bowls (Fig. 2). Remarkably, certain types of flat-bottom round-bellied jars ornamented with finger-nail impressions show direct analogies with the 'monochrome' Proto-Starčevo pottery in the Balkan area (Kotova 2002, 39; Dolukhanov 1978, 97).

The flint inventory as exemplified by the Bazkov Isle lower stratum assemblage was based on thin blades struck off single-platform cores, with unretouched blades making up a considerable part of the tool kit. End-scrapers on blade are the most common among the accomplished tools, which also included angle scrapers, borers and microliths.

At earlier sites, about 80% of animal remains belong to wild species, mostly roe deer and red deer. Among the domestic animals, pig, cattle and (on later sites) sheep/goat have been identified. Archaeological deposits contain huge amounts of *Unio* molluscs and tortoise shells. Roach (the most common), wels and pike are found among numerous fish bones. Numerous bird bones have been recorded, they belonged to sparrow hawk, honey buzzard and wood pigeon Remarkably, impressions of three varieties of wheat were found on the pottery: emmer, einkorn and spelt, as well as hulled barley and oat have been identified on the pottery at several BD sites (Markevich 1974, Kotova 2002, 2003).

The flint industry was based on the prismatic core technique with the common occurrence of retouched blades, backed blades, and small-size circular end-scrapers. Numerous geometrics include trapezes and triangles. Several blades at Soroki 1 show a sickle gloss. The BDC sites include bone and antler implements: points, awls, mattocks, chisels and 'hoe-like' tools. Polished stone axes, pestles and querns were found at a number of sites.

Table 1. Radiocarbon dates for Bug-Dniestrian sites.

Site	Index	Age BP	Sig ma	BC max	BC min	# sigma	Age BC	Cal 1 sigma	Error	X_i	X_i^2
Sokol'tsy 2	Ki-6697	7470	60	6420	6170	2	6295	63	63	7.1	51.0
Sokol'tsy 2	Ki-6698	7405	55	6410	6010	3	6210	67	67	5.4	29.4
Pechora	Ki-6693	7305	50	6190	6000	2	6095	48	48	5.2	26.9
Pechora	Ki-6692	7260	65	6190	5960	2	6075	58	58	3.9	15.5
Sokol’tsy 2	Ki-6697	7440	60	6439	6213	2	6326	57	57	8.4	71.3
Sokol’tsy 2	Ki-6698	7405	55	6433	6078	3	6255.5	59	59	6.9	47.3
Soroca 2	Bln-586	6830	150	5998	5490	2	5744	127	127	-0.8	0.7
Soroca 2	Bln-587	7420	80	6746	6048	3	6397	116	116	4.7	22.2
Soroca 2	Bln-588	7520	120	6708	6015	3	6361.5	116	116	4.4	19.7
Soroca 5	Bln-589	6495	100	5719	5207	3	5463	85	85	-4.5	20.4
Bazkov Isle	Ki-8186	6720	70	5736	5513	2	5624.5	56	56	-4.0	16.2
Bazkov Isl., u.s.	Ki-8169	6580	80	5644	5374	2	5509	68	68	-5.0	25.3
Savran, dwl. 2	Ki-6633	6920	50	5971	5716	2	5843.5	64	64	-0.1	0.0
Savran	Ki-6654	6985	60	5986	5743	2	5864.5	61	61	0.3	0.1
Mikolina Broyarka	Ki-6656	6520	70	5618	5358	2	5488	65	65	-5.6	30.8
Pugach 2-2;	Ki-6656	6895	50	5891	5673	2	5782	55	55	-1.2	1.5
Pugach 2.5-2.6 m	Ki-6657	6810	60	5895	5557	3	5726	56	56	-2.2	4.8
Pugach 2, XIX-51	Ki-6678	6520	60	5625	5320	3	5472.5	51	51	-7.4	54.8
Pugach 2-1,	Ki-6679	6560	50	5631	5372	3	5501.5	43	43	-8.0	64.7
Pugach 2.4-2.5 m	Ki-6687	6640	50	5636	5486	2	5561	38	38	-7.7	58.9
Pugach 2-1,	Ki-6655	6930	55	5988	5666	3	5827	54	54	-0.4	0.2
Baz'kov Ostrov	Ki-6651	7325	60	6240	5990	2	6115	63	63	4.3	18.1
Baz'kov Ostrov	Ki-6696	7215	55	6170	5950	2	6060	55	55	3.8	14.7
Baz'kov Ostrov	Ki-6652	7160	55	6180	5810	3	5995	62	62	2.4	5.6

Based on the occurrence of ‘hoe-like’ bone implements and the impressions of cereals on the pottery, several archaeologists (Danilenko 1969; Markevich 1974, Kotova 2002, 2003) held the view that BDC groups were involved in agriculture practices. This view was contested by Dolukhanov (1996), who argued that in view of their environmental setting on low-lying flood-plains with meadow-type soil poor in organic matter the occurrence of agriculture at these sites was highly improbable. He regards these sites as seasonal settlements of local hunter-gatherers involved in trade contacts with neighbouring farming communities.

Altogether 24 radiocarbon measurements have been obtained predominantly for samples of animal bones and antler from BDC sites (Table 1). The assessment of the coeval subsample yields T = 5848 calBC with σ_c = 316 years.

The plotting of frequencies (Fig. 3) shows an even distribution in the time-range between 6.4 and 5.6 ky calBC, without pronounced peaks suggestive of distinct stages.

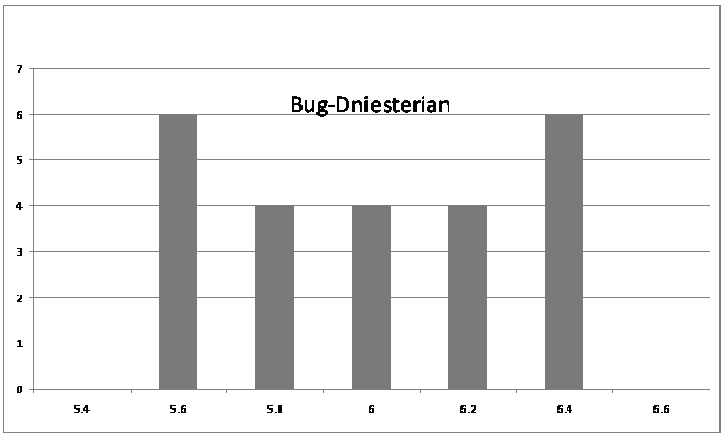


Fig. 3. Frequencies of radiocarbon dates for BDC sites.

The Linear Pottery (LBK)

The Northern Pontic area forms the easternmost extension of LBK sites, which reflects the early spread on fill-fledged farming economy into Central Europe.

The analysis of a large dataset of radiocarbon measurements of LBK sites in Central and Western Europe (Dolukhanov et al. 2000) shows that forty out of 47 analysed LBK dates satisfy the criterion of contemporaneity, forming a nearly Gaussian distribution with the most probable age of 5154±62 cal BC, and without any apparent temporal substructure. The average propagation rate of the LBK in the studied area is estimated as about 4 km/yr. This value is consistent with the earlier estimates of about 6 km/yr obtained by Ammerman and Cavalli-Sforza (1973) and Gkiasta et al. (2003).

A considerable number of sites are known to exist in the eastern area, namely, in river basins of the upper and middle Dniester, the Prut, and the Reut. Mainova Balka, the settlement in the Southern Bug basin north of Odessa which contains the typical LMK 'music notes' pottery, is the easternmost site of this type. Remarkably, according to Larina et al. (1999) the dwelling at this site contained also the pottery attributable to BDC. This confirms the earlier observation regarding the contacts between the farming and foraging communities as the possible source of agricultural products in the latter.

Radiocarbon measurements obtained for the bone samples for this dites yielded the following dates: 6430±140 (Ki-11243; 5650-5050 cal BC) and 6.310±150 (Ki-11242; 5650-4850 cal BC) (Sapozhnikov and Sapozhnikova 2008). Three radiocarbon dates obtained for the LBK site of Bil'shivitsy in the Ivan-Frankivsk province (the Upper Dniester basin) edxcavated by T.M. Tkachuk (Kotova 2002, pp. 30, 104), show the medium age of c. 5300 BC, thus close to the distribution range of LBK dates for Central Europe.

Surskian

The Surskian-type sites were first identified in the Dnieper River valley upstream the Rapids in the late 1920s. To this date about 30 sites are known in that area and also in the Azov Sea coastal area and the lower stretches of the Seversky Donets River (Telegin 1996). The small-size sites were found mostly on river islets, sand dunes on flood plains, and, rarely, on the slopes of river terraces. The sites on the islets Sursky and Shulaev included remains of a dwelling in the form of an oval hollow 100 sq m in size with traces of hearths inside and post holes along the edges.

The pottery made of clay tempered with sand and crushed shells consist of conic vessels with S-shaped walls, decorated by the rows of comb impressions and, rarely, incised lines. Kotova (2002) based on stylistic characteristics of the pottery, distinguishes three chronological stages. The oldest one is essentially similar to that of Rakushechnyi Yar and Bug-Dniestrian. It consists of conic vessels made of clay tempered with crushed shells and sand and ornamented with incised lines separated by comb impressions (Fig. 4).

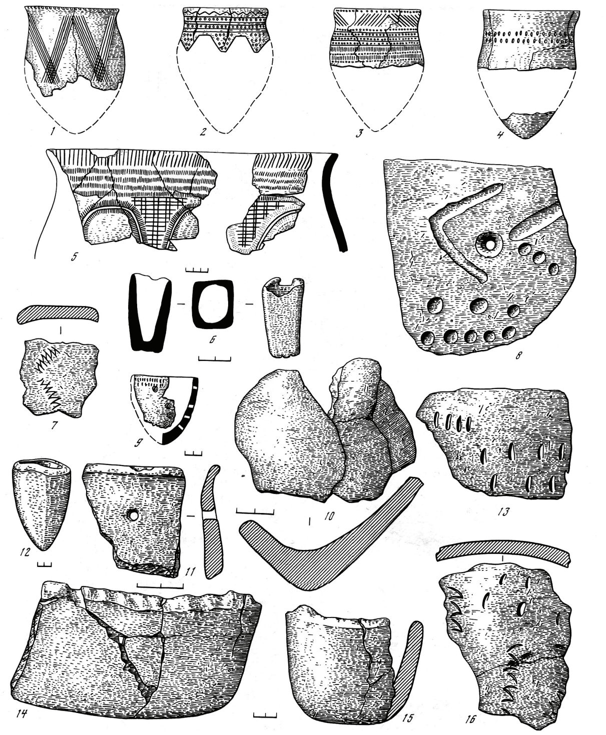


Fig. 4. Surskian pottery (from Telegin 1996).

The second stage features vessels made of clay with admixtures of crushed shells, sand and organic matter. The novel elements are noted in the vessels of rims cut inside, and ornaments consisting of large comb (often two-tooth) impressions.

The third stage marks the emergence of flat-bottomed vessels, shoulder-like rims often cut inside. The ornament consists of comb impressions forming zigzags and bands, and those of a 'receding spatula'.

The topographical location of the sites, the common occurrence of fish hooks, and arrowheads, as well as numerous finds of fish and birds remains, leaves one in little down the subsistence of Surskian sites was essentially based on fishing and waterfowl hunting (Telegin 1966, 44). On the other hand, Kotova (2002), based on numerous remains of cattle, sheep/goat, pig and horse identified by Pidoplichko (1956), in Surkian-related strata of Kamennaya Mogina and on Sursky Isle views the Surskian sites as reflecting an early stage of stock-breeding in the south East European area.

Radiocarbon dating of bone samples from two sites yielded a set of 10 dates (Fig. 4). The estimation of the coeval subsample produced $T = 5940 \pm 167$ with $\sigma_c = 167$.

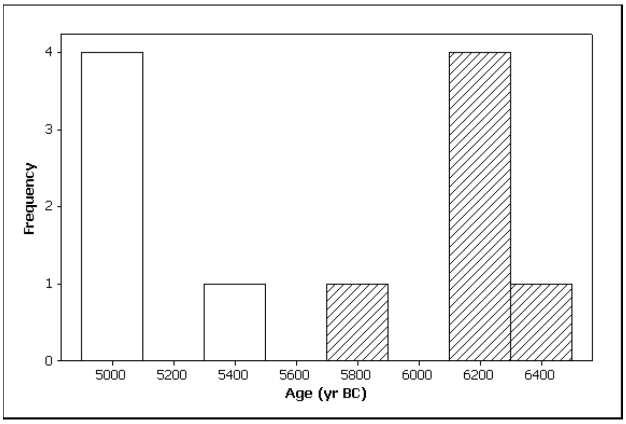


Fig. 5. Frequencies of radiocarbon dates for Surskian sites.

Strumel-Gastyatin

The sites of Strumel-Gastyatin (SG) type are considered (Telegin 1970) as belonging to the earliest stage of Neolithic in the Ukraine's forest-steppe. These sites are found on the River Dniepr in the vicinity of Kiev, either on the sand dunes of the flood-plain, or on the slopes of the river terrace. The pottery which consists of large conic vessels was made of clay with an admixture of vegetable matter. The ornaments consist of rows of comb impressions restricted to the vessels' the upper part.

Recently six radiocarbon dates have been obtained by direct dating of pottery from SG sites Pustynka 5, Lazarevka, Shmayevka and Studenok. The estimation of the coeval subsample yields $T = 5819 \pm 160$ with $\sigma_c = 128$ The projection of frequencies (Fig. 6) shows an even distribution in the time-range of 6.0 – 5.5 ky calBC.

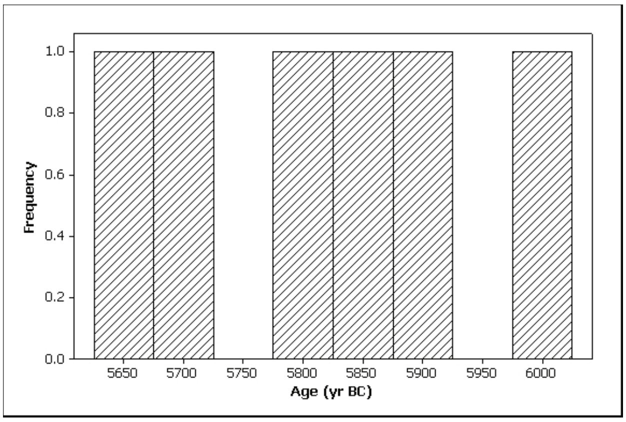


Fig. 6. Frequencies of radiocarbon dates for SG sites

Dnieper-Donetsian

The sites which belong to the Dnieper -Donets Culture Group (DDCG) are found in the middle and upper stretches of the Dnieper basin and that of the Seversky Donets River. More that 150 dwelling sites and about 20 cemeteries are known in northern Ukraine and southern Byelorussia (Telegin 1968, 1996). There exist controversies regarding the regional divisions and the overall extent of the DDCG. Kotova (2002, 2003) distinguishes several 'regional cultures': Volhynian, Kiev-Cherkassyan, Lisogubovian, and Donetsian. Telegin (1968, 1996) includes in its scope also the Azov-Dnieprian, which Kotova (2002, 2003) considers as belonging to the 'Mariupol cultural entity'.

The main characteristic of DDCG is its pottery which is defined as 'comb-and-stroked' decorated. According to Telegin (2002, 2003), this pottery consists of thick-walled either conic or flat-bottomed (at its latest stages) vessels. They are made of clay tempered with organic matter and, rarely, sand or crushed pottery. The vessels are decorated with comb impressions and strokes, as well as incised lines, covering the entire surface (Fig. 7).

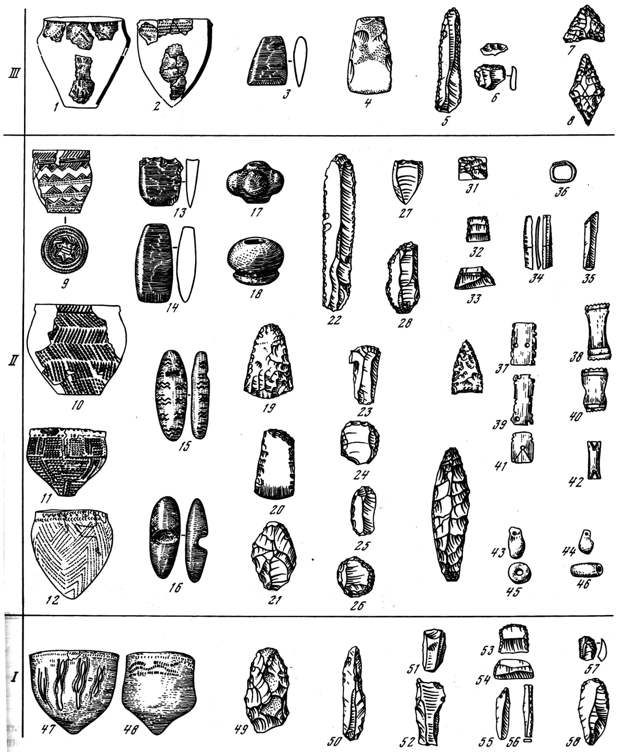


Fig.7 DDCG. Pottery and stone tools (after Telegin 1996).

Note. Roman digits correspond to three chronological stages according to Telegin (1966, 1996).

Kotova (2002, 2003) based on the improved stratigraphy, distinguishes two stages in the evolution of DD pottery. The writer notes that its former stage is essentially similar the Bug-Dniestrian one. It includes bowls and straight-rimmed pots decorated either by oval-shaped impressions and incised lines or comb impressions and incised lines. The pottery of the second stage included the collared flasks or pots with rims cut inside, ornamented by comb impressions, strokes and incised lines forming geometric patterns with zigzags, triangles, bands, herringbones. In some cases these geometric patterns are similar to that on the funnel beakers in Poland and Germany (Behrens 1961). Kotova (2003) notes the the influence of 'Mariupol cultural entity'.

The flint inventory included bifacially retouched axes, arrow- and spearheads, end-scrapers, knives, borers, as well as numerous microliths (symmetrical and asymmetrical trapezes, backed bladlets). Bone and antler implements were not numerous and included harpoons, spearheads, adzes and awls.

There is little doubt that the subsistence of DD groups was essentially based on hunting and food collecting with the special importance of fresh water fishing. There is evidence for stock breeding, particularly in the southern areas. Domesticated species prevail in the animal remains of Buz'ki site (the Kiev-Cherkassyan culture); they are dominated by cattle (28%), followed by sheet/goat (2%) and pig, (2.5%). In a few cases impressions of cultivated cereals have been identified on the pottery of the sites of the Kiev-Cherkassyan culture (Vita Litovskaya, near Kiev, and also Grini, Kamenka, The identified specimens belonged to the hulled wheats (einkorn and emmer), hulled barley, oat, bitter vetch and possibly peas (Kotova 2002). The question remains, whether these cereals were really cultivated by the local groups or they were imported resulting from the trade with the neighbouring farming communities. Likewise in the case of Bug-Dniestr sites, the lack of arable land in the vicinity of DD sites, makes the latter scenario more plausible.

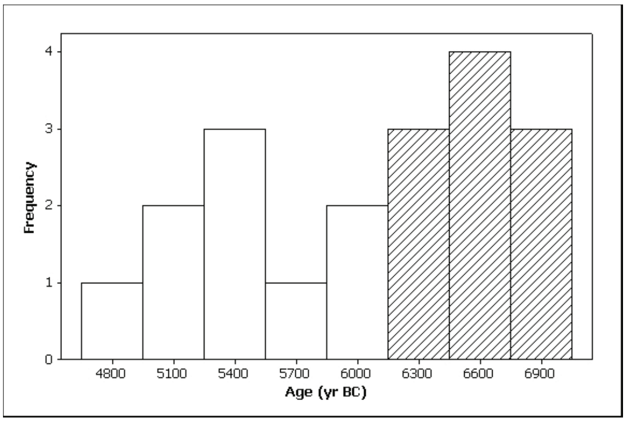


Fig. 8. Frequencies of radiocarbon dates for Dniepr-Donets Cultural Group. Neolithic Cemeteries

The DD cultural area contains about 20 cemeteries, several of which having more than 100 graves. According to Kotova (2002), the Dereivka cemetery which generally belongs to the Kiev-Cherkassy culture, includes the burials, which belong both to the Dniepr-Donets (longitudinal orientation) and Azov-Dnieprian (latitudinal) rites. The burials of the later stage of the same cemetery contain skeletons in the supine position having the longitudinal orientation. The burial inventory includes then pottery belonging to the second stage of the Kiev-Cherkassyan culture. The radiocarbon measurements obtained for human bones from DD cemeteries have been processed with the use of 'coeval subsample' and yield $T = 6601 \pm 209$ with $\sigma_c = 209$ (Fig. 8).

Donetsian Culture

The sites of Donetsian Culture are located in the basin of the Seversky Donets River. Series of radiocarbon dates were obtained for samples of animal bones from the stratified settlement on Tuba Lake (Fig. 9). The coeval subsample of the dates show the age of $T = 5045 \pm 199$ with $\sigma_c = 199$

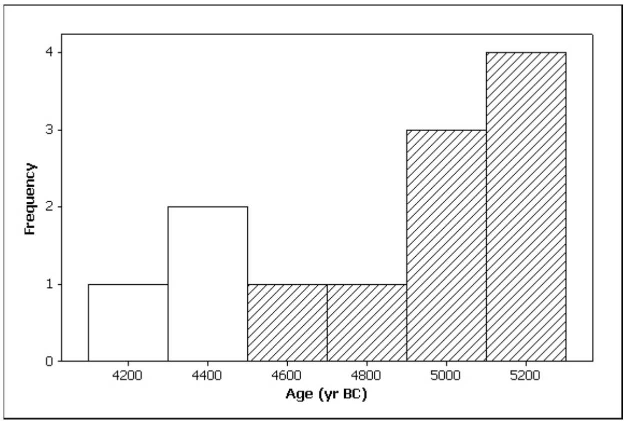


Fig. 9. Frequencies of radiocarbon dates for Donetsian Culture

Azov-Dnieprian Culture

According to Kotova (2002, 2003), the Azov-Dnieprian culture (AD), which this writer considers as part of the 'Mariupol cultural entity', is focused on the Lower Dnieper basin, the Crimea and western Azov Sea coastal area. This culture includes several dwelling sites (Sobachki, Vovchok, Vovnigi, S Demenovka and others) and cemeteries (Bokolsky, Lysogorsky, as well as several cemeteries in the Dnieper Rapids area, Vasilievka b5, Vovnigi 2, and others). The attribution of these cemeteries to the Azov-Dnieprian culture is based on the common features of the burial rite (the latitudinal orientation of the deceased, the occurrence of burial pyre, the red ochre and specific funerary inventories).

The earlier stage, according to Kotova (2002) includes the pottery manufactured from clay tempered by crushed shells and decorated by bands of comb impressions. The pottery of the later stage is made of clay with the addition of sand and organic matter. It features more diversified shapes of flat-bottomed vessels which include pots and bowls with collared rims cut inside. The ornamentation consists of triangular, oval or rectangular impressions incised lines forming simple geometric patterns: zigzags, herring bones, and angular figures.

Several sites of this stage are found in the valley of the Molochnaya River, in the Azov Sea coastal area: Semenovka 1 (second level) and Kamennaya Mogila (site 2, lower level). The latter site lies on the broad flood-plain, in the vicinity of limestone outtcrops on which the carvings of wild animals are visible.

The Azov-Dnieprian (AD) sites are found in the valley of the Molochnaya River and in the Azov Sea coastal area. Nearly 90% of the animal remains from the Neolithic layers belong to domesticates–predominantly cattle, followed by horse, sheep, goat, and pig. The wild species include red deer, boar, and bison, with numerous remains of fish and birds. Pollen analysis performed by G.A. Pashkevich reveals vegetation of bunchgrass steppe with rare occurrence of trees (birch, alder, elm, and hornbeam).

Series of radiocarbon dates were obtained for several AD sites, including the corresponding layers of Semenovka, Kamennaya Mogila settlement, Stril'chya Skelya, Yasinovatka I, Nikol'ski and Dereivka cemeteries (Fig. 10). These dates yield $T = 5313 \pm 187$ with $\sigma_c = 187$

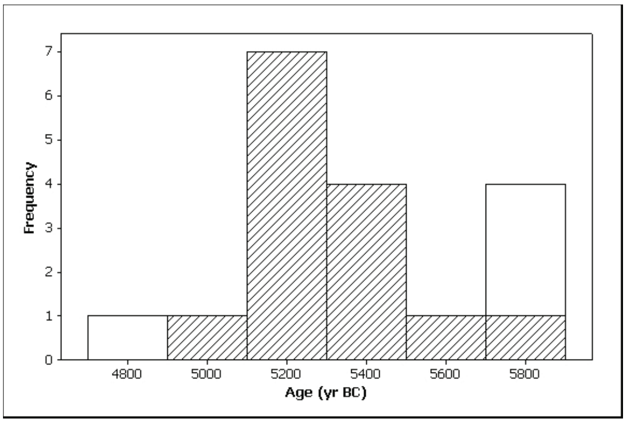


Fig. 10. Frequencies of radiocarbon dates for AD Culture.

Discussion

The classical theory views the European Neolithic as essentially resulting from the spread of farming from Western Asia either by means of direct migrations or by absorption and acculturation of indigenous Mesolithic populations. According to existing archaeological and radiometric evidence, the earliest manifestations of agriculture in south-eastern Europe are acknowledgeable at c. 8.6-7.5 kyr cal BC (Franchthi Cave). The next stages of early Neolithic in Central and Northern Greece include Proto-Sesklo (6.5-6.0 kyr cal BC) and Sesklo (6.0-5.3 kyr cal BC).

The spread of agricultural Neolithic further north, into the northern Balkan area and Middle Danube basin, took the form of several early farming cultural entities: Karanovo I-II (6.1 – 5.8 kyr cal BC); Karanovo III (5.4 – 5.1 kyr cal BC), Karanovo IV (5.3 – 4.8 kyr cal BC), Starčevo-Körös-Criş and Vinča (5.9 – 5.5 kyr cal BC)..

The expansion of early agriculture into the loess-covered plains of Central and Western Europe in the form of Linear Pottery Culture that started at 5600-5500 BC. Linear Pottery settlements were spreading with an average speed of 4-6 km/yr with the mean value of age of c. 5154 ± 62 BC (Dolukhanov et al. 2005).

The newly available radiocarbon measurements discussed in this and preceeding chapters strongly suggest that 'early Neolithic' cultures in the South East European Plain, including Yelshanian, North Caspian, Rakushechnyi Yar, Surskian and Bug-Dnestrian emerged during the 7th millennium BC (Fig. 11).

Considerable number of radiocarbon dates discussed above have been obtained for freshwater molluscs, organic matter included into the pottery fabric and human bones. Zaitseva et al. (2009) has demonstrated radiocarbon dates obtained for freshwater molluscs, including those inside the pottery fabrics, to be strongly affected by reservoir effect causing an offset which may exceed 500. On the other hand, Lillie et al. (2009) have shown the reservoir effect causing offsets in the dates of Neolithic-Eneolithic human bones towards older ages. At the same time, the experiences show a sufficient reliability of the radiocarbon measurements of other organic constituents in the pottery. Nonetheless, even taking into consideration these limitations, existing radiocarbon datasets strongly suggest early pottery-bearing culture in the South East Europeaqn Plain to be considerably older that early farming communities in the Balkans. 'Early Neolithic' entities in the eastern steppe area feature the developed pottery-making, which at their earlier stage shared certain common elements: conic and flat-bottom vessels ornamented by stokes and incised lines (Kotova 2002, 76). The question of the origins of this pottery-making tradition remains debatable.

In view of the existing evidence there is little doubt that the grater part of sites of 'early Neolithic' sites in the South East European Plain were small seasonally habituated settlements with the subsistence based on the local aquatic food resources, and, at a later stage involved in trade contacts with farming communities. Kotova (2002, 77) based on the evidence of Kamennaya Mogila and related sites suggests a local domestication of cattle, sheep/goat and pig, resulting in an emergence of a stock-breeding centre in the Pontic steppe area in the 7th millennium BC. This suggestion contradicts present-day genetic evidence. Mitochondrial DNA data unequivocally show that both Neolithic cattle (Bolognio 2005), and sheep (Tapio ei al. 2006) and pig (Larson et al. 2007) having a Near Eastern and not local origins. The initial easternmost penetration of fully developed agriculture stemming from the west is apparent starting with the mid-6th millennium BC, with the appearance of Linear Pottery sites in the western and south-western Ukraine. Significantly, at that time, the cultural and economic influence of LBK became at BDC sites.

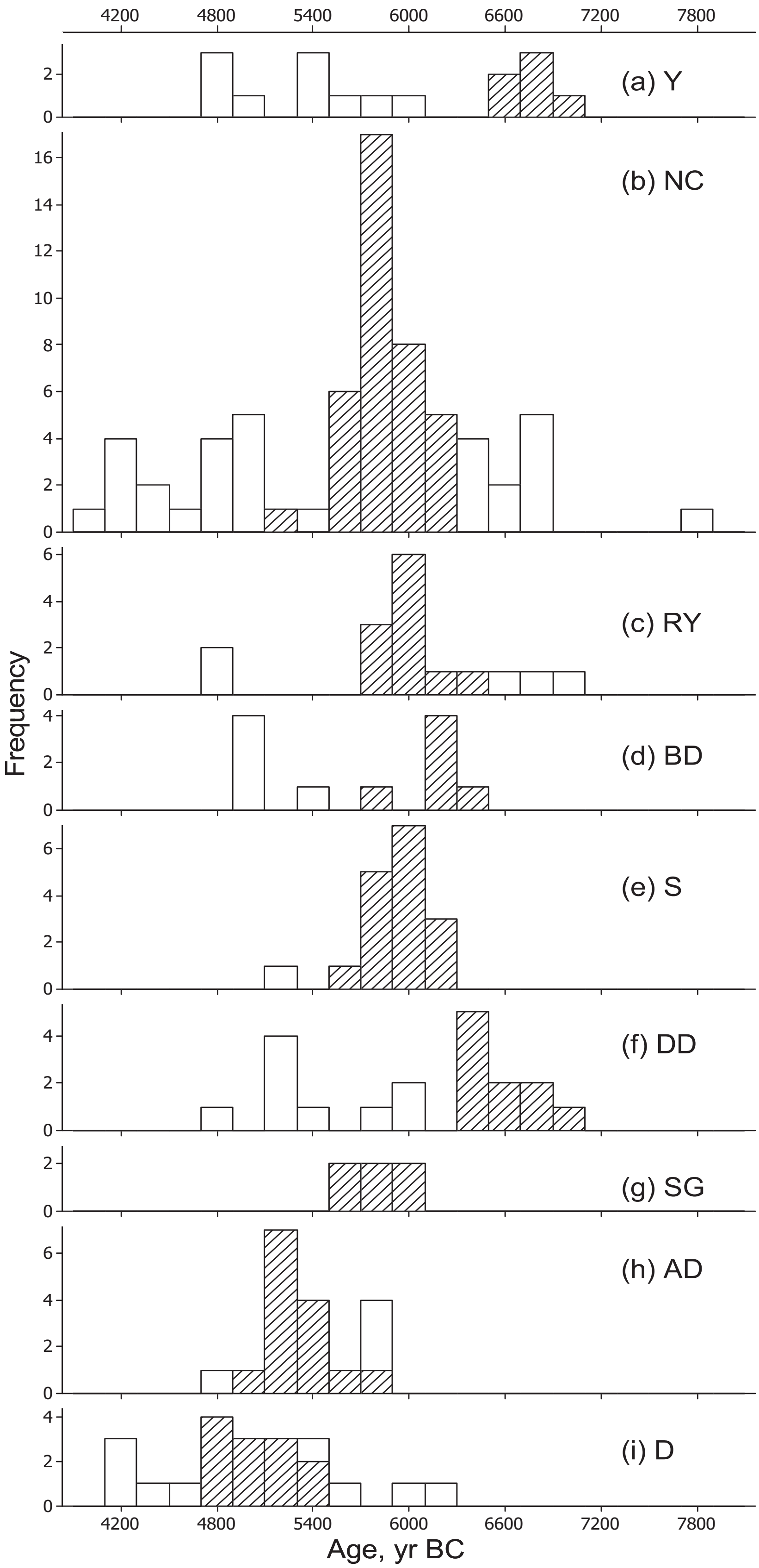


Figure 11. Frequencies of radiocarbon dates (coeval samples hatched).
a – Yelshanian; b – North Caspian; c – Rakushechnyi Yar; d –Bug-Dniestrian; e – Surskian; f – Dniepr-Donetsian; g – Strumel-Gostyatin; h – Azov-Dnieprian; i – Donetsian.

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The Holocene Environments in North-Western and Central Russia

Kh.A. Arslanov,[1] P. M. Dolukhanov, [2] L.A. Savelieva,[1] E.N. Dzinoridze,[2] G.F. Kuzmin[3] and V.P. Denisenkov[4]

[1] *Geographical Research Institute, University of St. Petersburg, 41 Srednii Pr., 199004, St. Petersburg, Russia*
[2] *School of Historical Studies, Newcastle University, UK*
[3] *Institute for Peat Industry, 5 Marsovo Pole, 191065, St. Petersburg, Russia*
[4] *Dept. of Geography and Ecology, University of St. Petersburg, 10th Line, 199044 St. Petersburg, Russia*

Introduction

The variations of climate in northern Europe in Late- and Post Glacial times and the impact of climate changes on past human societies remain in the area of highly topical interests. Over the past few years these topics have been discussed at several major international forums (Straus *et al.* 1996; Miller *et al.* 1999, NorFA 2002). International initiatives have been started (PEPIII, European Lake Drilling Programme) aimed at co-ordinating research efforts in this direction. (http://www.geog.ucl.ac.uk/ecrc/pep3/).

Notwithstanding considerable progress, numerous problems remain unresolved. The ongoing debate is focused on the following issues: the 'Last Glacial Terminal' and the human initial settlement (Schild 1996); Early Holocene environmental changes and their impact on the human settlements and subsistence (Dolukhanov 1995); transition to agriculture and stockbreeding in the boreal zone and their effect on the environment (Rimantiene 1996; Zvelebil 1996; Matiskainen 2001; Dolukhanov forthcoming).

To address these issues a team of experts in Prehistoric Archaeology, Palaeoenvironment and Radiocarbon dating has initiated an international research project sponsored by the INTAS (International Association for the Co-operation with Scientists from the former USSR). The programme of research included multidisciplinary investigations of both archaeological sites and their environments.. As a case study, we selected sequences located near the town of Velizh (Smolensk Oblast, Russia), and in the area of Lake Zhizhitsa (Pskov Oblast, Russia), in the vicinity of of several important archaeological sites. The obtained data were compared with the evidence obtained from other area of Central and North-Western Russia and Fennoscandia

Methods

We carried out sampling the organic and mineral deposits at the selected sites, using the Russian hand corer. Samples of organic sediments for radiocarbon analysis were taken each 10 cm. These measured at the Radiocarbon Laboratory of St. Petersburg University using conventional dating methods (Arslanov *et a*l., 1999). Samples for pollen analysis were taken from the entire sequence. Pre-treatment of samples was carried out with the use of the laboratory technique described by Berglund and Ralska-Jasiewiczowa (1986, 456). 600-400 pollen grains were counted per sample, and the pollen counts were expressed in percentages using the traditional procedure (Berglund and Ralska-Jasiewiczowa 1986, 462). In interpreting the pollen stratigraphy, we follow Mangerud's classification (Mangerud *et al.* 1982) and use pollen zones (PAZ) as equivalents of chronozones (CSZ). These are essentially radiocarbon-dated *biozones,* which, by definition are time-transgressive within wider geographical areas (Björck *et al.* 1998, 284). The reconstruction of palaeoclimate was carried out as described later.

Diatom analysis was also performed for the total sequence. The samples were treated with 30% H_2O_2 and enriched by a heavy liquid with specific gravity of 2.6. The coverslip was mounted with the use of an aniline resin, with a refraction index of 1.6. For the identification of the diatoms we used a light microscope with magnification of x1000. We also used the standard reference sources (Diatomovyi analiz, 1951, Diatomovye vodorosli SSSR, 1974, 1991; Cleve-Euler, 1953,1955; Krammer and Lange-Bertallot, 1991) We also studied the botanic composition of the peat.

Results

1. Prigorodnoe peat bog

The peat-bog, located at an absolute altitude of 174 m above sea-level, 7 km south of the town of Velizh and 100 km north-west of the city of Smolensk in North-western Russia (Fig. 1). Belonging to the upper catchment of the Western Dvina River, this area is part of the distal zone of the Last (Valdai-Weichselian) glaciation, just south of the limit of the end-morainic zone. The surrounding area consists of an evenly undulating sandy fluvio-glacial plain at an altitude of 150-180 m, with isolated occurrences of terminal morainic landforms (Malakhovsky & Markov 1969).

Starting with the maximum expansion of the Valdai (Weichselian) ice-sheet at 20-18 ka, a system of ice-dammed

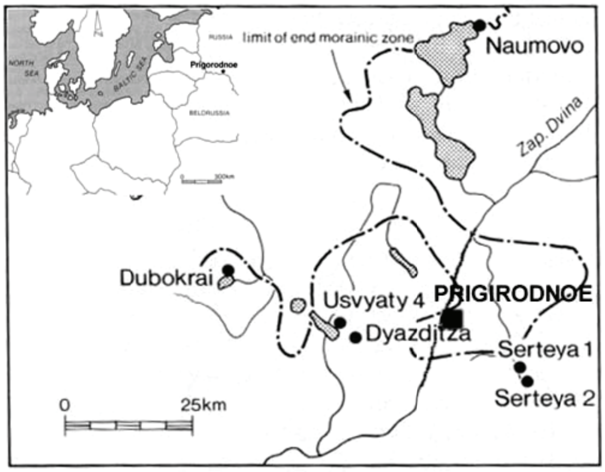

Fig. 1. General setting

lakes arose in the upper catchment of the Western Dvina and Dniepr Rivers (Kvasov 1975). Lake levels dropped as the glaciers retreated, opening the lower thresholds. Following the glacial retreat, the Orsha-Surazh basin emerged with its level at 180 m. At a later stage, the level of another Polotsk lake, lowered consequently to 165-160 and 130 m. This lake disappeared abruptly following the drainage of the Baltic Ice Lake at 8200 BC. The present peat-bog developed in a place of a smaller lake, a relic of the Late Glacial basin.

The total thickness of bog and lake deposits reaches 850 cm. Judging by the botanical composition, three stages in the develelopment of the lake/mire may be distinguished. First there was a eutrophic stage of limited duration, which included the accumulation of organic lake mud and *Carex* peat. During the mesotrophic stage that followed, the *Scheichzeria* peat was formed at the depth of 520-550 cm. The oligotrophic stage, which started at 5100-5200 BP, was marked by the accumulation of *Scheichzeria* peat, cotton grass peat and *Sphagum* peat. The high content of the *Sphagnum-Fuscum* and *Fuscum-Magellanicim* peat in the upper 2.2 m of the sediment shows an increased humidity in the final stage of development of the peat-bog.

Altogether 45 radiocarbon dates have been obtained for the Prigorodnoe bog sediments (Table 1).

Based on these dates the average rate of sediment accumulation was calculated (Berglund and Ralska-Jasiewiczowa 1986, 462) as 0.26 mm/year in the eutrophic stage and 0.62 mm/year in the mesotrophic stage. During the oligotrophic stage the accumulation rate steadily rose reaching a value of 6.8 mm/year in its final episode (Table 2).

The following pollen chronozones could be identified (Fig. 2)

Older Dryas (OD), c. 13150-12900 cal BP (according to Björck *et al.* 1998), established for the layer of clayey mud, at the depth of 850-825 cm. *Betula* (30-35%) and *Pinus* (20-40%) dominate, accompanied by *Betula nana* and *Salix* with ca. 5%. The total NAP value ranges between 20% and 40%, amongst which Cyperaceae, *Artemisia,* Poaceae and Chenopodiaceae. The occurrence of spores is insignificant, less than 7%, consisting of Bryales and *Equisetum*.

Table 1. Radiocarbon ages of the samples from Prigorodnoe peat-bog

Depth (cm)	Laboratory identification	δ^{14}C (‰) or ^{14}C age (yr BP)	Calibrated age (AD/BC)
20-30	LU-4853	108.4±7.0	ca 1950-1960 AD
30-40	LU-4852	145±0.7	
50-60	LU-4849	130±40	1679-1951 AD
70-80	LU-4848	300±70	1491-1655 AD
90-100	LU-4847	610±50	1301-1399 AD
100-110	LU-4846	800±50	1193-1279 AD
130-140	LU-4845	740±50	1223-1297 AD
150-160	LU-4844	840±40	1161-1255 AD
170-180	LU-4843	1020±60	901-1155 AD
190-200	LU-4842	1080±70	893-1021 AD
210-220	LU-4841	1210±60	719-891 AD
230-240	LU-4840	1480±60	539-643 AD
250-260	LU-4839	1790±60	133-323 AD
270-280	LU-4838	2140±60	351-57 BC
290-300	LU-4837	2340±50	515-261 BC
310-320	LU-4836	2400±60	755-399 BC
330-340	LU-4834	2670±50	895-797 BC
340-350	LU-4833	2900±60	1211-999 BC
350-360	LU-4832	2930±60	1257-1021 BC
360-370	LU-4831	3140±60	1495-1319 BC
370-380	LU-4830	3250±50	1603-1443 BC
380-390	LU-4829	3420±60	1873-1635 BC
390-400	LU-4828	3560±70	2013-1773 BC
400-410	LU-4827	3510±60	1913-1743 BC
410-420	LU-4826	3640±60	2131-1921 BC
420-430	LU-4825	3970±60	2573-2351 BC
450-460	LU-4822	4570±70	3495-3101 BC
460-470	LU-4821	4550±100	3495-3095 BC
480-490	LU-4817	4480±60	3335-3039 BC
490-500	LU-4816	4980±60	3907-3665 BC
500-510	LU-4814	4960±70	3889-3657 BC
510-520	LU-4813	5200±100	4220-3815 BC
520-530	LU-4806	5130±60	3981-3803 BC
530-540	LU-4805	5310±90	4245-4001 BC
550-560	LU-4803	5550±60	4453-4343 BC
560-570	LU-4802	5560±60	4453-4347 BC
570-580	LU-4801	5960±60	4909-4735 BC
580-590	LU-4800	6410±70	5469-5321 BC
600-610	LU-4798	7060±110	6020-5805 BC
610-620	LU-4797	7350±110	6375-6080 BC
620-630	LU-4796	7410±120	6395-6110 BC
630-640	LU-4795	8100±140	7325-6825 BC
640-660	LU-4794	8370±120	7570-7205 BC
660-680	LU-4792	9200±120	8550-8285 BC
680-700	LU-4790	9600±170	9220-8745 BC

Table 2. Accumulation rates of sediments in Progorodnoe peat-bog

Depth, cm	Mire/ lake stages	Sediments	Accumulation rate, mm/year
0-30	Oligotrophic	*Sphagnum fuscum* peat	6.8
30-100	Oligotrophic	*Sphagnum fuscum* peat	0.95
100-190	Oligotrophic	*Sphagnum fuscum* peat	2.18
190-220	Oligotrophic	*Sphagnum medium* peat	2.18
220-290	Oligotrophic	*Scheuchzeria* peat	0.62
290-340	Oligotrophic	*S. Medium* peat	0.62
340-490	Oligotrophic	Cotton grass peat	0.62
490-520	Oligotrophic	*Scheuchzeria* peat	0.62
520-550	Mesotrophic	*Scheuchzeria* peat	0.62
550-610	Eutrophic	*Carex* peat	0.26
610-690	Eutrophic	Organic lake mud	0.26

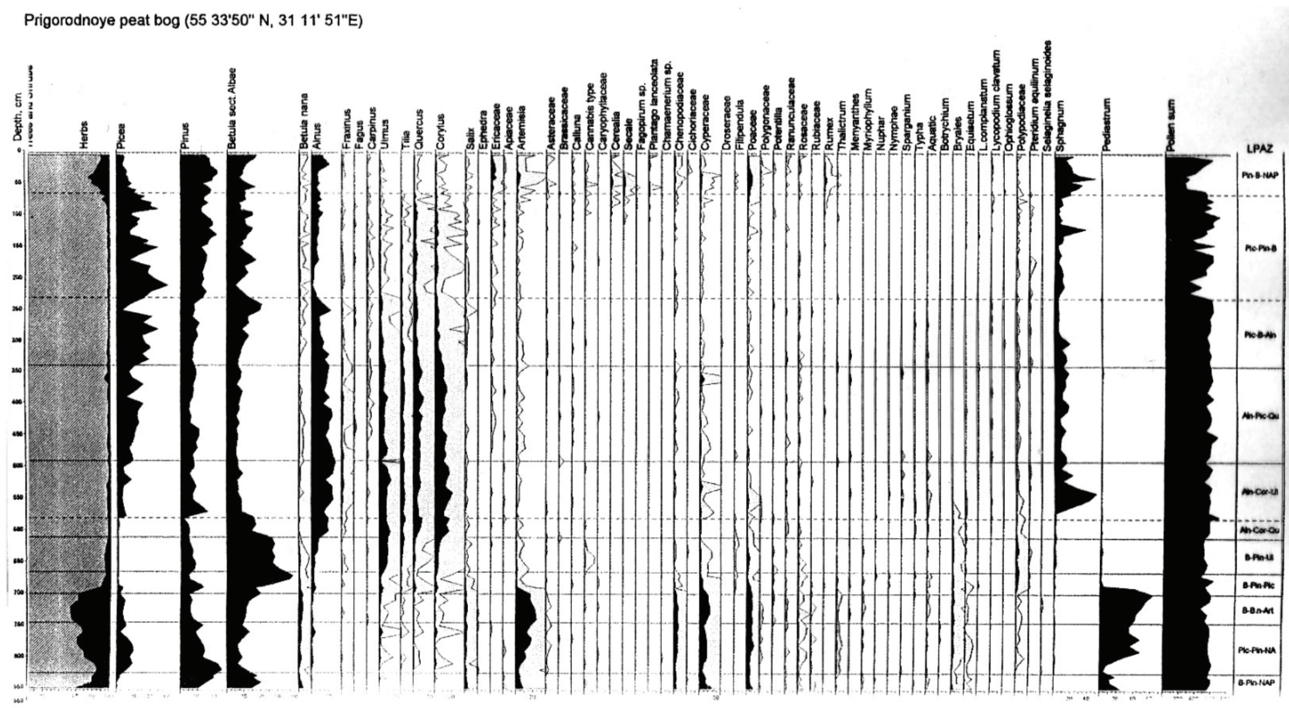

Fig. 2. Prigorodnoye peat-bog pollen sequence

Alleröd (AL), 12900-12650 cal BP (according to Björck *et al.* 1998) or 10680 BP in northwestern Russia (Arslanov *et al.* 1999), established in the sandy mud between 825-745 cm. *Pinus* pollen dominate (30-46%), followed by *Betula* (10-27%). The total amount of *Betula nana* and *Salix* less than 2-3%. There are regular occurrences of broad-leaved species (*Ulmus, Quercus, Tilia*) and *Corylus.* The abundance of herbs ranges from 18% to 39%, and consists of *Artemisia,* Cyperaceae, Poacea and Chenopodiaceae. The spores include Bryales, *Equisetum* and Polypodiaceae, with rare occurrences of *Botrychium* and *Selaginella selaginoides.*

Younger Dryas, (YD), 10900 cal BP (our data), established in the layer of clayey-calcareous mud, at the depth of 745-700 cm. *Betula* dominates the AP with about 25%, followed by *Pinus* (11%) and *Picea* (ca 5%). High percentage of *Betula nana* (7%) and *Salix* (5%). Notable occurrence of broad-leaved species (*Ulmus, Quercus, Tilia*) and *Corylus.* NAP taxa reach 50%, with, *Artemisia*, 25%; Cyperaceae, 12%; and *Poaceae*, 6%. Bryales dominate the spores, with occurrences of *Selaginella selaginoides.*

Preboreal (PB), 10900-9340 cal BP (our data) established in the layer of organic lake mud at the depth of 700-665 cm. The chronozone is marked by the rapid decrease of NAP pollen, from 35% to 5%. *Betula* treaches the highest values for the entire sequence attaining 80%, while *Pinus* ranges between 7% and 25%. *Alnus, Corylus, Ulmus, Tilia* and

Quercus occur regularly, albeit in small quantities (1 - 5%). Rare occurrence of spores, mainly Polypodiaceae, Bryales, and *Sphagnum* were noted.

Boreal (BO), 9340-7860 cal BP (our data) established in the layer of organic lake mud, at the depth of 665-610 cm. *Betula* remains dominant with 55%; *Pinus* with 15%. A notable increase in the amounts of *Alnus* and *Corylus*. *Ulmus* increases attaining 10%, *Picea* occurs sporadically. Starting from this level upwards, the abundance of NAP never exceeds 6%, with the exception of the most recent chronozone, SA-3. Spores show the same concentration as in the previous chronozone.

Early Atlantic (AT-1), 7860 – 7345 cal BP (our data) established in the layer of grass peat with an admixture of lake mud, at the depth of 610-580 cm. The percentage of *Betula* decreases to 25-30%, and that of *Pinus*, to 5-10%, with the increases of *Alnus* (23%), *Corylus* (15%) and *Quercus* (10%). Starting from this level, *Fraxinus* occurs regularly and *Ulmus* attains 10%. Spores are rare.

Late Atlantic (AT-2), 7345 – 5670 cal BP (our data) established in the layer of grass peat, at the depth of 580-490 cm. A reappearance of *Picea* (5-10%) is notable. The proportions of *Betula* and *Pinus* range from 15% to 30%. That of *Alnus* reaches the highest values for the entire sequence (10-27%). Increased values of *Corylus* (10-20%), *Ulmus* –12%, *Quercus* -9%, *Tilia* –5% and *Fraxinus* - 2% . The amount of spores increases, mainly *Sphagnum* (5-50%).

Subboreal (SB), 5670 – 3055 cal BP (our data) established in the layers of *Eriophorum* and *Sphagnum* peat at the depth of 490-340 cm. *Picea* and *Alnus* are the commonest with 15-35% and 12-24% respectively. The values of *Betula* and *Pinus* decreased to 10-22%. The total rate of broad-leaved species remain high (10-20%), with the value of *Quercus* increasing by 2% in relation to the preceding chronozone and attaining 11%. *Sphagnum* is dominant amongst the spores, with 5-17%.

Early Subatlantic (SA-1), 3055 – 1360 cal BP (our data) established in the layers of *Scheuchzeria-Sphagnum* and *Magellanicum* peat, at the depth of 340-230 cm. The total percentage of the broad-leaved species and *Corylus* notablt decreases. *Picea* is dominant with the values ranging between 10 and 40%. *Alnus* and *Pinus* pollen are in the range of 8-22%.

Middle Subatlantic (SA-2), 1360-372 cal BP (our data) established in the layer of *Fuscum, Magellanicum* and *Scheuchzeria* peat at the depth of 230-65 cm. High percentage of *Picea* (15-62%), *Betula* and *Pinus* varying from 10 to 45%, and *Alnus* less than 10%. A gradual disappearance of the thermophilous species, with the exception of *Quercus* and *Corylus*, which total rated, is c. 4%.

Late Subatlantic (SA-3), 372 cal BP – 0 (our data) established in the uppermost section of the *Fuscum* peat, at the depth of 65-0 cm. *Betula* and *Pinus* are dominant; *Picea* falls to 9%, simultaneously with the increasded abundance of herbs: Ericaceae, Poaceae, *Artemisia,* Chenopodiaceae, Cyperaceae, and *Rumex* (reaching in total 28%):. A notable increase in the percentage of Cerealia (reaching 4% at the depth of 40 cm).

The diatom analysis revealed the following pattern in the lacustrine environments (Fig. 3). A rich assemblage of diatom flora has been identified in the clayey mud at the depth of 8.1-8.5 m. Each sample included up to 100 taxa with the concentration of valves reaching 2-3 million per 1 g of dry sediment. Benthic species are in clear dominance. Quantitatively dominant are mesophytic overgrowth species*:* *Fragilaria brevistriata, F. construens var. venter* and *F. pinnata*. The subdominants are the peryphyton-bethonic species: *Cocconeis placentula, Gomphonema intricatum, Opephora marthyi, Nitzschia denticula*, and the *Cymbella, Amphora ovalis, Navicula pupula,*and *N. vulpina* genera. The total amount of the planktonic species is less than 5% and includes: *Cyclostephanos dubius, Synedra berolinensis*, and *Tabellaria fenestrata*.

The dominance of oligo-, haplo- and alkaliphilous species in the diatom flora, making up 92-97% of the total assemblage, is remarkable. A high mineralization rate is indicated by the occurrence of a euryhaline variety of *Mastogloia smithii* var. *lacustris* (1-3%), typical of slightly brackish or freshwater basins. The assemblage includes the species commonly found in Late Glacial lake deposits in Latvia and North-Western Russia: *Navicula oblonga, Opephora marthyi, Amphora ovalis, Gyrosigma attenuatum* (Diatomovye..., 1974). The total amount of the valves of Boreal species is less than 35%, the North Alpine species form 7%, the remaining ones being cosmopolitan. Hence these sediments were formed in a shallow eutrophic macrophyte-rich lake, less than 2 m deep.

The epiphytic species of *Fragilaria* genus are dominant in the sediments at the depth of 8.1-7.0 m. Species become less diverse and include only 25-26 taxa, with a concentration of 130 – 170 thousand valves per 1 g of dry sediment. The alkaliphilous species remain dominant (89-93%) suggesting a moderately alkaline lake with a high trophic status. The growth of benthic species was inhibited, as the development of macrophytes prevented the sunlight reaching the bottom. Hence the diatom ecology suggests the occurrence of a shallow eutrophic lake with macrophyte coverage. An increase in Boreal species at the depths of 8.1-7.0 suggests a

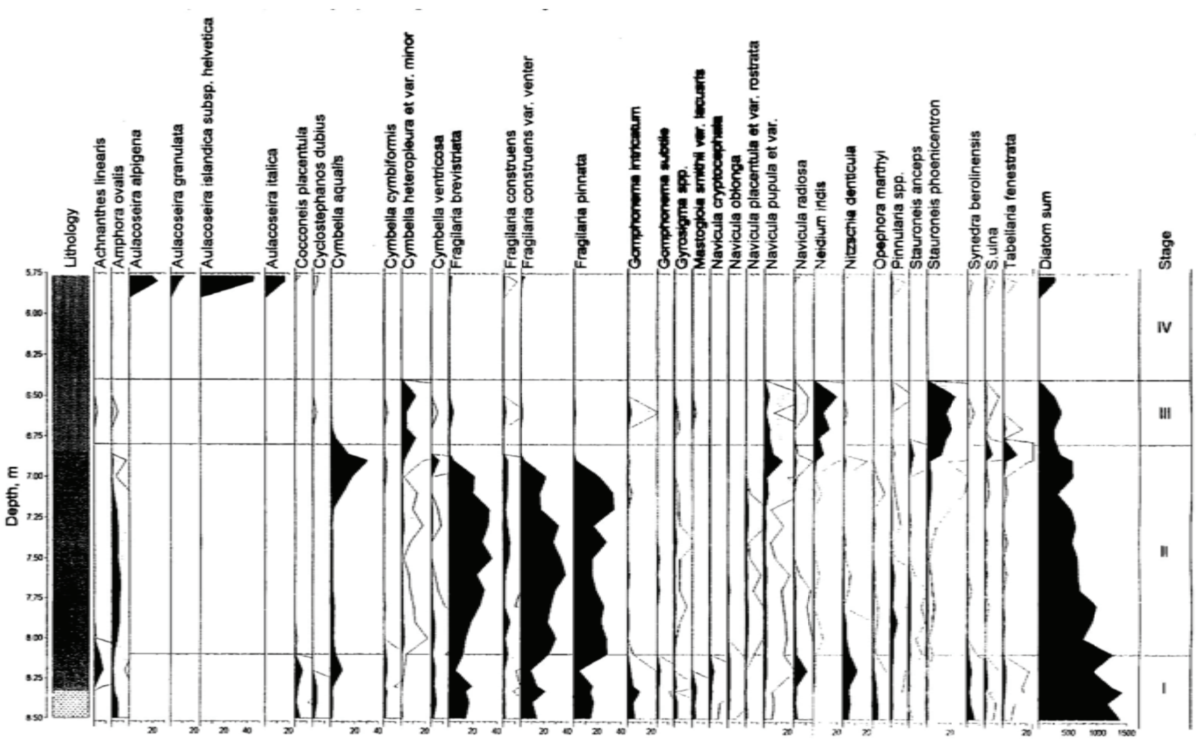

Fig. 3. Prigorodnoye peat-bog diatom sequence

rise of water temperature. At the depth of 7.5-7.0 this amount is reduced to 15-40%, apparently due to the low temperature during the Younger Dryas.

Epiphytic species become less numerous in the deposits of organic lake mud at the depth 660-700 cm (radiocarbon dated: to c. 10900-10300 cal BP). The benthic species and the overgrowth form a dominant-subdominant assemblage (*Cymbella aqualis, C. ventricosa, Navicula pupula,* and *N. vulpina*). The Boreal species rise in number reaching 70%. A similar assemblage has been established for the organic lake mud at the depth of 6.6-6.4 m (c. 9340 cal BP). The benthic species remain dominant: *Stauroneis phoenicentron,* and *Navicula vulpina*; the subdominants are: *Navicula pupula, Synedra ulna,* and *Cymbella heteropleura*. The proportion of alkaliphilous taxa is reduced to 58-78%, and their diversity declines (18-10 per sample), with a concentration of 70-10 thousand valves per 1 g of dry sediment. Thin-shell species are practically absent. The valves are often chemically dissolved, apparently due to the higher pH values. The percentage of boreal species reaches 80-90%. The assemblage reflects the continuing rise in water temperature.

Diatoms completely disappear in the top portion of the lake mud and the bottom of the *Carex* peat at the depth of 6.4-5.7 m, radiocarbon dated to c. 9340-7340 cal BP and corresponding to the Early Atlantic (AT-1) chronozone. They reappear in the Late Atlantic (AT-2) deposits at the depth of 5.8 – 5.7 m (c. 6800 cal BP). At that level the planktonic species bedcame dominant making up 86-95% of the total assemblage. The North Alpine species are most common. Amongst these one notes both the inhabitants of oligotrophic lakes: *Aulacoseira islandica subsp. helvetica* (40-44%) and *A. alpigena* (15-20%), and mesotrophic ones: *A. granulata* (5-6%) and *A. italica* (13-14%). The total of 30 species and their varieties have been identified, with a concentration of 19-10 thousand valves per 1 g of dry sediment. The proportion of alkaliphilous species is reduced to 52-55%, mostly due to an increased abundance of pH-indifferent species (*A. islandica,* and *Cyclotella bodanica).* Hence in the Late Atlantic the lake may be viewed as an oligotrophic one with a reduced trophic state.

2. Serteya 2

Several pollen chronozones could be identified resulting from the the studies of the samplesfrom the coring of the mire in the immediate proximity of Serteya 2 site yielded the following pollen assemblages (Fig. 4):

4.6 –4.05 m. Compact clayey lake mud. Clayey lake mud. The dominance of *Betula* (40-55%) followed by *Pinus* (15-20%). *Ulmus* (10-13%) dominates broad-leaved species, with *Tilia at 4-5%. Quercus* appears only at the end of this unit, likewise *Alnus* and *Corylus.* The herb taxa vary between 5-15%, most common are Poaceae and Cyperaceae. Spores are represented by Polypodiaceae in insignificant quantity.

4.05 – 2.65 m. Clayey fine detritus lake mud with fragmented lake shells. A stable state of the woodland with

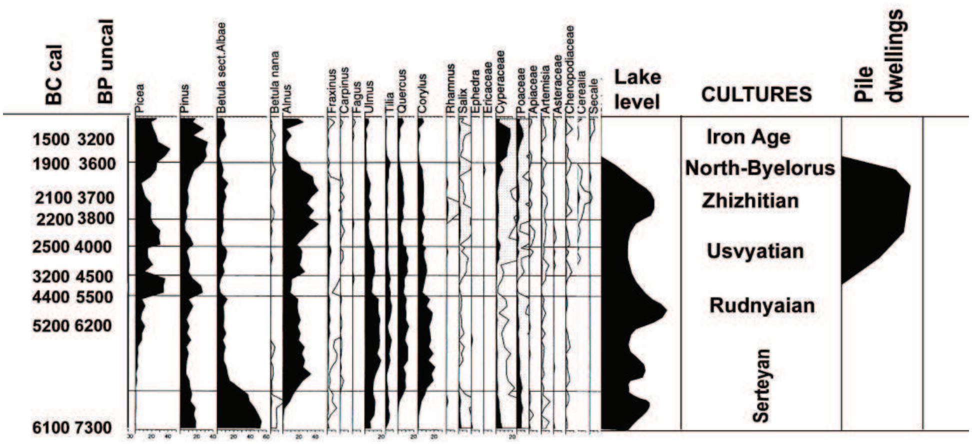

Fig. 4 Serteya 2. Pollen, lake-level changes and prehistoric cultural sequence

low amounts of herbs (<3%). High content of *Alnus* (20-35%) and the low presence of *Pinus, Picea* and *Betula* (<15% in total). Comparatively high rates of broad-leaved species, *Ulmus* (12-18%), *Quercus* (7-12%), *Tilia* (2-7%), and also *Corylus* (10-20%).

2.65 – 2.4 m. Clayey fine detritus lake mud with fragmented lake shells. A rapid rise of *Picea* and *Pinus,* with the decrease of *Betula, Alnus,* and broad-leaved species, *Ulmus, Quercus, Tilia,* and also *Corylus.* An increased amount of herbs, Poaceae and Cyperaceae. The notable appearance of water chestnut, *Trapa natans.*

2.4 – 2.0 m. Clayey fine detritus lake mud with fragmented lake shells. A decrease in *Picea* and *Pinus,* concomitant with the rise of *Betula* and *Alnus,* and an increase in broad-leaved species, *Ulmus, Quercus, Tilia,* and also *Corylus.* A general increase of herbs, Poaceae and Cyperaceae, including the appearance of heliophytic herbs, *Artemisia* and Chenopodiaceae, and isolated occurrence of grains of *Cerealia.*

2.0 – 1.8 m. Clayey lake mud with plant detritus. Increase in the amount of *Picea*, *Pinus,* and *Betula.* Decrease in *Alnus* and *Ulmus, Quercus, Tilia, Fraxinus* and *Corylus.* Increased rates of herbs, Poaceae and Cyperaceae, heliophytic herbs, *Artemisia* and Chenopodiaceae. Rare grains of *Cerealia.*

1.8 – 1.5 m. Lake mud and archaeological deposits (lower part). Decreased rates of *Picea* and *Pinus,* with the rise of *Betula* and *Alnus* (up to 40%). Further fall in the rate of broad-leaved species, *Ulmus, Quercus,* and also *Corylus.* Further increase in the abundance of herbs, Poaceae and Cyperaceae, *Artemisia,* Chenopodiaceous, Cyperaceae, and Gramineae. One notes the appearance of *Filipendula, Lythrum* and Lamiaceae. Increased frequency of *Cerealia.*

1.5 – 0.9 m. Lake mud and archaeological deposits (upper part). Rapid decrease in the rate of *Picea* and slight increase of *Pinus.* A rapid increase in the abundance of *Alnus* (up to 40%). Further reduction and quasi total disappearance of *Ulmus, Quercus,* and also *Corylus.* General decline in the content of herbs, notably, Poaceae and Cyperaceae, and also *Artemisia,* Chenopodiaceae. The maximum frequency of *Cerealia*, and the appearance of weeds (notably, *Plantago lanceolata*) and apophytes or plants indicative of human impact (Apiaceae, Rubiaceae and Rosaceae).

0.9 – 0.0 m. Lake mud with plant detritus (0.9-0.5 m); peat accumulated in a low fen mire (0.5 – 0.0 m). Rapid reduction of forests which became dominated by *Picea* and *Pinus.* Vast expansions of open treeless places and wet meadows as indicated by a rapid increase of Cyperaceae and mixed herbs including *Filipendula,* Apiaceae, Asteraceae and Carophyllaceae. Human impact on the vegetation becomes particularly apparent after 1110 ± 60 BP, signalled by the *Cerealia* pollen (*Triticum* and *Secale*-like), and the variety of anthropochores and ruderals, including *Artemisia,* Chenopodiaceae, Brassicaceae, and *Cannabis*-type pollen.

The following diatom assemblages could be identified in the studied sequence of Serteya 2 (Fig. 4):

4.6 –4.3 m. Compact clayey lake mud. rare finds of valves.

4.3 – 3.9 m. Clayey lake mud. Concentration of valves varies from 16 to 50 thousand per 1 g of dry sediment. 49 taxa are recorded. Epiphytic species are in clear dominance (65-80%). The dominant species is *Fragilaria construens* var *venter*; the subdominants are *Fragilaria brevistriata, F. inflata* and the planctonic species, *Aulacoseria italica,* and *A. ambigua.* The total amount of planctonic valves form 7 – 16%. Alkaliphilous taxa typical of moderately alkaline lakes make up 90-97% of the total spectra. Ecologically indifferent species are in clear majority. The species adapted to boreal moderately warm conditions constitute 17-26%. Cold water species are represented by those typical of Late Glacial and early Holocene lakes in Central Russia: *Navicula scutelloides, Fragilaria inflata.* Hence one may suggest the occurrence of a mesotrophic – moderately eutrophic lake which included a body of free water and a macrophyte coverage. The fall in productivity of planctonic species recorded at 4.1 – 3.9 m, was supposedly due to the lowering of the lake level.

3.9 – 3.2 m. Clayey fine detritus lake mud .Concentration of valves varies from 0.1 to 0.5 million per 1 g of dry sediment. The total number of taxa rises to 65, mostly due to the boreal species (20-30%). *Fragilaria* are dominant, with the subdominant remaining the same as in the lower unit. Fluctuating amounts of planctonic species (15-24%) indicative of an unstable lake level. The appearance of planctonic species, such as *Cyclostephanos dubius* and *Stephanodiscus hantzschii*, indicates the lake's increased trophic state. High abundance of alkaliphilous taxa (97-99%) shows eutrophic character of the lake.

3.2 – 3.0 m. Clayey fine detritus lake mud. Planctonic species form 7-11%. Productivity of benthic diatoms reaches 1 – 2.3 million per 1 g of dry sediment. The lake-level supposedly lowered.

3.0 – 2.4 m. Clayey fine detritus lake mud with fragmented lake shells. Productivity of diatoms reaches the highest value of 1.5 – 4.5 million per 1 g of dry sediment. The total number of taxa rises to 78. An increased rate of planctonic species (25-35%) indicates a stable rise of the lake-level. The dominant species include the peryphytic *Fragilaria* ssp, combined with the planctonic, *Aulacoseira ambigua, A. italica,* and *A. granulata.* The subdominants consist of the benthic and epiphyte species, *Amphora ovalis, Gyrosigma attenuatum, Cocconeis placentula, Achnanthes* ssp, *Navicula* benthic genus is represented by 10 taxa. The proportion of epiphytes diminishes to 60-72%. The rise of the lake-level led to the restriction of the macrophyte coverage. This combined with the improved light condition of the water column, was beneficial for the development of planctonic and benthic species. Alkaliphilous taxa remain dominant (96-99%). *Cyclostephanos dubious* being subdominant. One note also the planctonic species of *Stephanodiscus hantzschii* (< 1%). At that time, the lake reached the maximum depth, while retaining its eutrophic character.

2.4 – 1.5 m. Clayey lake mud with plant detritus. Rapid decline in the rate of planctonic species (3 – 11%). Productivity of diatoms varies in the range of 0.7 – 2.0 million per 1 g of dry sediment. Total number of taxa reaches 114, due to the appearance of benthic species: *Pinnularia* (11 taxa), *Navicula* (15 taxa), and *Gomphomena* (9 taxa). In addition to *Fragilaria,* the dominant – subdominant group includes *Cocconeis placentula, Amphora ovalis, Achnanthes* ssp. The dominance of alkaliphilous taxa shows a moderately alkaline and eutrophic character of the lake. The lake-level was lower as in the preceding unit.

1.5 – 0.9 m. Lake mud and archaeological deposits. High productivity of diatoms reaching the values of 0.9 – 1.5 million per 1 g of dry sediment. High rate of planctonic species (39 – 42%), markedly dropping at 0.9 m. The dominant group consists of *Aulacoseira ambigua* and epiphyte *Fragilaria* ssp. The subdominants include the benthic species, *Amphora ovalis,* and *Synedra ulna.* Alkaliphilous taxa are dominant (88-90%). The total proportion of epiphytes diminishes (41 – 67%). Considerable rise of the lake-level reduced the macrophyte cover.

0.9 – 0.5 m. Lake mud with plant detritus. Diatom productivity varies in the range of 0.2 – 1.0 million per 1 g of dry sediment. At the depth of 0,8- 0.85 one notes the cells of the plantktonic species, *Aulacoseria ambigua,* and a considerable amount of *Aulacoseria* ssp. Spores, making up >50% of the total amount of valves at the depth of 0.55 – 0.85 cm. The dominant – subdominant group includes the epiphytes and thermophilous species, adapted to small streams and springs rich in free oxygen: *Gomphonema angustatum, Meridion circulare, Eunotia preaerupta.* The rate of alkaliphilous taxa reduces to 45-75%. The increased rate of acidophilous taxa is indicative of the moderately acidic reaction. At the end of the unit the lake-level finally drops and the lake transforms into a low fen mire.

0.5 – 0.0 m. Peat accumulated in low fen mire. Diatom productivity varies in the range of 0.06 – 0.2 million per 1 g of dry sediment. Benthic species are dominant, *Eunotia preaerupta, Synedra ulna, Meridion circulare. Fragilaria* ssp appears at 0.4 – 0.0. One notes the occurrence of edaphic species adapted to soils and moist habitats: *Pinnularia borealis, Navicula mutica.* The diatoms of mire habitat show a wide diversity: *Pinnularia* (8 taxa), *Eunotia* (7 taxa); they are usually found in organic-rich slightly acid (pH<7) water bodies. Acidophilous taxa form 13-26% at then depth of 0.3 – 0.5 m. Their rate reduces to 6% at 0.2 – 0.0 m. At the same level, alkaliphilous taxa rapidly increase, reaching 80-85%. The rate of planctonic species increases in the same interval from 6 to 12%. The occurrence of species indicative of anthropogenic-related eutrophication: *Cyclostephanos dubius, Stephanodiscus hantzschii.*

3. Zhizhitsa Lake

The Lake Zhizhitsa is located in the south-eastern part of the Pskov Oblast, 70 km east of the town of Velikie Luki, on the Moscow-Riga railway line (Fig. 1). This area lies in the distal zone of the Last (Valdai-Weichselian) glaciation, on the southern edge of the limit of the terminal morainic zone. The surrounding terrain includes the terminal morainic hills reaching 190-200 m in the north and the west, flanking the evenly undulated sandy fluvio-glacial terrain at an altitude of 166-180 m, in the east and the south (Malakhovsky & Markov 1969).

Starting with the maximum extension of the Valdai (Weichselian) ice-sheet at 20-18 ka, a system of ice-dammed lakes encompassed the upper catchment of Western Dvina and Dniepr Rivers (Kvasov 1975). Their level dropped as the glaciers retreated, opening new thresholds. Following the glacial recession, the Orsha-Surazh basin emerged with an threshold at 180 m. After the abrupt fall of the Baltic Ice Lake at 11560 cal years BP (Agrell 1979; Andren *et al.* 20020, the entire hydrological area in the Western Dvina catchment collapsed. A chain of small lakes emerged in the place of the ice-dammed basin. The present-day lakes in that area are the remains of huge Late Glacial lakes. The Lake Zhizhitsa is connected with the small lake Kodosna in the north. In the south through the system of lakes Zhekto – Dvin'ye – Velinskoe and the river Dvinka, the Lake Zhizhitsa is connected with the Western Dvina River.

Quaternary deposits vary in thickness between 25 and 100 m, and consist predominantly of fluvio-glacial sand and gravel with the boulder clay forming the morainic hills. The soils are podzolic; soddy-podzolic on fluvio-glacial sands; superficially podzolic on morainic hills.

The deposits of Late Neolithic – Bronze Age which included pile settlements were identified in the course of the excavations of Naumovo site, located in inshore area of the northern part of the Zhizhitsa Lake, in the mouth of the small river, Barabanovka.

The subsequent period of the Early Iron Age (mid-1st millennium BC) saw the appearance of the settlements located on top of the morainic hills, traditionally referred to as 'hill-forts' (*gorodishche*). These hills are usually 10 – 15 high with at least one abrupt slope; there is no evidence of artificial fortifications, at least at the initial stage.

The pollen analysis of samples obtained by coring of the mire close to the Naumovo settlement identified the following pollen chronozones:

8.5- 8 m. Younger Dryas, (YD), 11140-10250 BP *Betula* sect *Albae* dominates the AP with about 40%, followed by *Picea* (25 %) and *Pinus* (11%).High percentages of *Betula nana* (10%) and *Salix* (5%). Very high rates of NAP taxa reaching 50%, including, *Artemisia* with 25%, *Cyperaceae*, with 12%, and *Poaceae*, with 20%. *Bryales* dominate the spores, with occurrences of *Selaginella selaginoides*.

8.0 – 6.5 m. Preboreal (PB), 10250-9960 BP.The rapid fall of NAP, from 35% to 5%. *Betula* sect *Albae* attains 60%, *Pinus* ranges between 25% and 60%. *Alnus, Fraxinus* and *Corylus* occur sporadically albeit in small quantities (1 - 5%), with *Ulmus* regularly rising towards the end of the chronozone. Rare occurrences of spores, mainly *Polypodiaceae, Bryales,* and *Sphagnum*.

6.5 – 5.5 m. Boreal (BO), 9960 - 7800 BP *Betula* and *Pinus* remain dominant, yet with decreasing values (40-20 % and 20-15% correspondingly). A regular increase in the rates of *Alnus* and *Corylus*. *Ulmus, Tilia* and *Quercus* increase significantly each attaining 10%. Rare occurrences of *Picea*. Starting from this level upwards, the abundance of NAP never exceeds 6%, with the exception of the most recent chronozone, SA-3. The same range of spores as in the previous chronozone.

5.5 – 4.0 m. Atlantic (AT-1+AT-2), 7800 – 5000 *Betula* falls to 25-30%, *Pinus*, to 5-10%, simultaneously with increases of *Alnus* (23%), *Corylus* (20%) and *Quercus* (10%). Starting from this level, *Fraxinus* occurs regularly and *Ulmus* attains 20%. Increased abundance of herbs (Cyperaceae, Poaceae, *Filipendula)* and ferns (Polipodiaceae). Rising amounts of spores, mainly *Sphagnum*.

4.0 – 2.5 m. Subboreal (SB), 5000 – 3600 BP. *Betula* and *Picea* increase attaining 40% and 20% respectively, with the high abundance of *Alnus* (20-24%). *Pinus* remains unchanged at 20-22%. A general decline in the values of *Ulmus,* whereas other broad-leaved species (*Tilia* and *Quercus)* and *Corylus* remain unchanged. *Sphagnum* dominates the spores, with 5-17%.

2.5 – 2.0 m. Early Subatlantic (SA-1), 3600 – 3000 BP A rapid increase (40%) and subsequent fall of *Betula* and a regular increase of *Picea.* A simultaneous decrease of the broad-leaved species total and *Corylus*. Amounts of *Alnus* remains high, 22-25%. Increased abundance of herbs (Cyperaceae, Poaceae, *Filipendula)* and decline of ferns (Polipodiaceae).

2.0-1.0 m. Middle Subatlantic (SA-2), 3000-l710 BP. The maximum abundance of *Picea* (58%), increased amounts of *Pinus* and decline of *Betula* and *Alnus* (both less than 20%). Gradual disappearance of broad-leaved species and *Corylus*, with the total value of 4%. Relatively high abundance of herbs, particularly, Cyperaceae.

1.0-0 m. Late Subatlantic (SA-3), 1700 BP – 0 (our data) established in the uppermost section of the peat, at the depth of 65-0 cm. *Pinus* is dominant with 60%; the rate of *Picea* decreasing and *Betula* slightly increasing. Rapid rise in the abundance of herbs (reaching 40%), consisting mainly of *Ericaceae, Poaceae, Artemisia, Chenopodiaceae, Cyperaceae,* and *Rumex.* A notable increase in the percentage of *Cerealia* (reaching ca. 4%), *Secale* and *Plantago.*

The following assemblages were identified by the diatom analysis:

8.3 – 8.5 m. 11000 BP. High concentrations of diatom valves, 20 to 80 thousand per 1 g of dry sediment. 40 taxa are recorded. Epiphytic species are in clear dominance (75-85%). The dominant species are *Fragilaria brevistriata, F. construens* et var, *Achnantes lanceolata, Amphoraovalis* et var. *pediculus.* The planctonic species, with *Aulacoseria granulata* var.*angustissima,* and *Cyclotella distinguenda* form 15 – 20%. The temperature was generally cold as the North Alpine species constitute 15-20%, with the percentage of the boreal species, 10-17%. This assemblage is suggestive of a mesotrophic lake of a Late Glacial character which included a body of free water and the macrophyte coverage.

7.8 – 8.1 m. 10200 BP. Concentration of valves markedly increased and varies from 0.6 to 1.5 million per 1 g of dry sediment. The total number of taxa rises to 92, mostly due to the boreal species, which form 32% and include *Aulacoseria granulate* var.*angustissima, Stephanodiscus minitules,* and also *Cyclotella distinguenda* et var.*unipunctata* , *C. radiosa, C. rossi, C. ocellata* as *Cyclostephanos dubius* and *Stephanodiscus hantzschii*,

The diminant species consist of *Fragilaria* and include the benthic and epiphyte species: *Gyrosigma* ssp., *Amphora ovalis, Achnanthes* ssp, *Synedra ulna.* The *Cyclotella* species coexist with alkaliphilous taxa (up to 80%), suggesting a mixed oligotrophic-mesotrophic character of the lake.

7.5 – 7.8 m. 10200 BP. Productivity of diatoms decreases and forms 0.3 million per 1 g of dry sediment, with the total number of taxa, 73. Planctonic species increase and reach 46%. Epiphyte species *Synedra ulna, Amphora ovalis* remain abundant. A relatively low content of alkaliphilous taxa (55-60%) implies an oligotrophic character of the lake, with a high water level.

6.7 - 7.5 m. 9600 BP. No diatoms identified, implying the absence of any lake.

6.0 – 6.7 m 8800-8500 BP. Low diatom productivity with 20-210 thousand valves per 1 g of dry sediment. Planctonic species are absent. The dominant species consist of periphytonic and benthic ones: *Fragilaria* ssp., *Navicula* ssp, *Epithemia* ssp., *Amphora ovalis* et var., *Tabellaria fenestrata.* Rare benthic species, *Aulacoseria crenulata,* indicative of oligotrophic shallow lakes rich in chloride of lime. A low content of alkaliphilous taxa (60-75%) is equally indicative of the lake's oligotrophic character

6.0 – 5.7 m. 8450-8300 BP.A quasi total absence of the diatoms.

5.1- 4.2 m. 6800-6100 BP**.** A gradual increase of productivity (0.2 - 8 million per 1 g of dry sediment), with the total number of taxa reaching 92. Planctonic species constitute c. 1%. Absolute dominant are epiphyte species, *Fragilaria, Epithemia, Synedra. Navicula* include 10 taxa, and *Cymbella,* 6. The dominant-subdominant group includes *Aulacoseria crenulata, Navicula oblonga, N. pupula* var. *rectangularis, N. radiosa.* Acidophilous species (*Tabellaria fenestrata* and *T. flocculosa)* form 3-5%. Alkaliphilous taxa constitute 50-60%. All this indicates a shallow oligotrophic with a a macrophyte coverage.

4.2- 4.0 m. 5000 BP**.** Concentration**:** 120 thousand valves per 1 g of dry sediment, with 120 taxa. Planctonic species constitute 13%, and include *Aulacoseria ambigua,* typical of small lakes. Dominant are *Fragilaria* epiphyte species. Boreal species constitute 36%, with alcaliphilous species exceeding 80%. This indicates a short-lived mesophitic lake with a body of free water and a macrophyte coverage.

3.9- 3.1 m. 4600 BP. No diatoms found, implying the lake being dried up.

3.1- 3.0 m. 4500- 3600 BP. Concentration**:** 5 thousand valves per 1 g of dry sediment, 14 taxa. Dominant are epiphyte species with *Synedra ulna, Epithemia zebra.* Numerous *Eunotia* species. Acidiphilous species form 14%, and alcaliphilous ones are reduced to 53%.

Upper levels did not contain diatoms.

Discussion

Late Glacial chronozones identifiable at the bottom of the investigated sequence find analogies all over Eastern Europe (Velichko *et al.* 2002). The Alleröd on the East European plain took the form of a spread of spruce woodland/open forest in combination with periglacial steppe communities. According to pollen-based reconstruction, the mean temperature was slightly lower than today, by 1° C in July, and 2° C, in January. The Younger Dryas on the East European plain featured the reduction of spruce forest and the spread of periglacial steppe communities. The temperature was lower as compared to present-day values: thermal depressions are estimated as 6° C in July, and 8° C, in January.

The Late Glacial period corresponded to the initial penetration of human groups into the area. Clusters of flint tools, which include Swidry-type points, have been found at several sites, on aeolian dunes in the Usvyaty area, c. 40 cm north-west from the Prigorodnoe peat-bog (Miklyaev 1994, 14-15). Small-size sites were of seasonal character and apparently made no discernible impact on the environment. Groups of Late Glacial hunter-gatherers were supposedly attracted by the productivity and diversity of local resources. They apparently came from the west, moving along lakes interconnected by tunnel valleys.

Recent evidence including the GRIP Greenland core (Björck *et al.* 1998), suggest a rapid and dramatic environmental response to the warming at the Pleistocene/Holocene boundary, c. 11500 cal BP. Records from the East European plain indicate that conspicuous changes in the vegetation occurred in that area not earlier than 11000 cal BC (Subetto *et al.* 2002). According to Velichko *et al.* (2002) with the advent of the Preboreal the temperature rose to the present-day level with the annual precipitation being 50 mm lower. In our case, the Preboreal chronozone saw the gradual spread of pine woodland followed by the immigration of thermophilous deciduous trees. Pollen-based climate reconstructions for Russian Karelia indicate that winter temperatures rose from −25 °C to −20 °C and summer temperatures from 12 °C to 16 °C at ~11.5 cal ka BP (Wohlfarth et al., 2004).

As the level of the Baltic Ice Lake abruptly fell, following the drainage at 11560 cal. BC, the entire hydrological network of North-eastern Europe collapsed, triggering intensive fluvial erosion. Between 8000 and 7000 BC, lake levels dropped in Northwestern Russia, Lithuania and Byelorussia (Davydova 1992, Kabailiene *et al.* 1992, Yakushko *et al.* 1992). This notable drop in lake levels may be correpated with a aprominent short-lived cool and dry event at c. 8200 calBP, recorded in many proxies including stable isotope records in Greenland ice-cores (Alley et al. 1997). Significantly palaeotemperature modelling based on Chironimids assemblages in lake deposits of Northern Fennoscandia (Korhola et al. 2002) indicated pronounced cold episodes at 9.2, 8.6 and 8.2 kyr calBP.

No authentic archaeological sites of that age have been found in our area. Apparently these sites are situated at a considerable depth, underneath the younger deposits. This was indirectly confirmed by the finds of Kunda-type bone and antler tools reportedly made (and later lost) during land reclamation in the mire near Lake Zhizhitsa (Miklyaev 1994, 15).

The conditions of the thermal optimum became established in our area at 8000 and lasted until c. 6000 cal BP. Recent evidence shows that the 'Atlantic period' of the Blytt-Sernander classification took different forms in various parts of Europe (Gardner 2002). Our evidence confirms that the maximum rise of temperature was metachronous even within northern Europe. In our case the maximum July temperature of 19.7°C. was attained at c. 6000 cal. BP. In northern Fennoscandia the maximum rise of 13°C allegedly occurred much earlier: 7950-6750 cal. BC (Sepä & Birks 2001). This period in our case saw the massive expansion of pine and deciduous forests with an understory of *Corylus*.

The data obtained from the sequences in the St. Petersburg indicate that the maximal percentage of broad-leaved species falls there on the first half of the Atlantic ,radiocarbon dated to 5450±140 BP, or 4450-4050 cal BC (Arslanov eb al. 2002).

The degree of human impact on the vegetation at this stage remains under discussion. The first wave of intensive settlement of the residual glacial lakes in the vicinity of our site (Serteya and Usvyaty, occurred in the time-span of c. 8000-6500 cal BP. These were settlements of Mesolithic-Subneolithic type, where subsistence was based on intensive hunting, gathering and fishing (note the remains of an extended fishweir at Rudnya-Serteya site dated to c. 6500 cal BP). The pottery-bearing levels of these sites include ceramics with analogies in the Narvian (eastern Baltic area), Upper Volga and Upper Dniepr cultures (Miklyayev 1994). Remarkably during that period, the climate reached the maximum warmth, with a new rise in the lake levels. Apparently, the influx of hunter-gathering population was motivated by the high biological productivity of the local landscapes. It is unlikely that at that stage human settlements made any notable impact on the environment.

A new stage of prehistoric settlement occurred in the time-span of 6500-4500 BC cal when the pile settlements were constructed in several lakes, including Serteya and Usvyaty. According to our evidence (Dolukhanov *et al.* 1984), the subsistence of these settlements was based on the exploitation of a wide spectrum of wild life resources. Archaeological deposits contain 40 species of animals and fishes including large mammals: elk, brown bear and boar being the most common, and also fur animals: marten, otter and squirrel. Pike and perch were the most common among the fish. At least 30 edible plants were identified; hazel-nut and water chestnut (*Trapa natans*) were apparently the main source of plant protein. So far, no evidence of either agriculture or stockbreeding has been identified. Supposedly, the richness of the local landscape in readily available low-cost nutrients prevented the earlier adoption of these strategies.

This stage coincided with a gradual rise of lake-levels and the further expansion of pine and deciduous forests. Considerable fluctuations in the abundance of *Pinus, Betula, Alnus, Ulmus, Quercus* and *Corylus* are noted This, together with the rising frequencies of herb taxa (notably, *Artemisia* and Cyperaceae), may be seen as indirect evidence of Neolithic 'woodland management' (Gardner 2002). Remarkably, Poska and Saarse (2002) report the first signature of human impact on vegetation on Saarema Island, Estonia, as occurring at about the same time, 6500-6000 BP.

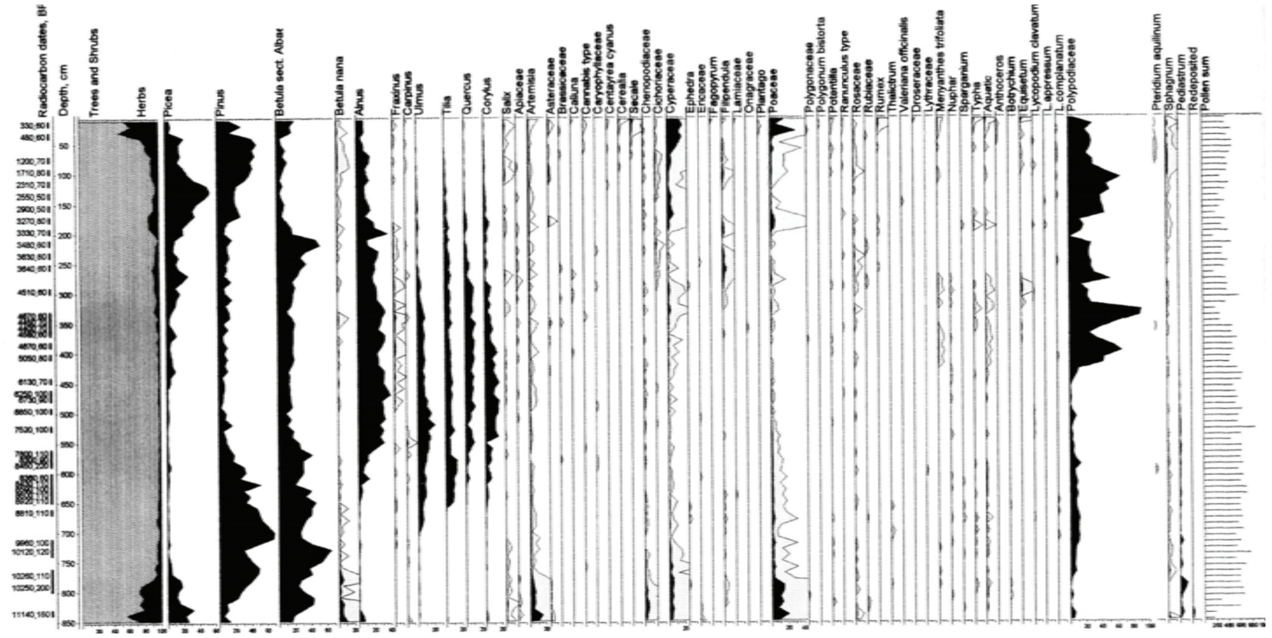

Fig. 5. Korovinskoye peat-bog pollen sequence

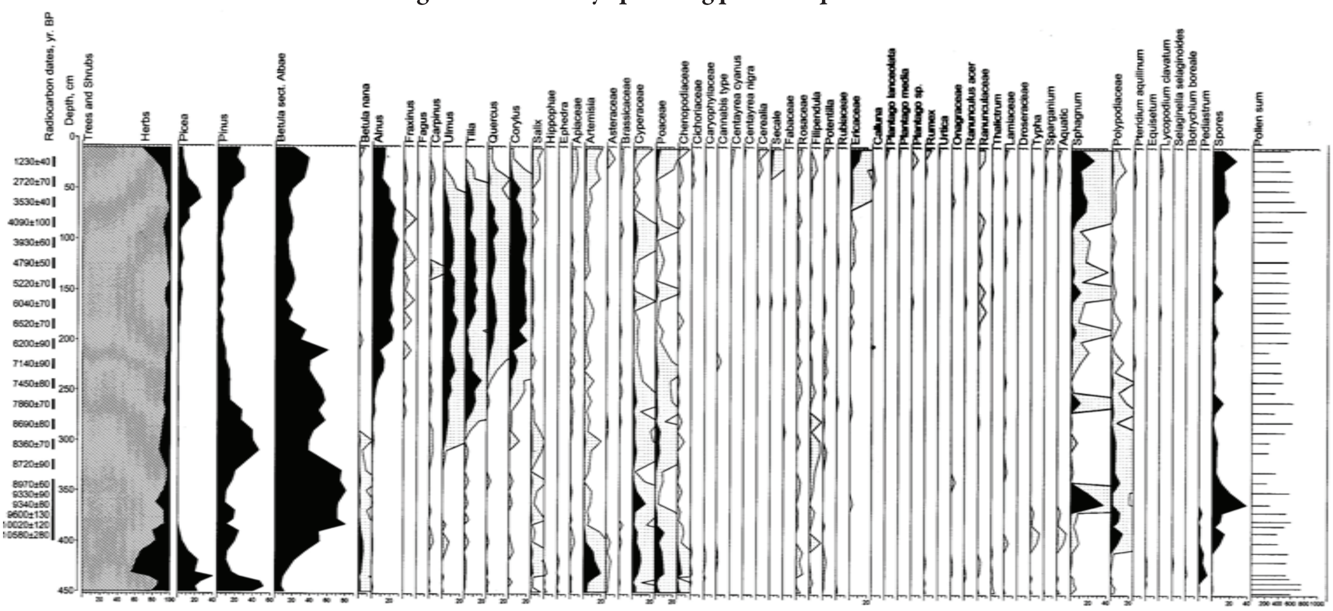

Fig. 6. Zmeinoye peat-bog pollen sequence

The first reliable evidence of stock-breeding and agriculture comes from the later levels of pile settlements dated to c. 4700-4000 cal. BP. They are attributed to Zhizhitsian and North-Byelorussian cultures, the latter viewed as a local variant of the European Corded Ware horizon (Miklyaev 1994). The deposits of this stage contain the bones of domesticated animals (pig, sheep, goat and cattle), although their overall proportion is less than 14%. The occurrence of agriculture is identified by the finds of cereal pollen grains at Serteya 2. The corresponding pollen spectra show a general decline in the frequencies of *Pinus, Ulmus* and *Corylus,* considerable fluctuations in the abundance of *Quercus* and herbs, with a notable expansions of *Picea,* and the early successional trees, *Betula* and *Alnus.* All that may be viewed as a signature of slash-and-burn cultivation.

A considerable expansion of pile dwellings occurred in the time-span of 4500-4000 cal. BP, in the wetter and cooler conditions, with July temperature decreasing by c. 2°C. This coincided with a new rise in lake-levels. Apparently, this was a pan-European phenomenon. A similar climatic trend is recognizable in the pollen profiles of northwestern Europe, including Northern Scotland. Lake levels also rose in various parts of Scandinavia, particularly in southern Sweden, and in French Jura (Anderson *et al.* 1998).

The pollen seuqnces obtained in the Zhizhitsa Lake area (Korovinskoye and Zmeinoye peat-bogs; Figs 5 and 6) there is very little evidence of agricultural signature in the pollen spectra coeval with Iron Age settlements. Archaeological materials at hill-forts yielded little of no evidence of agriculture, except rare finds of stone mortars and iron 'knives-sickles'. Evidence of agriculture in the basin of the Western Dvina came from the Iron Age hill-fort of Podgai, 30 km to the north-east, which belonged to a younger stage (Petrov 1960). The finds included grains of bread wheat *(Triticum aestiovum)* and naked six-row barley *(Hordeum vulgare* var. *nudum)*. One may suggest that the same plants were cultivated in the Zhizhitsa area. Early agriculture was apparently of slash-and-burn (swidden) type. Ethnographical evidence cited by Russian (Gromov 1968) and Finnish writers (Sarmela 1987) show that in northern Russia, Finland and Karelia 'burn clearances' were cultivated in sloping and hilly terrain. In our area, the may have been slopes of the morainic hills.

Conclusions

In many respects the newly obtained data have considerably improved our knowledge about the variations of climate in the boreal zone of North-Western Russia in the Late- and Post-Glacial time and its effect on human settlement and subsistence.

1. It becomes obvious that the major variations of climate identifiable in our area followed the global pattern. At the same time, it is remarkable that the maximum rise of temperature was time-transgressive even within northern Europe;
2. Major intrusions of population from outside identifiable in archaeological records apparently coincided with the periods of higher biological productivity, which made the local landscape attractive for groups of hunter-gatherers;
3. The first reliable signals of stock-breeding and agriculture which corresponded to considerable changes in the vegetation cover are acknowledgeable in the strata dated to c. 4700-4000 cal. BP.

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The Holocene History of the Baltic Sea, and the Ladoga Lake

P.M. Dolukhanov,[1] D.A. Subetto,[2] Kh.A. Arslanov,[3] D.A., N.N. Davydova,[4] G.I. Zaitseva,[5] E.N. Djinoridze,[3] D.D. Kuznetsov,[4] A.V.Ludikova,[4] T.V. Sapelko[4] and L.A. Savelieva[3]

[1] *School of Historical Studies, Newcastle University, Newcastle upon Tyne, United Kingdom, NE1 7RU, pavel.dolukhanov@ncl.ac.uk*
[2] *A.I. Herzen State Pedagogical University, St. Petersburg Russia*
[3] *Institute of Geography, St. Petersburg State University, Russia*
[4] *Institute of Limnology, Russian Academy of Sciences, St. Petersburg, Russia*
[5] *Institute for History of Material Culture, Russian Academy of Sciences, St Petersburg, Russia*

Introduction

The early human movements in the North-Eastern Baltic area occurred under the background of drastic environmental changes, primarily related to the modifications of the hydrological network. These were largely controlled by the changes in the configuration and hydrological regime of the Baltic Sea and those of the Ladoga Lake during the course of Final Pleistocene and Holocene. The advanced methods of radiocarbon dating combined with the palaeoenvironmental and palaeolimnological studies make it possible to correlate the early stages of human settlement with the evolution of waterways in the entire North-Eastern Baltic area. This was largely achieved in 2003-2006 in the frames of INTAS-sponsored field project conducted in the Karelian Isthmus and the southern part of the Ladoga Lake basin. The aims of the project included the detailed chronological assessment of the following processes:

1. Emergence and duration of the Baltic-Ladoga Strait;
2. Emergence and duration of the Ladoga Lake transgression;
3. Emergence of the Neva River;
4. The effect of changes in the waterways on the subsistence and movements of prehistoric communities.

The Study Areas

To achieve the aims, two study areas have been chosen (Fig. 1). The first one is located in the northern part of the Karelian Isthmus Lowland, ca 150 km north of St. Petersburg. It includes three sites in the Veshchevo area (formerly known as Heinijoki), in the immediate vicinity of the 'Vetokallio pass-sill', the Baltic-Ladoga watershed at 15.4 m above sea-level (Fig 1, *1,2,3*). These sites were located at Lake Lamskoye (LL), Lake Makarovskoye (LM), and Nizhneosinovskoye peat-bog (NO). Another site, Lake Uzlovoe (LU) is located further to north-east, 10 km south-west of Kuznechnoe railway station.

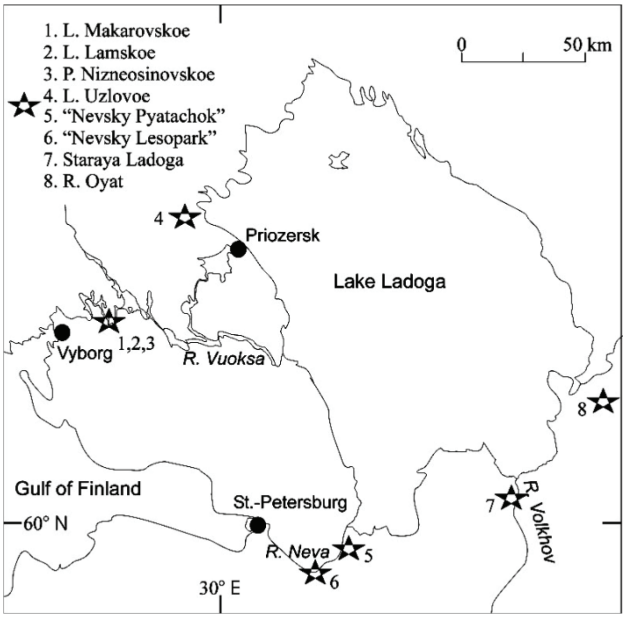

Fig. 1. Investigated sites

The second area included two sites on the River Neva, the Neva River: the 'Nevsky Lesopark' (The Neva Forest Reserve) and 'Nevsky Pyatachok' (The Neva Bridgehead). Two sites were studied south of the Ladoga Lake. One of the sites was on the lower stretches of the Oyat River (near Lenenergo settlement). Another site included the archaeological deposits and underlying sediments at the excavation site of Staroja Ladoga, the so-called 'Turf Hill-fort' (excavations by Professor A.N. Kirpichnikov).

Methods

As main methods of investigation we have chosen the coring and sampling of lake and mire deposits with the subsequent high-resolution radiocarbon dating, pollen and diatom analyses.

The core sampling was carried out with the use of a strengthened 1 m long Russian corer (inner diameter 5 and 7.5 cm). Coring of lake bottom deposits was carried out both

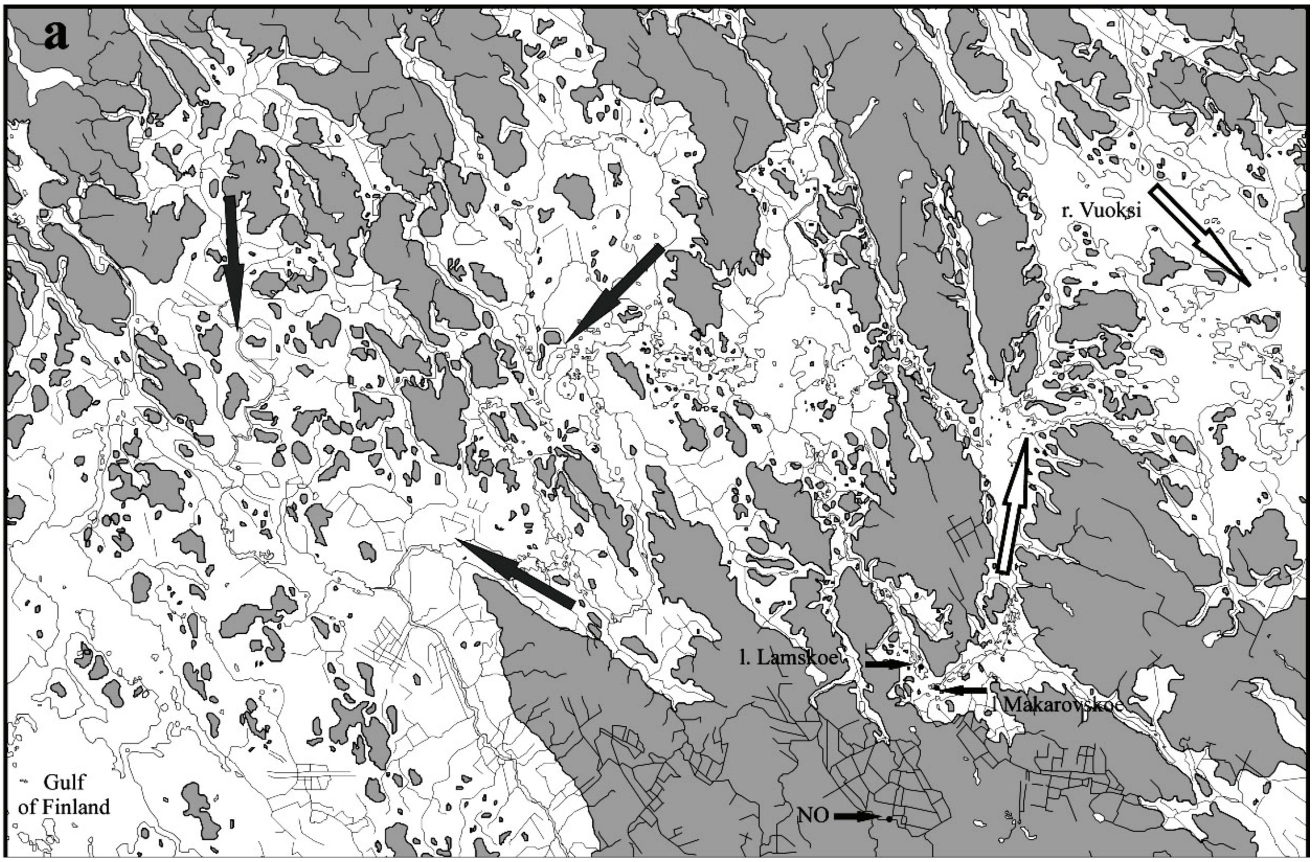

Fig. 2. General setting and investigated sites in the Veshchevo (Heinijoki) area. Arrows show directions of the water flow

from ice (in winter and early spring) and from rafts (in summer).

The cores were wrapped in plastic, placed in D-shaped plastic liners and carefully transported to the Institute of Limnology in St. Petersburg and to the Institute of Geography of the Saint-Petersburg State University, where they were stored at 4ºC in a cold-room until analyzed**.** Preliminary lithostratigraphic descriptions of the cores were made in the field, described in detail and correlated using lithological marker horizons in the laboratory**.**

Samples for pollen (1 cm^3) were taken from the cores at 5-10 cm intervals and prepared using standard techniques (Berglund & Ralska-Jasiewiczowa 1986). Pollen and spore identification were carried out using the published references and reference collections at the Institute of Limnology RAS and the Institute of Geography in St. Petersburg State University.

Samples for diatom analysis were prepared according to standard methods. In most samples 400-600 diatom valves were identified, with the minimun value of 250 In the case of Nizhneosinovskoe bog the diatom flora is classified into two ecological groups based on salinity preferences: the mesohaline (salinity tolerance 20–5‰) and freshwater ones (<0.5–0‰).

The radiocarbon dating of organic samples was carried out at the laboratories of Institute of Geography, St. Petersburg State University, and the Institute for Material culture, Russian Academy of sciences with the use of Liquid Scintillation (LS) counting method. The techniques of pre-treatment and measurements have been described elsewhere (Arslanov et al. 2003).

The loss of ignition (LOI) method has been used to estimate organic matter content in lake sediments. The analyses carried out at the laboratory of the Institute of Limnology and consisted of samples being dried at the temperature of 105 °C overnight and weighed, burnt at 550°C for 5 hours, and weighed again.

Results

1. ***The Karelian Isthmus***

A considerable amount of new evidence has been obtained in the Veshchevo area (formerly known as Heinijoki), located in the northern part of the Karelian Isthmus Lowland (Fig. 2). It constitutes the Baltic- Ladoga watershed and includes the 'Vetokallio pass-sill' at 15.4 m above sea-level.

1.1. Nizhneosinovskoe

Nizhneosinovskoe (NO) raised peat bog is located 5 km south of the 'Vetokallio pass-sill' and 3 km west of Veshchevo railway station (Fig. 2, NO). Its surface lies at 23 m a.s.l. The coring exposed the sequence of lacustrine and mire deposits spanning the age range of the entire Holocene.

Fine-grained light blue silt was fined at the bottom (800-650 cm), overlaid by fine-detritus gyttja at 650 – 570 cm. The upper part of the sequence consists of mire deposits and includes: low mire grass peat with *Carex*, *Equisetum* and *Phragmites* (570 - 550 cm); low mire sedge-moss peat (550-530 cm); low mire sedge peat (530 – 450 cm); low mire sedge wood peat (450-410 cm); highly decomposed low mire wood peat (410 – 170 cm); low mire grass peat with *Sphagnum*, *Phragmites*, *Menyanthes* and Equisetum (170-140 cm); mesotrophic grass peat and Sphagnum peat of transitional character (140-110 cm) and slightly decomposed Sphagnum and Scheuchzeria raised bog peat (110 – 0 cm).

Several pollen zones have been distinguished resulting from the pollen analysis of the NO sequence:

NO-1 (700-665 cm; fine grained light blue silt; > 11,600 BP cal): light birch forest with the patchy occurrences of periglacial steppe-tundra;

NO-2a (665 – 555 cm; fine-detritus gyttja; 11,000-9800 BP cal): boreal-type pine and birch forests with a Cyperaceae-Poaceae underwood;

NO-2b (555 – 515 cm; Carex peat; 9800-8500 cal BP): birch and pine forests with hazel with a small admixture of elm, and hazel in the underwood.

NO-3a (515-435 cm; Carex peat; 8500 – 8700 cal BP): mixed forests consisting of birch, pine and alder with an increasing admixture of elm and hazel;

NO-3b (435-315 cm; low mire wood peat; 8700- 7900 cal BP): mixed forests consisting of birch and alder forests with a participation of broad-leave species and hazel.

NO-3c (315-240 cm; mire wood peat; 7900 – 7000 cal BP*)* birch and alder forests with rapidly expanding spruce;.

NO-4 (240 – 180 cm; mire wood peat; 7000 – 1300 cal BP) boreal-type forest with an increased participation of spruce and the gradual decline of broad- leave species.

NO-5a (180-125 cm; mire wood peat; 1300-900 cal BP): boreal pine forest with alternating with spruce and birch, and increased open areas, apparently due to agricultural activities.

NO-5b (125-55 cm; mesotrophic peat; 900 – 200 cal BP): boreal pine forest with alternating with spruce and birch, and increased open areas, apparently due to agricultural activities, as witnessed by the occurrence of cereal pollen;

NO-5c (55-0 cm; raised bog peat; 200 – 0 cal BP) open pine forest with the appearance of secondary birch forest.

The diatom analysis performed for the samples from the lower part of the sequence has identified several distinct assemblages:

NOD1 (800-780 cm) fine grained light blue silt. The assemblage is dominated by the freshwater planktonic species, *Aulacoseira islandica subsp. Helvetica*. Rare valves of other fresh water species. Baltic Ice Lake (BIL).

NOD2 (780-750 cm) fine grained light blue silt. The assemblage is dominated by the freshwater species, *Gyrosigma attenuatum*. A short-lived regression of BIL, the Gyrosigma stage.

NOD3 (750-700 cm) fine grained light blue silt. The samples are dominated by brackish-water species, *Diploneis dydima*, *D. stroemii*, *D. smithii et var.*, *Opephora marthyi*, *Mastogloia spp.*, *Campylodiscus echeneis*. The deposits might be considered as being formed by the weakly saline Yoldia Sea. Rare occurrences of saline species, *Thalassiosira gravida*, *T. excentrica*, *T. anguste-lineata*, *T oestrupii*, *T. latimarginata*, *Coscinodiscus sp.*, *Chaetoceros diadema*, *Actinocyclus curvatulus*, *Bacterosira fragilis,* are apparently redeposited from the interglacial deposits.

NOD4 (700-670 cm) fine grained light blue silt. The assemblage is dominated by freshwater benthic species, *Epithemia zebra, Gyrosigma attenuatum*, *Opephora marthyi*, with rare occurrences of saline species, *Mastogloia smithii* et var., *Diploneis stroemii, Nitzschia tryblionella*. The deposits are seen as corresponding to a regressive, fresh-water stage of Yoldia Sea.

NOD5 (670-640 cm) fine-detritus gyttja (c. 11,000 calBP). The assemblage includes the species adapted to freshwater small lake environment, dominated by *Pinnularia viridis, P. mesolepta, attenuatum, Epithemia zebra, Cocconeis placentula, Aulacoseira inslandica* subsp. *helvetica.* The deposits were apparently formed in a small lake isolated from the Yoldia Sea.

NOD6 (640-610 cm) fine-detritus gyttja (c. 9800-9700 calBP). The assemblage is dominated by planktonic freshwater species, *Aulacoseira inslandica* subsp. *helvetic, A. italica, A. ambigua,* and by benthic species, *Cocconeis placentula*, *Nitzschia vermicularis, Amphora ovalis, Epithemia* *zebra.* The deposits reflect the maximum rise of Ancylus Lake transgression.

NOD7 (610-580 cm) fine-detritus gyttja (c. 9800-9700 calBP). The highest frequencies of *Epithemia zebra*, followed by *E. sorex.* A regressive stage of Ancylus Lake.

NOD8 (580-560 cm) fine-detritus gyttja (c. 9800-9700 calBP). The assemblage is dominated by a variety of periphytic species: *Cocconeis placentula, Fragillaria pinnata, F. construens* et var., *Epithemia zebra, Eunotia arcus* et var. The deposits were formed in a lake isolated from Ancylus Lake.

1.2. Lake Makarovskoye

Lake Makarovskoye, which level is 11.4 m a.s.l., lies immediately east of the 'Vetokallio pass-sill' (Fig. 2). The coring was made in its northern part, where the water depth was 0.9 m.

Three main sediment units could be recognised: gyttja (0.9 – 2.91 m); coarse sand (2.91-3.07 m) and silty clay (3.07-3.22 m).

Based on the total organic carbon content (TOC) the core could be subdivided into 3 main units:

Unit 1 (322-285 cm). Low LOI values, increasing towards the upper limit and exceeding 10%. Deposition of sand and sandy loam could facilitate the migration of organic matter;

Unit 2 (285-135 cm).LOI values vary between 20 and 23%, denoting a small lake with constant sedimentation conditions;

Unit 3 (135-95 cm). LOI values increase, reaching 46% in the upper part of the sequence. The sediments with plant macrofossils were formed in a shallow lake, with eutraphication by the fall of of the lake level

Based on the pollen evidence, six local pollen zones have been recognized.

LM_P1 (320 – 288 cm). The low concentration pollen assemblage is dominated by *Pinus*, with high percentages of *Picea* and *Betula*, and frequent occurrences of *Alnus glutinosa*.

LM_P2 (288- 233 cm). Much higher concentration of pollen dominated by *Pinus* and *Picea* and appearance of *Alnus incana* (and of *Alnus glutinosa*). Initial appearance of QM¸ *Corylus*, and aquatic plants. Occurrences of Poaceae, Cerealia, *Rumex*, Plantago, *Pediastrum* and *Isoëtes*.

LM_P3 (233 – 208 cm) Increased participation of *Pinus*, *Betula*, and *Alnus*. The highest pick of QM (*Quercus, Tilia, Ulmus*, and *Fraxinus*) as well as *Corylus*.
LM_P4 (208 – 178 cm) Increased participation of *Picea* and decreasing abundance of *Betula*, *Alnus, Poaceae* and Cerealia. Rare occurrences of *Pediastrum*. The zone's upper limit marked by decreased *Picea* and increased *Betula* (local SB/SA boundary).

LM_P5 (178 – 150 cm) Increrased pollen concentration dominated by *Pinus* and *Betula*. Increased abundance of Poaceae*, Cerealia, Rumex,* and Chenopodiaceae. Decreasing values of QM.

LM_P6 (150-95 cm) The maximum pollen concentration, dominated by *Pinus* and *Betula*. Inhcreased values of *Poaceae, Cerealia, Rumex, Plantago, Urtica*, and. Reappearance of *Pediastrum*, *Isoëtes* and *Juniperus*.

Four local diatom assemblages could be distinguished.

LM-D1 (320-307 cm). The assemblage dominated by benthic taxa (up to 60%) with *Fragilaria* spp. and *Achnanthes* spp.most abundant, with alkaliphilous species: *Fragilaria brevistriata* Grunow, *F. construens* var. *venter* (Ehrenberg) Hustedt and *F. exigua* Grunow predominate, and ubiquitous *Achnanthes minutissima* Kützing, most common. Other benthic taxa belong mostly to *Navicula* genus. The planktonic assemblage dominated by *Aulacoseira alpigena* (Grunow) Simonsen, which as seen as acidophilous (e.g., Grönlund 1989, Siver & Kling, 1997), and also by alkaliphilous species: *A. ambigua* (Grunow) Simonsen, *A. subarctica* (O. Müller) Haworth and *A. valida* (Grunow) Krammer. Remarkable is the presence of planktonic *Aulacoseira islandica* (Müller) Simonsen, a freshwater alkaliphilous taxon usually, found in large and deep-water oligotrophic basins such as Ladoga Lake. This assemblage includes, albeit rare occurrences of another planktonic taxa, alkaliphilous *Cyclotella radiosa* Grunow and *C. schumannii* (Grunow) Håkansson, common both for fossil and living diatom assemblages.

Benthic diatoms include oligotrophic cold-water *Navicula aboensis* (Cleve) Hustedt and *N. jaernefeltii* Hustedt, equally observed in sedimentary records of Lake Ladoga (Ludikova et al., 2006).

LM-D2 (307-280 cm). This interval is marked by a "peak" of *Aulacoseira islandica* accompanied by a small rise in the abundance of *Cyclotella* species and *Navicula* genera. Besides, alkaliphilous *N. jentzschii* Grunow, common littoral diatom in Ladoga Lake. These taxa show a rapid decline in abundance from 280 cm upward. Otherwise, planktonic and benthic assemblages are dominated by the same taxa as in the previous interval, and planktonic to benthic ratio remains almost unchanged. The diatom valves concentration increases from the level of 291 cm.

LM-D3 (280-135 cm). The species characteristic for Ladoga, except *Cyclotella radiosa,* almost completely disappear. *Aulacoseira* taxa remain domineering in the planktonic assemblage. Oligotrophic *A. alpigena*, *A. subarctica*, typical of mesotrophic (Gibson et al., 2003) and eutrophic waters (Kauppila et al., 2002), as well as eutrophic *A. ambigua*, are relatively abundant with c. 10%. *Aulacoseira perglabra* (Oestrup) Haworth and *A. tenella* (Nygaard) Simonsen are also common, both indicative of acidic oligotrophic to slightly mesotrophic environments and tolerating high contents of dissolved organic carbon. Other planktonic taxa are represented by oligotrophic *Cyclotella rossii* (Grunow) Håkansson and eutrophic *C. stelligera* Cleve & Grunow. The proportions of planktonic and benthic taxa generally remain almost equal with minor fluctuations. The latter remain dominated by alkaliphilous *Achnanthes* spp. and *Fragilaria* spp., followed by mainly neutrophilous species of *Eunotia* genus and neutrophilous-alkaliphilous *Navicula spp*.

LM-D4 (135-95 m). Rapid change in the composition. Planktonic taxa abruptly decrease in abundance, while the rate of the epiphytes increases, reaching 90% in the lower part of the interval. *Fragilaria* rapidly rising in abundance, in the interval's initial part, was later replaced by previously poorly represented *Cocconeis placentula* Ehrenberg et var. *euglypta* (Ehrenberg) Grunow, *Epithemia adnata* (Kützing) Brébisson, and *Gomphonema* spp. with *G. parvulum* Kützing, being the most abundant. Other, mainly alkaliphilous taxa, as well as acidophilous diatoms of *Eunotia* genus increase. Previously dominating species of *Aulacoseira* (with the exception *A. subarctica*) show a rapid decline. Alkaliphilous eutrophic *Aulacoseira italica* (Ehrenberg) Simonsen et var. *tenuissima* (Grunow) Simonsen occasionally increase, likewise planktonic *Fragilaria capucina* Desmazières et var. equally typical of nutrient-rich conditions. Other planktonic *Fragilaria*, namely, *F. nanana* Lange-Bertalot and *F. ulna* var. *acus* (Kützing) Lange-Bertalot appear at the level of 125 cm and gradually increase upwards. One notes an increase of species living either on or inside the sediments, mainly *Navicula* and *Nitzschia* genera including *N. palea* (Kützing) W. Smith.

1.3 . Lake Lamskoye

Lake Lamskoye, which level is at 14. 5 m a.s.l., lies immediately west of the 'Vetokallio pass-sill'. The coring was made in the southern part of the lake, where the water depth was 2.4 m.

The core sequence includes gyttja (2.4 – 4.27 m); sand (4.27-4.87 m); coarse sand (4.87 – 4.62 m and fine-grained sand (4.62 – 4.87 m).

Based on the total organic carbon content (TOC) three main units could be recognised.

Based on the LOI analyses two main units could be recognised.

Unit 1 (470-411 cm). TOC values below 10%, abruptly increasing upwards and exceeding 20% at the unit's upper limit. Sedimental conditions are essentially similar to those of the LM Unit 1.

Unit 2 (411-250 cm).TOC values vary between 23 and 29%. An isolated lake with constant sedimentation conditions and an insignificant increase in organic matter content in the unit's upper part.

Five pollen zones have been identified in the studied sequence.

LL_P1 (455-430 cm). Low pollen concentrations dominated by *Picea* and *Pinus*; high percentages of *Alnus incana*, and low values of *Betula*. *Bryales* prevail among the spores.

LL_P2 (430-408 cm). Rising pollen concentrations with high percentages of *Pinus*, *Picea* and *Betula*. Appearance of *Alnus glutinosa*, QM, *Corylus* and aquatic taxa (*Typha latifolia, Myriophyllum*, and *Carex*) suggesting a high water level. Radiocarbon dates: 3010 + 120 BP and 3500 + 160 BP.

LL_P3 (408-378 cm). Elevated rates of *Pinus*, *Picea*, and decreasing percentages of *Betula*. QM (*Quercus, Tilia, Ulmus*, and Carpinus) markedly increase. Notable occurrencse of *Cerealia*, *Plantago*, Chenopodiaceae and Asteraceae. *Pediastrum* and *Isoëtes* identified among the spores. Green algae (Pediastrum) represented by *P. integrum* and *P. integrum, indicative* of clear lake with the oligo- to distrophic environments

LL_P4 (378-318 cm). The zone dominated by *Pinus*, *Picea*, and *Alnus* and maximum values of *Quercus*, *Ulmus*. *Corylus* forms a peak in the middle part oh the zone. Increasing values of *Cerealia*, *Rumex*, *Urtica*, *Artemisia*, and Chenopodiaceae. *Pediastrum* is rather frequent. **LL_P5** (318-283 cm). The zone dominated by *Pinus* and *Betula*. Decreasing values of *Picea*, *Alnus*, and QM. Radiocarbon date: 2620 + 230 BP. The herbs dominated by Poaceae, Cerealia, Ericaceae and Cyperaceae.

The following assemblages have been identified resulting from the diatom analysis of Lake Lamskoye deposits.

LL-D1 (470-435 cm). Benthic diatoms dominate with the relative abundance exceeding 70%. Epiphytic *Fragilaria construens* (Ehrenberg) Grunow et var., *F. exigua* and *F. pinnata* Ehrenberg typical of alkaline and rather nutrient-rich water are the most common contributors with *Achnanthes* well represented. Numerous acidophilous *Aulacoseira alpigena* as well as alkaliphilous *A. ambigua* and *A. subarctica* show higher percentages among the planktonic taxa, while other *Aulacoseira* less abundant. Meso- eutrophic *Cyclotella stelligera* observable. *Aulacoseira islandica* and *Cyclotella radiosa*, common for Lake Ladoga observed in low proportions. The bottom-living species, *Navicula* and *Pinnularia* decrease in abundance from 12% at the lower to 5,5% at the upper limit.

LL-D2 (435-416 cm). The rate of planktonic versus benthic taxa almost unchanged. The doimineering species are the same as in the previous interval with some changes in frequency. Percentages of *Aulacoseira islandica* and *Cyclotella radiosa* increase remaining relatively low. Other typical Ladoga species, *Cyclotella schumannii*, *Navicula aboensis* and *N. jaernefeltii*, are also observed, the latter two being found only rarely.

LL-D3a (416-275 cm). The epiphytes prevail dominated by *Achnanthes* and *Fragilaria* followed by *Cymbella* spp. Eutrophic *Aulacosiera ambigua* and meso-eutrophic *A. subarctica* as well as rather oligotrophic *A. alpigena* remain the most abundant among the planktonic taxa, with variable ratios. The proportions of *Aulacoseira perglabra* and *A. tenella* increase, both known as acidophilous taxa tolerating high contents of humic substances. The Ladoga species are no longer observed, except *Cyclotella radiosa* found in very low quantities. Low and fluctuating abundance (less than 10%)of bottom- specie.

LL-D3b (275-240 cm). Proportions of benthic taxa noticeably increase due to increased abundance of *Achnanthes* and *Fragilaria* genera. Otherwise, the domeneering species remain unchanged.

1.4 Uzlovoe Lake

Lake Uzlovoe (formerly Rjukjärvi) lies 10 km south-west of Kuznechnoye railway station at the elevation of 13 m a.s.l. (Fig. 3) This area features an unusually high concentration of archaeological sites ranging in age

from Mesolithic up to Early Metal Age (Lavento et al., 2002). The coring has been carried out from ice in winter 2003. The water depth at the coring site was 5 m. units Based on the total organic carbon content (TOC), five stratigraphic were identified in the sediment core. The lowermost clay gyttja (5.44 – 9 m) with low organic content is seen as

Fig. 3. Coring the Uzlovoye Lake Spring 2005.

corresponding to the open contact with the Lake Ladoga Lake. The unit above (5.0 – 5.44 m) consist of mineral gyttja with a deceasing of organic content and corresponds to the isolation of the local basin. The above unit (3.75 – 5.0 m), rich in the organic content, corresponds to the existence of a small isolated euthrophic lake. The uppermost layer (3.0 – 3.75 m) consists of clay gyttja with evidence of human-induced an erosion processes on the watershed.

Six stratigraphic units have been singled out basing on the values of the mass loss-on-ignition (LOI):

Unit 1 (900-554 cm). LOI values increasing from 8-9% up to 12-13% with fluctuations. Clay gyttja formed in a basin connected with Ladoga Lake

Unit 2 (554-540 cm). LOI values decreasing from 13% to 7%. This unit and the next one were formed at a transitional phase corresponding to the lake isolation caused by the Ladoga Lake regression. Unstable sedimentary conditions with strongly varying organic matter content.

Unit 3 (540-500 cm). LOI values increasing from 8% up to 18%.

Unit 4 (500-340 cm). LOI values fluctuating between 18% and 23%. The sediments formed in an isolated lake lake. Increased organic matter content evidencing the eutrofication.

Unit 5 (340-320 cm). LOI values decreasing from 23% to 8%. The sedimentation apparently denoting either human-induced erosion processes on the watersheds (forest fires) or a change in hydrodynamic conditions (an increased outflow from the lake).

Unit 6 (320-300 cm). LOI values increasing from 8% up to 11-12%. Present conditions featuring a new stage of eutraphication.

Based on the pollen sequence of the Lake Uzlovoe, 12 local pollen zones could be identified:

Zone 1 (900 - 875 cm) The dominance of *Pinus* and *Betula* Limited occurrence of *Botryococcus* suggesting the bodies of clean, cool, oligo- to distrophic water.

Zone 2 (875 – 765 cm) Increased abundance of Betula*, Picea*, and *Alnus*; appearance of QM species (*Quercus, Tilia, Ulmus, Carpinus*) and *Corylus*. The bodies of clean, cool, oligo- to distrophic water

Zone 3 (765 – 675 cm) Increased abundance of Pinus, *Betula*. QM species and *Alnus* attain their maximum values. *Pediastrum* and *Isoëtes* appear among the spores. Abundance of *Isoëtes* indicates a nutrient-rich state and low to rich humic lake level

Zone 4 (675 – 630 cm) Increased abundance of *Picea*, and *Corylus* and the decreased participation of *Betula*, and QM species. The frequent occurrence of *Alnaster* (Duschekia). High percentage of *Pediastrum* and *Isoëtes*.

Zone 5 (630 - 600 cm) Spectra dominated by *Pinus, Picea, Betula*, and *Alnus*. Reduced participation of QM species, with Tilia disappearing. *Alnaster* (Duschekia) and *Salix*, rather frequent. Low percentages of *Pediastrum* and *Isoëtes*

Zone 6 (600 – 548 cm) Increased abundance of *Picea* and high percentages of *Pinus*, and *Betula*, and frequent occurrences of QM species. Initial appearance of Cerealia (with *Rumex*, *Plantago*, Chenopodiaceae, Cichoriaceae, and Artemisia). Low percentages of *Pediastrum* and *Isoëtes*.

Zone 7 (548 – 477 cm) Increased abundance of *Pinus*, with high percentages of *Picea* and decreased abundance of *Betula, Alnus*, and Cerealia. QM species are rather frequent with Tilia reappearing. *Pediastrum* and *Isoëtes* are no longer present. Frequent occurrence of aquatic plants (notably *Nuphar*,and *Numphaea*), suggesting the occurrence of water bodies less than 3 m deep.

Zone 8 (477 – 443 cm) Increased abundance of *Betula* and decreased frequency of *Picea*. QM species disappear, Cerealia remains frequent.

Zone 9 (443 – 388 cm) Spectra dominated by *Pinus*, *Picea*, and *Betula*, with increasing abundance of *Alnus*. QM reappear, likewise, *Pediastrum* and *Isoëtes*. Frequent occurrences of freshwater plants, notably *Typha latifolia, Potamogeton*, and *Nuphar lutea*.

Zone 10 (388 – 353 cm) Increased abundance of *Picea* and decreasing rates of *Betula*, *Alnus*, *Alnaster*, and *Salix*. QM remain frequent. *Juniperus* and *Ericaceae* appear among NAP. High frequencies of *Cerealia*.

Zone 11 (353 – 335.5 cm) Spectra dominated by *Pinus*, with high percentages of *Betula*, *Picea*; and total disappearance of QM. Increased values of *Poaceae*, and *Cerealia*.

Zone 12 (335.5 – 290 cm) Increased abundance of *Betula*, *Alnus* and decreasing values of *Picea*. QM reappear *(Quercus, Tilia, Ulmus, Carpinus, Fraxinus*), likewise *Corylus*. *Juniperus*, and *Ericaceae*, appear among NAP. *Poaceae*, and *Cerealia* attain their maximum values. *Pediastrum* and *Isoëtes* reappear.

Based on the evidence of the diatom analysis, several assemblages could be identified:

LU-D1 (900-546 cm).The interval is dominated by planktonic taxa, with the most common occurrence of typical Ladoga species (*Aulacoseira islandica* and and *Cyclotella radiosa*) reaching relative abundance of about 30%). Domineering planktonic species: *Aulacoseira subarctica* and *A. ambigua*. The bottom part also includes eutrophic *Cyclostephanos dubius* (Fricke) Round. Epiphytes consist of *Fragilaria* taxa (mainly, *F. construens* et var.) and, to a lesser extent, *Achnanthes* and *Cocconeis*. Bottom-living species which abundance is less than 15%, are dominated by *Navicula* spp. and *Pinnularia* spp. Other Ladoga-indicative species include the planktonic *Cyclotella schumannii*, *Stephanodiscus medius* Håkansson and *S. rotula* (Kützing) Hendey, as well as small amounts of bottom-living *Navicula aboensis*, *N. jaernefeltii* and *N. jentzschii*.

LU-D2 (546-504 cm). Rapid decrease in the abundance of "Ladoga species" *Aulacoseira islandica* and *Stephanodiscus* spp., followed by those of *Cyclotella schumannii*, *Navicula aboensis,* and decreased percentage of planktonic *C. radiosa*. Starting at 536 cm, Ladoga species totally disappear. Simultaneously, the abundance of eutrophic *Aulacoseira ambigua* rises up to 57%, accompanied by minor peaks of *A. granulata* (Ehrenberg) Simonsen et var. *angustissima* (O. Müller) Simonsen and planktonic *Fragilaria capucina* et var., both characteristic of nutrient-rich aquatic environment. Abundance of *A. ambigua* falls to 3,5% up-core while the rate of another eutrophic taxon, *Cyclostephanos dubius*, increases significantly. Abundance of benthic taxa reaches 50% at the interval's upper limit resulting from the efflorescence of *Fragilaria* spp.

LU-D3 (504-340 cm). Increased rate of epiphytic *Achnanthes* and *Fragilaria* genera, both characteristic of

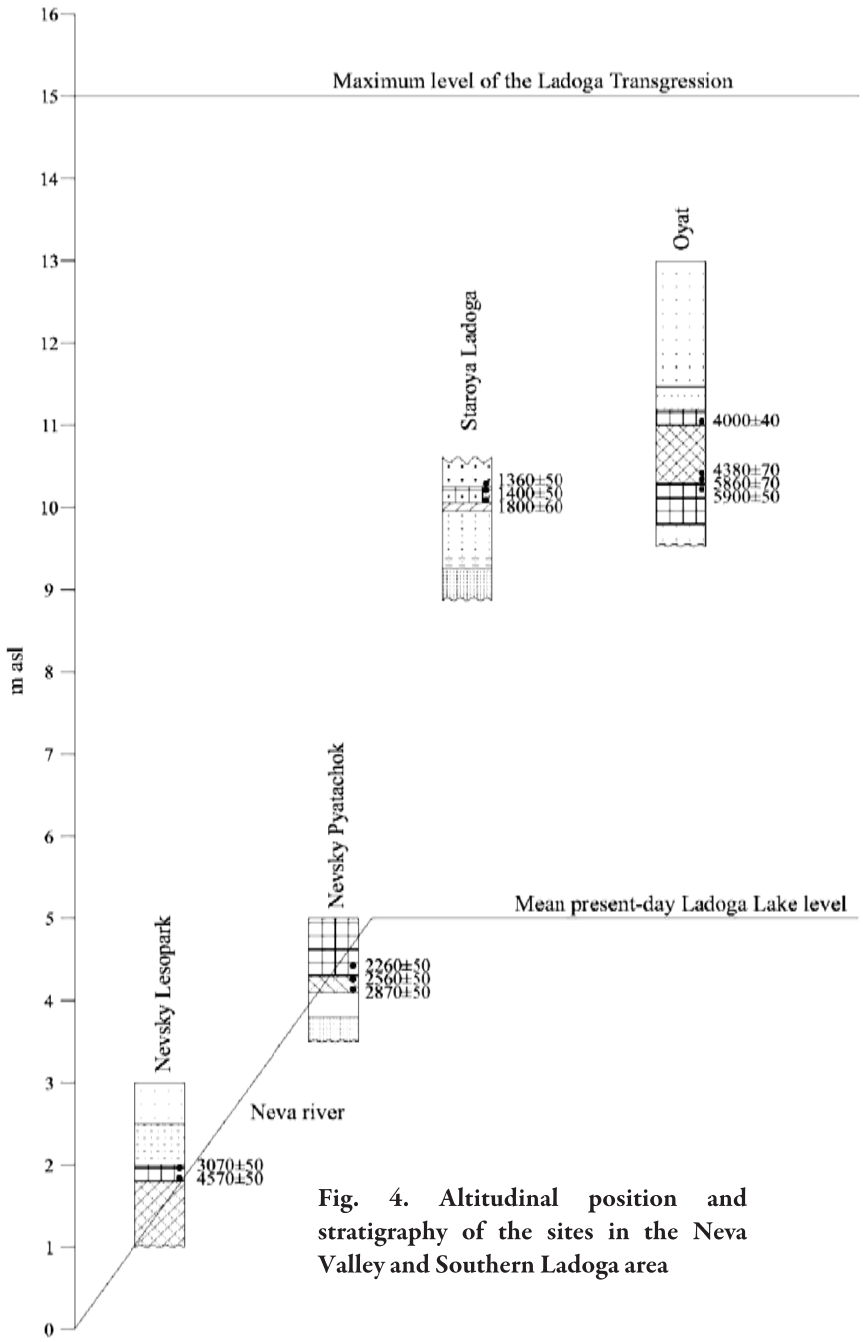

Fig. 4. Altitudinal position and stratigraphy of the sites in the Neva Valley and Southern Ladoga area

circum-neutral-slightly alkaline environment. Above the level of 459 cm, the abundance of benthic taxa decreases and the assemblage becomes plankton-dominated with *Aulacoseira* followed by *Cyclotella* being most common.

Oligotrophic acidophilous *A. tenella* reaches its maximum of 27% between 459 and 389 cm, increasing alongside the acidophilous *Eunotia* taxa (e.g., *E. incisa* Gregory, *E. pectinalis* (Kützing) Rabenhorst). The rate of *Aulacoseira ambigua* rises steadily from the level of 401 cm upwards, *A. subarctica* showing an opposite trend. Bottom substrate species are rare.

LU-D4 (340-290 cm). A prominent shift from planktonic to non-planktonic dominance mostly resulting from an increased abundance of epiphytic *Fragilaria* and *Achnanthes*, and a minor rise of *Cocconeis placentula* et var., *Cymbella* spp. and *Gomphonema* spp., likewise bottom-living *Pinnularia* spp. The rates of *Aulacoseira ambigua* and, especially, *A. subarctica* much lower than in the previous zone. Other planktonic taxa typical of eutrophic environments increase in abundance, particularly, *Aulacoseira granulata* et var. *angustissima*, *Cyclostephanos dubius*, and *Fragilaria capucina* et var., the latter hitherto being not recorded.

2. The Ladoga Lake – Neva River

Investigations carried out in 2005-2006 were focused on the detailed chronology of the 'Ladoga transgression' and the emergence of the Neva River. This included the coring and sampling of several key sites along the Neva River and the rivers falling into the Ladoga Lake from the south.

Two key sites have been investigated along the Neva River: the 'Nevsky Lesopark' (The Neva Forest Reserve) and 'Nevsky Pyatachok' (The Neva Bridgehead) (Fig. 4). These sites are known from previous investigations (Malakhovsky et al. 1993).

2.1. Nevsky Lesopark

The investigated site is located on the right bank of the River Neva, 24 km upstream from the river mouth in the south-eastern suburb of St. Petersburg (Fig. 1, *6*).the River Neva, 14 km. In the sequence of the river bank,. In the sequence which lies 3 m a.s.l the organic sediments, gyttja and peat, were overlain by the grey silt and fine-grained sand (Fig. 4).

The following assemblages have been identified based on the diatom analysis.

The lower gyttja level included rare planktonic species typical of the Ladoga Lake,: mostly *Aulacoseira islandica*, with rare occurrences of *A. alpigena, A. italica, A. ambigua, Fragilaria capucina.* Their frequencies increase upwards. Yence the gyttja was formed as this site was of low temperature Ladoga Lake.

Rare occurrences of *Aulacoseira islandica* were identified in the peat, which formation marked the regression of the lake. The number of diatoms markedly rose in the grey silt. The planktonic species nearly totally disappear, with overgrowth species *Fragilaria ulna* and *Epithemia frickei* becoming most frequent. *Epithemia adnata* and *Cocconeis placentula*, dominate among the epiphytic species.

The abundance of diatoms further rises in the fine-grained sand., mostly *Navicula capitata var. hungarica*. *Cocconeis placentula* and *Epithemia adnata* are most common among the epiphytic overgrowth species. The area was apparently taken up by a shallow lagoon of the Ladoga Lake with an environment favourable for benthic species.

The radiocarbon measurements obtained for the samples of organic sediments are shown in Table. The age of the phase boundary, which presumably preceded the maximum rise of the Ladoga Transgression, has been estimated to be about 3000 BP

3.2. Nevsky Pyatachok

The site is located on the left bank of the River Neva, 13 km downstream from the Neva, sources and the Ladoga Lake, opposite Nevskaya Dubrovka settlement (Fig. 1, *5*).

In the test-pit sequence the layer of peat overlays the grey sand and clay resting on the gyttja. The gyttja contains rare diatoms belonging to planktonic Ladoga Lake species: *Aulacoseira. islandica, A. ambigua, A. italica, and Tabellaria fenestrata*. The same species with the addition of *A. Alpigena*, yet in much larger quantities were encountered in the clay, which also contains rare epiphytic species, *Achnanthes oestrupii, Fragilaria construens and F. pinnata*. The grey sand includes richest assemblage dominated by the planktonic Ladoga Lake species; *Aulacoseira islandica* is most common, followed by *Tabellaria fenestrata*, with rare occurrences of *Aulacoseira ambigua, A. italica, Cyclotella bodanica, C. comta,C. vorticosa*. Rare benthic species include the epiphytic *Fragilaria, Cymbella*, and bottom species, *Navicula*. The diatom composition suggests the occurrence of a strait transporting the Ladoga Lake plankton.

3.3 Oyat River

The studied sequence is located on the left bank of the Oyat River, on the terrace 13 m above sea-level, near the Lenenergo Settlement (Fig. 1,*8*). The Oyat River is the left tributary of the Svir, which flows into the Lake Ladoga18 km further to the north, At this site organic deposits consisting of peat alternating with gyttja, were buried beneath the stratified silt and sand.

The bottom gyttja includes benthic overgrowth diatom species; the planktonic species became more frequent in its upper part; *Aulacoseira ambigua* is domiant throughout the unit, followed by *A. islandica* in its upper part. The planktonic *Tabellaria fenestrata* and several benthic species with *Fragilaria, Epithemia adnata* and *Tabelaria flocculosa* are sufficiently common.

Rare benthic overgrowth species (*Epithemia adnata* the most common) were encountered in the overlaying peat layer. *Aulacoseira ambigua* is most common among planktonic species.

The same epiphytic species, albeit in lesser quantities occur in the stratified silt: *Epithemia adnata*, *E. frickei*, and *Fragilaria ulna*. The planktonic *Aulacoseira islandica* was also found.

Rare diatoms were found in the sand. They are dominated by *Epithemia adnata*, and *Fragilaria ulna*, the botton species *Pinnularia major*, and *Navicula elginensis*. The uppermost levels include rare planctonic species: *A. islandica, A. italica, Fragilaria capucina et var. vaucheriae*, as well as bottom species: *Navicula laterostrata, N. amphibola, N. clementi*

The diatom composition suggests that the gyttja was formed in a shallow basin into which the plakton from the Ladoga Lake was brought in. The upper silt and were deposited during the latest Ladoga Lake transgression.

3.4. Staroja Ladoga

Archaeological deposits of early medieval fortified settlement of Staroja Ladoga ('The Earthen Hill-Fort') lie on the terrace 10 m a.s.l. of the Volkhov River, 14 km south of the Ladoga Lake (Nosov, Biske and Shitov 2005) (Fig.1, *7*). The soil studies (Aleksandrovsky et al. 2007) have identified a palaeosoil directly beneath the archaeological deposits. This highly fertile soil rich in phosphorus and humus featured a well developed plough layer.

The silt below include rare freshwater diatoms dominated by the plankton species typical of the open Ladoga Lake with *Aulacoseira islandica*, and *Stephanodiscus rotula*, and also *Aulacoseira granulata*, typical of offshore areas, the planktonic species, *St. minutulus*, as well as rare bottom species *Hantzschia: H. amphiozus* and *H. elongata*. The diatoms became slightly more varied in the overlaying layer where the silt is gradually transformed into loam. The composition is basically the same, with the planktonic species, typical of the open Ladoga Lake, *Cyclotella comta* and *C. bodanica*, as well as the epiphytes and overgrowth species typical of shallow basins, *Fragilaria ulna* and *Epithemia sorex*,as well as the bottom species, *Nitzschia sigmoidea*. The silt underlying the archaeological deposits includes rare diatoms dominated by the bottom species, *Hantzschia amphioxys*. The diatom assemblage suggests that at the time, when the silt was deposited, the area was an open bay of the Ladoga Lake into which the plankton easily penetrated.

The palaeosoil which lies directly beneath shows poor content of both humus and phosphorus (1.14% and 0.237% respectively).

Two radiocarbon dates were obtained from the bottom of archaeological deposits: 1360±50 (LU-5462) and 1300±25 (Le-7317) or 660-780 calAD. The upper part of the upper palaeosoil has been dated to 2510±170 (Le7315c) or 1000-150 cal BC). Its lower part has yielded the date of 2650±60 (940-750 cal BC (Ki-13033).

Discussion

As follows from the earlier studies (Dolukhanov 1979; Subetto 2003), the waterway between Ladoga Lake and the Baltic in the northern lowland of the Karelian Isthmus emerged following the ice-sheet retreat at ca 14,000-12,000 cal BP. During that period, and prior to the catastrophic fall of the Baltic Ice Lake (BIL) at ca 11,500 cal BP, Lake Ladoga remained an easternmost extension of the BIL. In the northern part of the Karelian Isthmus, the highest shoreline BIL reached c. 50-60 m a.s.l. The BIL encompassed the Ladoga Lake and covered an entire area of the Karelian Isthmus (except the Central Karelian Heights). The sediments of BIL have been identified in the bottom deposits of Nizhne-Osinovskoe bog sequence.

The opening of the Billingen channel in Central Sweden and the drop in the level of the Baltic Ice Lake led (11,500-11,000 cal BP) to the emergence of the weakly saline Yoldia Sea (Saarnisto et al. 2000). The Yoldia Sea reached the Heinijoki area, as weakly saline Yoldia Sea diatom species have been identified in the deposits of Nizhne-Osinovskoe bog.

The land uplift in central Sweden led to the isolation of the Baltic Sea from the ocean and the emergence of the Ancylus Lake at around 9500 cal BP. For about 300 years (9500-9200 cal BP) the sea level rose by 15-25 meters (Eronen 1990; Björck 1995). During the ensuing regression, large expenses of dry land emerged. The waterway connecting the Ladoga with the Baltic was still in place often consisting of numerous bays with a labyrinth of islands (Tikkanen and Oksanen 1999). One of such basins was located in the Heinijoki area, its deposits were found at the bottom of the studies sequence of Nizhneosinovskoe bog.

Following the regression of the Ancylus Lake 9800-9700 cal BP, this basin became isolated and turned into a mire, while the lakes with running water remained at the lower levels. The oceanic eustatic rise above the threshold in the Straits of Denmark led to the penetration of the saline water into

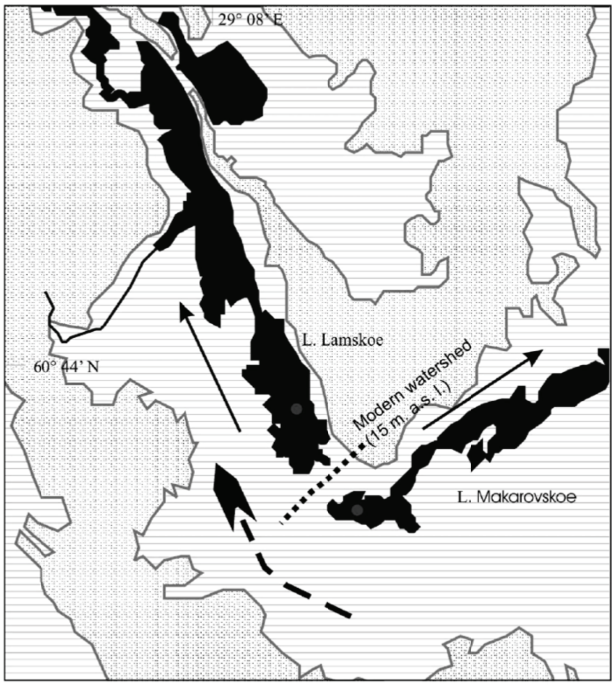

Fig. 5. Reconstruction of the straits in the Heinijoki area

Baltic basin at around 8400-8300 cal BP and the emergence of the Littorina Sea. Its deposits became acknowledgeable in Finland by ca 7500 BP (Eronen 1974; Björck and Svensson 1994). Yet the lack of diagnostic diatom assemblages proves that the Littorina Sea never reached the Heinijoki area.

One notes considerable fluctuations in the sedimentation rate in the time range 11,000 - 7000 cal BP. With the establishment of boreal-type forest which prevailed 7000-3000 BP, the sedimentation rate markedly decreased.

Saarnisto (Saarnisto 1970) has demonstrated that beginning with 5000 cal BP the Saimaa Lake in the present-day south-eastern Finland, started to drain into the Ladoga Lake via the Vuoksa (Vuoksi) River. The resulting influx of fresh water led to the rapid rise of the Ladoga Lake and the ensuing Ladoga Transgression. Our data suggest the current inflow of the Ladoga water in the direction of the Gulf of Finland. Fig. 5 shows the location of the channels and the direction of water flow in the Veshchevo (Heinijoki) area.

Investigations carried out in low-laying Makarovskoye, Lamskoye and Uzlovoe lakes shed light on the final episodes of the Ladoga-Baltic waterway. Two stages in the development of these lakes might be recognized, based on the diatom evidence. The former stage features the occurrence of planktonic diatom species (notably *Aulacoseira islandica*) that dominate the present-day diatom flora of Ladoga Lake (Davydova et al. 1997), alongside the sedimentary diatom assemblages of small lakes, experiencing an incursion of Ladoga waters (Saarnisto & Grönlund 1996). In the Makarovskoye and Lamskoye lakes, the fossil diatom assemblages were apparently formed under relatively shallow-water, in circumneutral or slightly alkaline and rather nutrient-rich environment. Fossil diatom records from Uzlovoe Lake provide much strong evidence of the intrusion by Ladoga waters at the earlier stage of its existence. The "Ladoga assemblage" of Uzlovoe is more diverse and includes several large-lake *Stephanodiscus* species. The probable explanation lies in different depositional environments: the diatom assemblages of the former two lakes were formed under the running-water conditions unfavourable for accumulation of diatom frustules, while in Uzlovoe the sedimentation took place in a larger bay of Ladoga Lake. One should take into account that Uzlovoe was directly linked to the Ladoga, while the Makarovskoye and Lamskoye lakes could receive Ladoga waters only through the intermediary of a riverine-lacustrine system. High contents of meso-eutrophic diatom taxa indicate nutrient-rich conditions resulting from the influx of nutrients from the soils eroded by the transgressing Ladoga.

Following 3500-3000 BP, the disappearance of the "Ladoga assemblage" from the fossil diatom records indicates that the regressing Ladoga water could no longer reach the lake basins. The diatom compositions of both Makarovskoye and Lamskoye lakes are fairly similar, suggesting the development of both lakes being essentially similar. The diatoms denote a high trophic state, implying lower water transparency as a result of the higher concentrations of dissolved organic matter. Noticeable changes are visible in the uppermost samples, especially those of Lake Makarovskoye. These changes should be attributed to an increasing human impact.

Recent environmental changes were less articulate in Lamskoye Lake being only recorded as a prominent shift of planktonic to benthic ratio in favor of the latter. A possible explanation resides in an increased nutrient input and/or decreasing water depth. Judging from an abrupt decrease in the abundance of the large-lake taxa, the isolation event from the Ladoga proceeded at a rapid pace and was followed by a noticeable eutrophication. This was apparently caused by an inwash of nutrients from formerly inundated areas. Decline in the percentages of acidophilous taxa was accompanied by a rise in abundances of meso- eutrophic alkaliphilous planktonic taxa providing and evidence of increasing productivity. At the latest stage of its existence, the Uzlovoe Lake became epiphytes-dominated. Its most recent phase features increased proportions of planktonic eutrophic taxa and decreased abundances of the epiphytes; these signals should be attributed to a human activity.

The pollen data and radiocarbon measurements obtained for both Lake Makarovskoye and Lake Lamskoye strongly suggest that the accumulation of gyttya occurred in an environment of boreal pine and spruce forests with the varying participation of alder and broad-leaf species (oak, lime, elm and ash), culminating in the level postdating 3500-3000 BP. Remarkably that level signals the presence of Cerealea and indicators of agriculture (notably, *Plantago*).

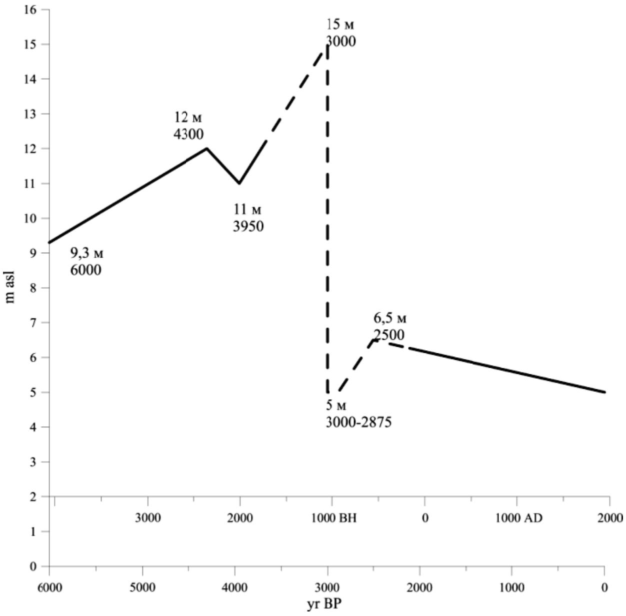

Fig. 6. Fluctuations of the Ladoga Lake in the Southern Ladoga area.

Our data obtained for the southern Ladoga area and the Neva Valley enable one to clarify the character of the Ladoga transgression in that area. Judging from the Oyat section the lake level at c. 6000 BP stood at about 9 m a.s.l. From that from that time onwards the level steadily raised reaching c. 15 m level at c. 3500-3000 BP, (the stratified sand and silt in the upper part of the Oyat sequence). This was followed by an abrupt fall of the Ladoga level by no less than 10m, as witnessed by the gyttja overlain by the peat at Nevsky Pyatachok sequence dated to c. 2800 BP. This rapid fall should have been caused by the breakthrough of the Neva River at the Ivanovskie rapids, and the outflow of the Ladoga water through the newly emerged channel. Apparently, this caused the fall of the water level in the entire hydrological system that encompassed the Ladoga Lake, the Volkhov River and the Ilmen Lake. The fluctuations of the Ladoga Lake as follow from the above evidence are shown in Fig. 6.

The earliest evidence of human settlement in north-eastern Baltic Area is attested at Antrea-Korpilahti (11,200-10,250 cal BP). In 1914 Mesolithic artefacts which included remains of a willow bark net, as well as objects of antler, bone and stone, were found in the sandy silt at Antrea-Korpilahti (Pälsi1920). Bark net floats were later radiocarbon-dated to 9200-8250 BC (Matiskainan 1989, 71). Currently conducted survey of that area has identified the lacustrine clay in which, according to Pälsi (1920), Mesolithic artefacts were found. Organic-rich gyttya overlying the clay has been radiocarbon dated to 5650-5050 BC. Supposedly, the Mesolithic artefacts were deposited on the bottom of a shallow lagoon, or in a shallow channel which was part of the Ladoga-to-Baltic drainage system.

At Häyrynsuo bog near Vyborg (17.2 m a.s.l.), close to Häyrinmäki esker on which a group of Stone Age sites was found at the altitude of 17- 20 m a.s.l. (Hyyppä 1937; Siiriainen 1969), the diatom evidence clearly signals two peaks of the Litorina transgression separated by a stage of regression with the dominance of fresh-water diatom species. The sample *Sphagnum* peat postdating the peak of the later transgression was radiocarbon dated to: 3650-2900 BC (Dolukhanov 1995).

The Ancylus Lake and the initial Littorina Sea periods corresponded to the occurrence of Mesolithic sites on the Ladoga-Baltic Isthmus. The Mesolithic site found on the Bol'shoe Zavetnoe Lake (Juoksemajärvi) at the altitude of 24-25.5 m was radiocarbon dated to dated to 7050-6200 BC) (Timofeev *et al.*. 2003; Gerasimov *et al.* 2003; Lavento *et al.* 2002; Timofeev *et al*. 2002*).*

Increase population density and sedentariness was signalled by an intensive pottery-making that started at c. 6500 BC or 5560-5250 cal BC. This may be related to the general increase in the biomass and biodiversity, as indicated by the spread of mixed boreal – broad-leaved forests observable in the pollen records. The early Neolithic site on the Bol'shoe Zavetnoe Lake lies at the altitude of 23.5 m a.s.l. All that time, the Ladoga Lake (of which the Bol'shoe Zavetnoe Lake-Juoksemajärvi was a bay), remained at the level of 20-21 m, in agreement with the earlier assessment of Finnish scholars (Lavento *et al.* 2002, c. 13).

The early Neolithic sites with the Sperrings (I:1 style) pottery were correlated by Hyyppä (1937) with the Litorina II terrace. Siiriäinen (1970, 1982) linked it up with the maximum transgression of Pajänne Lake at c. 5,200 BC. In his later publication Siiriäinen (1982) suggests an age of 6300-6200 BP (or 5300-5000 BC). Recently, earlier radiocarbon dates have been obtained for the Sperrings-type assemblage at the site of Hepojarvi: 5560-5250 BC (Vereshchagina 2003, Gerasimov *et al.* 2003)

The data obtained in the southern Ladoga area strongly suggest that the maximum level of the Ladoga Transgression was attained at c. 1000 BC. It reached the level of 10-12 m in the mouth of the Volkhov River at Staroya Ladoga site. Even higher level (c 15 m) is suggested at the Oyat River sequence.

The ensuing rapid fall of the lake level which is acknowledgeable in the interval of 2.8 – 2.4 ky ago (1000-4000 BC) opened the way for agricultural colonisation of low-laying terraces of the Ladoga Lake and the Volkhov-Ilmen system.

Recently available data (Yeremeyev 2007) indicate the occurrence of agricultural activities at the sites on the eastern shore of the Ilmen Lake at 1250-1100 BC. The pollen data obtained for Riberik mire near Novgorod identify the agriculture signatures at the levels of 3370-2200, 2300-1700, and 600-150 BC (Königsson et al. 1997).

The first evidence of that was the spread of the Volkhov Culture along the Il'men-Volkhov waterway with the subsistence based on cattle breeding, hunting and fishing and fishing (Yuškova 2003, 2006). One of the sites, Shkurina Gorka site, located on the terrace on the left bank of the River Volkhov. A series of radiocarbon dates shows its age as 950-350 cal BC. The altitudinal position of the site (18 m a.s.l.) implies that it was situated above the maximum height of the Ladoga transgression, which is estimated as 15 m a.s.l.

Following the final lowering of the lake- and river-levels, a network of agricultural settlements, and, eventually, the urban-type trade- and military centres arose along the waterway. The fortified hill-fort at Staraya Ladoga arose on the 6-meter high terrace of the Volkhov River formed during the final stages of the Ladoga transgression.

Existing evidence (Heinäjoki & Aalto1997) indicate the occurrence of sufficiently well developed agriculture in that area during the second half of the first millennium. According to ethnobotanical data this included cultivation of a wide spectrum of cereals (several species of whet, barley and millet) and pulses.

Conclusions

The conducted investigations substantiated the existence of a major Baltic-Ladoga waterway in the Karelian Isthmus that emerged c. 11,500 cal BP, and remained in action for c. 7000 years. The predominant location of prehistoric sites in the catchment area proves that this waterway effectively controlled the movements of hunter-gathering groups during the greater part of the Holocene.

Our data show that a general increase of population density and sedentariness, signalled by the beginning of an intensive pottery-making at c. 6500 BP (5560-5250 cal BC) in an environment of increased biodiversity and the establishment of mixed boreal – broad-leaved forests observable in the pollen records.

The obtained data indicates that the transgression of the Ladoga Lake reached its peak between 3500-3000 BP that was followed by the breakthrough of the Neva River and the general fall in the water level of the Ladoga-Volkhov-Ilmen hydrological system. The availability of low-lying fertile soils stimulated the rapid expansion in agriculture, acknowledgeable in the occurrence farming-related pollen and the changes in the sedimentation and resulted in the rapid spread of farming communities.

Table 1 . Radiocarbon dates for Nizhne-Osinovskoe sequence

Lab. code	Type of sample, depth (cm)	14C age (yr BP)	Calibrated age (AD/BC)	(yr BP)
LU-5305	Fine detritus gyttja, 650-655	9980±280	10700-8600BC	11600±1050
LU-5306	Fine detritus gyttja, 640-650	9580±100	9250-8600 BC	10875±325
LU-5307	Fine detritus gyttja, 630-640	9440±70	9150-8450 BC	10750±350
LU-5308	Fine detritus gyttja, 620-630	9530±90	9250-8600 BC	10875±325
LU-5309	Fine detritus gyttja, 610-620	9400±130	9150-8250 BC	10650±450
LU-5311	Fine detritus gyttja, 590-600	9300±130	8900-8250 BC	10525±325
LU-5313	Fine detritus gyttja, 570-580	8730±150	8250-7500 BC	9825±375
LU-5315	Carex peat, 540-560	8810±120	8250-7600 BC	9875±325
LU-5316	Low mire sedge-moss peat, 530-540	8440±110	7585-7350 BC	9417±117
LU-5317	Low mire sedge peat, 510-520	8540±80	7750-7100 BC	9375±325
LU-5318	Low mire sedge peat, 490-500	8410±70	7590-7310 BC	9400±140
LU-5319	Low mire sedge peat, 470-480	8070±100	7350-6650 BC	8950±350
LU-5321	Low mire sedge peat, 450-460	7920±140	7200-6450 BC	8775±375
LU-5322	Low mire sedge wood peat, 430-440	7850±140	7100-6400 BC	8700±350
LU-5323	Low mire sedge wood peat, 410-420	7990±70	7080-6680 BC	8830±200
LU-5324	Low mire wood peat , 390-400	7620±110	6690-6220 BC	8405±235
LU-5326	Low mire wood peat , 350-360	7360±110	6430-6010 BC	8170±210
LU-5327	Low mire wood peat , 330-340	7270±90	6270-5980 BC	8075±145
LU-5328	Low mire wood peat , 310-320	7100±100	6110-5740 BC	7875±185
LU-5329	Low mire wood peat , 290-300	7000±110	6070-5660 BC	7815±205
LU-5331	Low mire wood peat , 250-260	6580±80	5640-5360 BC	7450±140
LU-5378	Low mire wood peat , 240-250	6080±60	5210-4800 BC	6955±205
LU-5332	Low mire wood peat , 230-240	5300±70	4260-3970 BC	6065±145
LU-5333	Low mire wood peat , 210-220	2880±70	1290-840 BC	3015±225
LU-5376	Low mire wood peat , 200-210	2480±70	790-400 BC	2545±195
LU-5334	Low mire wood peat , 190-200	2090±60	360BC-60AD	2050±100
LU-5335	Low mire wood peat , 170-180	1390±50	540-720 AD	1300±50
LU-5336	Low mire grass peat, 150-160	1490±50	430-660 AD	1360±50
LU-5380	Low mire grass peat, 140-150	1090±60	770-1040 AD	1000±60
LU-5337	Mesotrophic grass peat, 130-140	950±60	990-1220 AD	860±70
LU-5338	Raised bog peat , 90-100	570±60	1290-1440 AD	590±60
LU-5379	Raised bog peat, 80-90	580±60	1290-1440 AD	590±60
LU-5377	Raised bog peat, 60-70	570±80	1280-1470 AD	590±80
LU-5374	Raised bog peat, 40-50	180±70	1630-1960AD	≤200
LU-5342	Raised bog peat, 30-40	210±80		≤200
LU-5373	Raised bog peat, 20-30	70±50		≤200
LU-5343	Raised bog peat, 10-20	$\delta^{14}C$= 1.22±0.63%		Modern

Table 2. Radiocarbon datres for Lake Lamskoye and Lake Makarovskoye sequences

Lab. index	**Type of sample, depth (cm)**	14C age (yr BP)	**Calibrated age BC**	**(yr BP)**
Le-7006c	Gyttja, 422-427 Lake Lamskoye	3560±160	2400-1500	3950±450
Le-7006b	Gyttja, 422-427 Lake Lamskoye	3010±120	1550-900	3175±325
Le-7007c	Gyttja, 417-422 Lake Lamskoye	3860±160	2900-1850	4325±525
Le-7007b	Gyttja, 417-422 Lake Lamskoye	3100±120	1700-1000	3350±350
Le-7008c	Gyttja, 310-320 Lake Lamskoye	2620±230	1400-200	2750±600
Le-7008 b	Gyttja, 310-320 Lake Lamskoye	2620±220	1400-200	2750±600
LE-7309c	Gyttja, 190-200 Lake Makarovskoye	2130±110	400BC-80AD	
LE-7309b	Gyttja, 190-200 Lake Makarovskoye	3010±150	1650-800	
LE-7310c	Gyttja, 200-210 Lake Makarovskoye	3810±120	2600-1900	
LE-7310b	Gyttja, 200-210 Lake Makarovskoye	2720±170	1350-400	
LE-7311c	Gyttja, 260-270 Lake Makarovskoye	3040±90	1500-1020	
LE-7311b	Gyttja, 260-270 Lake Makarovskoye	3560±200	2500-1400	
LE-7312c	Gyttja, 270-278 Lake Makarovskoye	2960±100	1420-920	
LE-7312b	Gyttja, 270-278 Lake Makarovskoye	2690±160	1300-400	

Table 3. Radiocarbon dates for Uzlovoe Lake

Lab. index	**Material**	**Depth, m from above**	**14C age (yr BP)**	**Calibrated date (yr AD/BC)**	
				68,2% probability	95,4% probability
LE-7257c	Gyttja	3.35-3.40	1240±80 BP	680AD-870AD	650AD-970AD
LE-7255b	Gyttja	3.40-3.45	2000±130 BP	200BC-140AD	400BC-350AD
LE-7259	Gyttja	3.95-4.00	1520±90 BP	430AD-610AD	340AD-670AD
LE-7258b	Gyttja	5.25-5.30	3850±200 BP	2600BC-2000BC	2900BC-1700BC
LE-7254c	Gyttja	5.30-5.35	3780±150 BP	2460BC-2030BC	2650BC-1750BC
LE-7254b	Gyttja	5.35-5.40	3740±100 BP	2300BC-1970BC	2500BC-1900BC
LE-7255c	Gyttja	5.40-5.45	3900±600 BP	3400BC-1600BC	4000BC-800BC
LE-7256b	Gyttja	5.50-5.60	2710±90 BP	980BC-790BC	1150BC-550BC

Table 4. Radiocarbon dates for Nevsky Lesopark sequence

Lab index	Depth, m from below	Material	BP uncal	Calibrated age	
				BC cal	BP cal
LU-5443	0.95 ; gyttja layer	Wood	4630±40	3499-3359	5380± 70
LU-5449	1.12-1.15; top of gyttja layer	Gyttja	4540± 70	3363-3101	5180 ±130
LU-5447	1.52-1.55; bottom of peat layer	Peat	4260± 50	2917-2707	4760 ±105
LU-5444	1.15-1.88; bottom of peat layer	Wood	4570± 50	3493-3105	5250 ±190
LU-5446	1.52-1.55; top of peat layer	Peat	3070± 50	1403-1265	3280 ±70
LU-5445	1.52-1.55; top of peat layer	Wood	2940± 60	1257-1047	3100 ±105
LU-5448	1.55-1.65; bottom of silt layer	Wood	3120 ±50	1487-1317	3350 ±85

Table 5. Radiocarbon dates for Nevsky Pyatachok seuqnce

Lab index	Depth, m, from above	Material	BP uncal	Calibrated age	
				BC cal	BP cal
LU-5459	0.8-0.82; bottom of gyttya	Gyttja	2870±50	1125-945	2985±90
LU-5460	0.76-0.78 gyttja layer	Gyttja	3560±50	801-549	2625±125
LU-5461	0.62-0.64; peat layer	Peat	2260±50	393-209	2250±90

Table 6. Radiocarbon dates for the Oyat sequence

Lab index	Depth, m, from above	Material	BP uncal	Calibrated age	
				BC cal	BP cal
LU-5454	1.91; peat layer	wood	4220±70	2903-2677	4740 ±110
LU-5458	2.0-2.2; gyttja layer	Wood, peat	4000±40	2567-2469	4470±50
LU-5456	2.67-2.7; gyttja layer, bottom	wood	4380±90	3305-2889	5050±210
LU-5453	2.7; peat layer, top	wood	5860±70	4829-4619	6725±60

Table 7. Radiocarbon dates for Staraja Ladoga sequence

Lab index	Depth, m, from below	Material	BP uncal	Calibrated age	
				AD cal	BP cal
LU-5462	Base of the lower archaeological layer, 1.2-1.21	Wood	1360±50	641 - 761	1250±60
LU-5463	Top of palaeosoil, 1.16-1.2	Wood	1400±50	603 - 667	1315±30
LU-5464	Top of palaeosoil, 0.9-1.0	Wood	1800±60	133 - 319	1725±90

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The Upper Volga Neolithic

A. Mazurkevich

The State Hermitage Museum

Upper Volga Culture (UVC) consists of small-size predominantly seasonal sites. Considerable part of these sites is found on the sand dunes developed on the river terraces of the Upper Volga basin and elevated lake shores (Fig. 1). The larger sites which often include remains of dwellings on post frames are found inside the bogs and mires (Krainov, 1996). There are indications that early Neolithic dwelling sites appeared at the time of considerable rise of lake levels. As show the pollen data (Krainov and Khotinsky 1984), the early Neolithic settlements coincided with the Middle Atlantic zone which featured the maximum expansion of mixed broad-leaf forests rich in thermopile elements with a high biomass. The subsistence of the Upper Volga groups was based on hunting (elk, red deer, roe deer aurochs, wild boar, and other wild forest animals), supplemented by fishing and collecting of edible wild plants.

The early pottery had been first recognized in Central Russia in the 1920s, when B.S. Zhukov excavating the site of Yazykovo II encountered rare fragments made of burnt clay with an abundant admixture of coarse sand and decorated by elongated parallel strokes (Zhukov 1920). This discovery passed almost unnoticed and in the following years another culture, that of Lyalovo, became generally acknowledged as the oldest pottery-bearing culture in the Upper Volga – Oka catchment (Bryusov 1952). Large-scale archaeological investigations conducted in the area in the 1960s-1970s led to the discovery of several early pottery assemblages at such sites as Strelka I, Kukhmar I and Shchadrino IV (Krainov and Khotinsky 1977, 42). In all these cases the pottery was found in a context of Mesolithic-type stone industry. Multidisciplinary studies carried out at several wetland settlements in the Yaroslavl, Ivanovo and Tver (formerly, Kalinin) Oblasts led to the discovery of several key sites (Yazykovo I, Ivanovskoye III and Sakhtysh I (Urban 1976, Krainov and Khotinsky 1977), where the early type pottery (the so-called 'stoked-comb' decorated) was found in clear stratigraphic sequences. Several publications (Krainov and Khotinsky 1977, 1984) contained general characteristics of different varieties of pottery, the stone and bone-and-antler industries on which basis the Upper Volga Culture (UVC) has been identified. A special emphasis was laid on its age, environments and the stratigraphic relations vis-à-vis early Lyalovo strata, which were since then reclassified as the Middle Neolithic. Significantly, these observations were substantiated by the pollen-based stratigraphy. In the case of Ivanovskoye III and VII bog sites, the Upper Volga levels which corresponded to the Middle Atlantic pollen zone, where separated from the Late Mesolithic strata by a sterile layer with the Early Atlantic pollen spectra. Both at Yazykovo I and Sakhtysh I, the Upper Volga materials were found in the deposits corresponding to the very beginning of the Atlantic-2 pollen zone (Krainov and Khotinsky 1984, 103, 108). Combining stratigraphic and typological observations, Kostyleva (1986, 1994) followed up the relative chronology of the varieties of the Upper Volga pottery types.

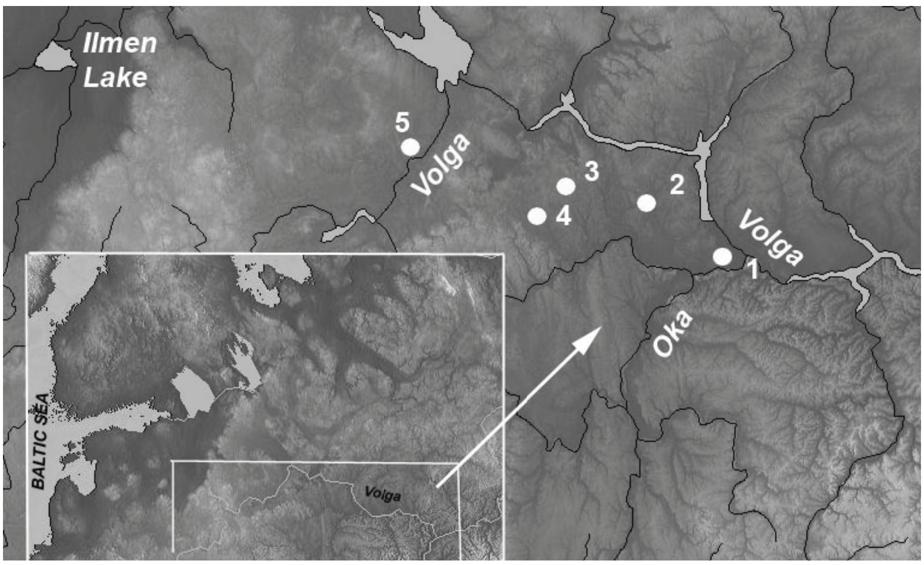

Fig. 1. Upper Volga key sites.
Key: 1 – Shchadrino, Strelka, 2 – Sakhtysh, 3 – Ivanovskoye, 4 - Pol'tso. Pleshcheyevo, 5 – Yazykovo.

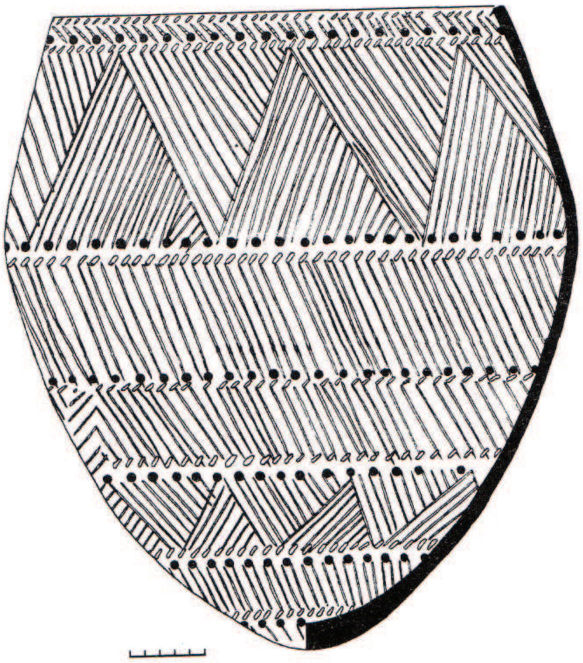

Fig. 2. UVC pottery (afterZhilin et al. 2002).

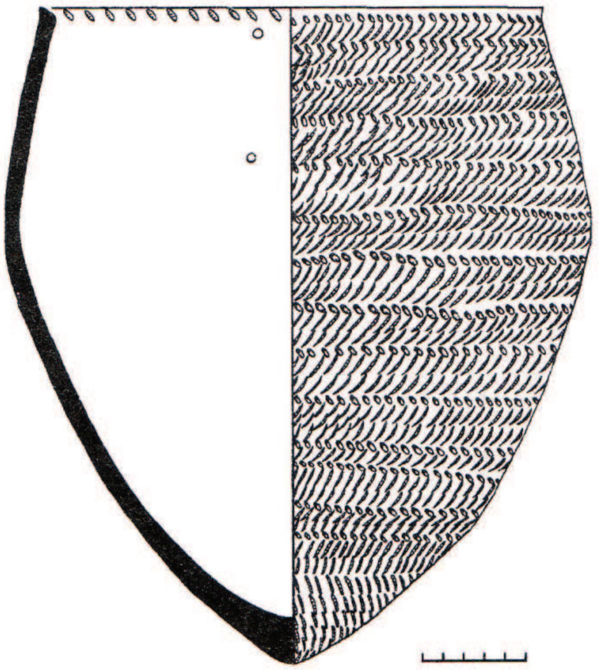

Fig. 3. UVC pottery, Zamostye 2 (after Lozovsky 2003b).

Summing up the existing publications (Krainov 1996; Kostyleva 1994 and others) one may visualize the following temporal evolution of the main features of the UVC. At its early stage the pottery was apparently made of lake clay tempered with organic matter, shells and crushed pottery. The vessels were either pointed-conic or flat-bottomed from 2.5 to 10 cm in diameter. The rims were either straight or rounded, with 14-16 cm of neck diameter. The vessels were either undecorated or ornamented with rare impressions concentrated either in the vessel's upper or lower portions. The same type of ornament is found on the bottom. The sub-triangle, drop-like, oval and crampon-like impressions are distinguishable (Engovatova 1998, 241). Several vessels had a rill with through holes beneath the neck. Kostyleva (1994, 55) notes the appearance of pots ornamented with incised lines, shallow teeth impressions and 'pseudo-cord' stamps towards the end of the first stage (Figs. 2, 3).

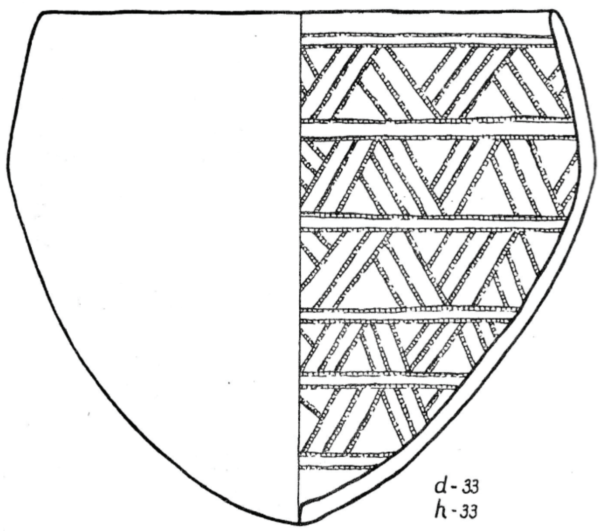

Fig. 4. UVC pottery, Voymezhnoye 1 (after Engovatova 1997).

The tradition of flat-bottom vessels stops with the beginning of the UVC second stage (Fig. 4) which pottery consisted of small-size round-bottomed pots with 10 cm of neck diameter, as well as C-shaped point-based variety with the neck diameter of 30 cm. The tempering with chamotte (crushed pottery) is typical of this pottery, ornamented with shallow teeth impressions; other varieties include coarse sand admixture. The organic matter is no longer observable. The vessels became thicker. Incised lines and pseudo-cord ornamental patterns gradually disappear. This type of ornament was found at several sites (Sakhtysh II, VIII, Ivanovskoye III, V and others) on the vessels with red-painted surface (Kostyleva 1994, 55, Krainov 1996, 169). The ornaments cover the entire vessels' surface. One notes the general increase of the pottery frequency in archaeological deposits.

The chamotte tempering is also observed in the pottery of the third stage, yet the coarse sand became more common. Along the C-shaped vessels, one observes larger pots with the opened neck diameter of up to 40 cm, and protruding walls, as well as straight-walled vessels with wide opened mouths. The bases are either pointed or rounded. Various teeth stamps predominantly long-teeth ones, form the main ornamental patterns. They are combined with impressions of various shapes, often forming dividing belts. One notes a new element of ornament, the 'receding comb'. As Kostyleva

(1994, 56) notes, this type of evolution is observable in the central UVC area only, those in its peripheral parts being somewhat different.

Tsetlin (1991) suggests a different trajectory for the evolution of the UVG. In this writer's opinion, the 'pure' UVC elements are observable at the initial stage only, the second one reflecting its interaction with that of the pit-and-comb decorated pottery. The first stage includes the pottery made with the admixture of coarsely crushed pottery and birds' dung and the punctuated ornamental pattern. The second stage features the new type of admixture (crushed pottery, birds' dung and coarse sand) apparently resulting from the contacts with the pit-and-comb pottery culture. At this stage the ornamental patterns commonly consist of combinations of comb impressions. As the writer notes, the cultural interaction is usually observed only in the eastern area, suggesting that the intrusion of pit-and-comb pottery culture proceeded from that direction.

Basing on Ivanovskoye VII site stratigraphy, Tsetlin (1996, 159-160) considered both the unornamented and stroke ornamented pottery with the organic admixture as the oldest variety. The pottery with crushed pottery and organic admixture had ornaments consisting of stoked and dotted lines, and at more recent stages, also doted and comb ornaments. He further suggests that the pottery with crushed pottery and organic admixture and that with crushed pottery, organic and coarse sand admixtures were manufactured throughout the entire period of the UVC existence. Both technologies emerged beyond the Upper Volga area, the former one belonging to an independent culture, predating the UVC.

Kostyleva (2003) considers the oldest UVC as consisting of flat- and pointed bottomed vessels, with straight and flat rims, either unornamented or decorated by oval or triangular strokes. The UVC is generally deemed as having the southern origins. Engovatova (1997, 119) argues that it had resulted from impulses stemming from the Lower Volga. Kostyleva (2003) notes the similarities of the UVC pottery with the of the Yelshanian and RYar cultures. Summing the bulk of existing evidence Zhilin et al. (2002) conclude that the evolution of UVC pottery proceeded from the earlier stage dominated by the stroked ornament, to the later one, featuring the comb pattern, through the intermediate one with the prominence of pseudo-cord, linear and shallow-teethed patterns.

The flint industry manufactured from the nodules found in the morainic till. According to Krainov (1996, 169), the stone industry was based on the blade technique, with the abundance of either unretouched blades or backed blades and their sections. Arrowheads were manufactured from either partially or totally retouched leaf- or tanged points. At the later sites one notes the points with the covering ventral or the lateral reverse retouch. End scrapers, angular burins, and truncated bladlets were manufactured from the blade blanks. Circular end scrapers and other scrapping tools, as well as knives and burins were based on the flake blanks. Heavy duty tools included axes and adzes polished along the cutting edges.

A different variety of the stone industry has been acknowledged at Zamostye 2 site, with the dominance of flake blanks and the common occurrence of laterally retouched thick blades, and the prevalence of end scrapers among the tools. One also notes a high proportion of heavy duty tools, and particularly, polished axes. Differently to Late Mesolithic, a higher proportion of combined tools, and the emergence of bifacially retouched thin bifaced arrowheads is remarkable (Girya et al. 1997; Lozovsky 2003a).

In Engovatova et al. (1998) view, the UVC early stage features the predominance of flake blanks, with the main varieties of points and cutting tools manufactured from blades. At the middle stage one notes the further decrease of blade blanks, with an increased rate of ventrally retouched arrowheads and polished axes. Totally retouched spearheads and knives became more frequent at the UVC later stage.

The excavations of the bog sites yielded large series of bone and antler implements. They include the tools of Mesolithic type, such as arrowheads, lances, knives with bird-shaped handles, large objects with the working edge cut under 45 degrees, awls, needles, spoons, tools made from beaver mandible, and antler axes. One notes an increase in the proportion of projectile points, needles, figured points with bulges, biconic points, thin-teethed points, and harpoons, and the appearance of fish hooks (Lozovsky 2003; Krainov 1996, Engovatova et al. 1998).

Dwelling structures were identified at several sites. At Sakhtysh VII site, two oval-shaped structures with the floors submerged by 40-50 cm below the ground and the oval hearths either in the middle or close to the wall were found. Pot holes were visible around the heath and along the dwellings' rims, both inside and outside. Kostyleva (1986, 149-150, Fig. 7), the dwelling's entrance was oriented towards the west, in the direction of the river. Semi-rectangular dwellings, 2.2 by.5 m and 2.5 by 2.8 b in size and submerged by 40 cm below the surface were identified at Malaya Lamna I site.

The artworks consist of ornamented clay discs about 5 cm in diameter that were found at several sites: Sakhtysh II, VII, Yazykovo I, Ivanovskoye VII and Maslovo Boloto V. The disc from Sakhtysh VIII had an ornament in the form of a red deer head inside a circle and a hole, apparently serving for hanging. One should note a series of ornamented pebbles found at Zamostye 2, Sakhtysh VIII and Pol'tso.

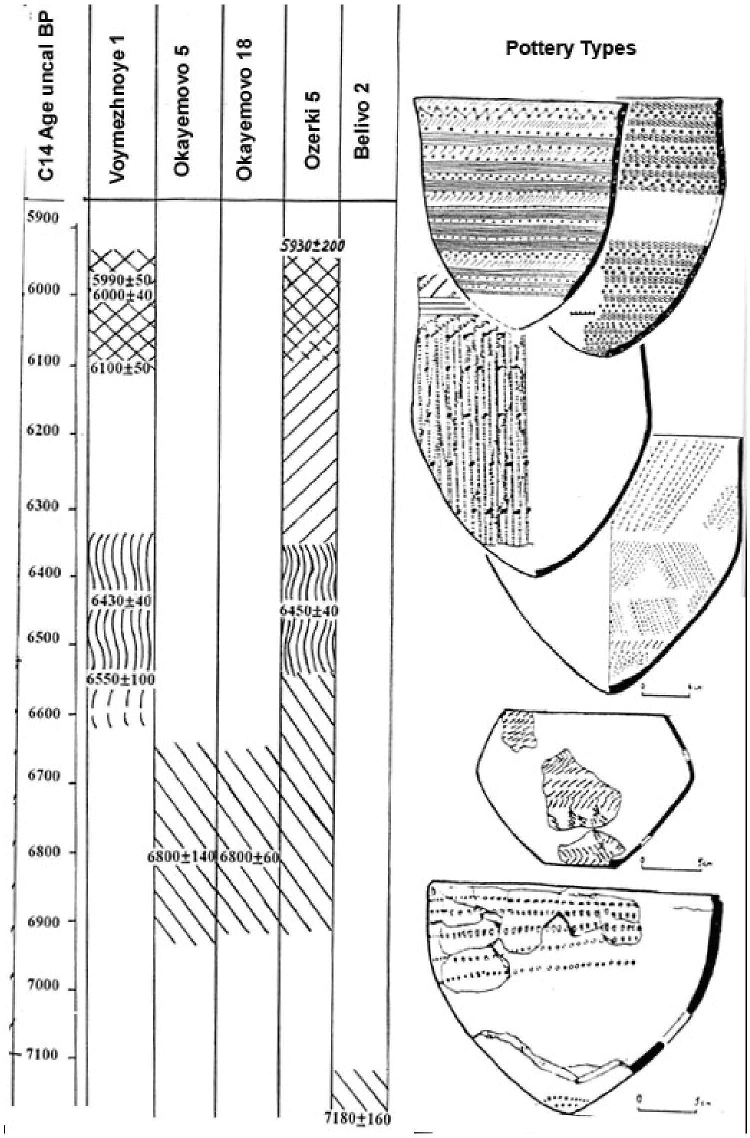

Fig. 5 UVC chronological sequence (after Engovatova et al. 1998)
Sakhtysh 2a

1. Fragments of unornamented pottery considered as belonging to the UPC early stage (Kostyleva & Zaretskaya 2004; Engovatova 1998). The date obtained for food crust: 6500±100 (GIN-10924).
2. The upper part of the same layer that includes the stroked ornamented pottery. The date obtained for the scull of a juvenile elk: 6230±50 (GIN-10923).
3. The underlying Late Mesolithic layer. The date for a fishing weir: 7390±40 (GIN-10860). The date for peat layer that include Late Mesolithic materials: 7390±40 (GIN-10861) (Kostyleva & Zaretskaya 2004).

Ivanovskoye VII

1. Dates obtained for peat and gyttja layers that contain archaeological deposits with UVC pottery (Zhilin et al. 2002): 6410 ±50/ 6260+/-90 (GIN - 9378; I / II); 6690 ± 110 / 6670±140 (GIN – 9378; I / II);
2. Late Mesolithic layers of the same site: 7090±100, 7000±140 (Zhilin et al. 2002, Fig. 117).

Belivo II

The date for archaeological deposits containing the UVC pottery of an 'earliest type' from clay tempered with organic matter: 7180±60 (GIN-4726).

Zhabki III

The dates for archaeological deposits containing the UVC pottery of an 'earliest type' from clay tempered with organic matter: 6870±100 (GIN-2767) and 6460±160 (GIN-3214).

Chronology

The suggested chronological division of the UVC (Fig. 5) is based on the totality of available radiocarbon measurements obtained both for the samples of archaeological materials and for the deposits where there materials were found. In both cases these dates might be deemed as not fully adequate, particularly for the case of multiple habitation of the same site It is particularly obvious in the case of Ozerki 5, where the Early and Middle Neolithic materials were found in a single lithological layer and may be distinguished only in plane (Smirnov 2004, 13, Fig. 10). This results in obviously exaggerated duration of certain Neolithic stages, on the one hand, and the gaps within certain periods, on the other. The preliminary chronological scheme for UVC is shown on Fig. 4. With the advent of new radiocarbon dates this scheme is likely to change.

Stanovoye 4: 7030±100 (GIN-8387); no additional information.

Ozerki 5. The bottom part of archaeological layer IIa. The date obtained for wood fragments: 6450±160 (GIN-7215). According to Engovatova (1998, 240) and Zhilin (1996, 122), this contains the pottery of UVC stage three. Smirnov (2004, 106, 113) views this either unornamented or ornamented with 'receding strokes' pottery as belonging to the UVC first stage.

Okayemovo 5. The date for the gyttja layer containing the stroked ornamented pottery of UVC early stage: 6800 ±140 (GIN-61194). The layer features the Early Atlantic pollen spectra (Zhilin 1997, 170).

Okayemovo 18. Archaeological deposits with the pottery of UVC early stage. The dates obtained for an elk skull: 6800 ±60 (GIN-8416) (Zhilin 1997, 167).

Zamost'ye 2.

1. The layer with the pottery of UVC early stage. Date for the bone fragment: 7200±90 (GIN-7988); date for wood fragments: 7000±70 (GIN-7986);
2. Food crust from pottery vessels: 66500±45 (Ua-37101; AMS);
3. Peat with UVC artefacts (the exact relation to archaeological deposits not specified): 7050 ±40 (GIN - 6564), 6850±60 (GIN -6557), 6680±100 (GIN -6190), 6290±40 (GIN -7985), 6250±100 (GIN -6199). The pottery assemblage consists predominantly of UVC early type pottery, with a limited amount of those of second and third stage (Lozovsky 2003). The UVC latest stage is dated: 6290±40 (GIN -7985); stratigraphic details were not given (Lozovsky & Lozovskaya 2003, 33)

Voimezhnoye 1. Charcoal from the hearth containing the fragments of a pot of UVC second stage: 6560±100 (GIN - 6868). The date obtained for wood fragments of the same layer: 6430±40 (GIN -5926) (Engovatova 1998, 239).
The following dates for UVC were quoted by Krainov (1978) without further details:

Ivanovskoye V: 5560±100 (LE-1109);

Yazykovo I: 6370±70 (LE -1189), 6250±60 (LE -1080)6 5950±90 (LE -1190), 5490±70 (LE -1188), 5280±130 (LE - 1079);

Sakhtysh I: 6560±250 (LE -1021), 5150±40 (LE -1024).

Relative chronology

The following sites are considered as exemplifying the UVC **first stage** (): pure assemblages – Okayemovo 5, 18; Overki 5, layer III, Belivo II, Al'ba I,III, Davydovskaya, S hadrino IV, Alekseyevskoye; in mized assemblages: Sakhtysh II, VIII, Ivanovskoye III, V, VII, Kukhmar' I, Pol'tso, Varos, Maslovo Boloto 8, Yazykovo I, Vladychinsko-Beregovaya I, and Zamost'ye 2 (Kostyleva 1986; Engovatova 1998; Lozovsky 2003).

The second stage. Pure assemblages: Voimezhnoye I, Oxerki 5, layer IIa, Ozerki 17, layer III, and Pleshcheyevo I (Kostyleva 1986; Engovatova 1998, Zhilin 1982; Kol'tsov & Zhilin 1999). Mixed assemblages: Sakhtysh II, VIII, Ivanovskoye III, Nikolo-Perevoz 1, 3. The occurrence of this type pottery was also reported at Ivanovskoye II, V, Kukhmar' I, Berendeyevo IIa, Torgovishche and Zamost'ye 2 (Lozovsky 2003).

The third stage. Pure assemblages: Ozerki, layer II, upper part; Brendeyevo IIa, Zolotoruch'ye III and Karash III. Mized assemblages: Sakhtysh I, II, IIa amd VIII; Ivanovskoye III and VII, Yazykovo I and III; Vaslovo Boloto 7, Biserovo Ozero, Torgovishche I, Spasskaya I, Glivistenka, Zastan'ye and Zamost'ye (Kostyleva 1986; Engovatova 1998; Lozovsky 2003).

Tseitlin (1966) distinguished several sites with early type pottery forming a special entity predating the UVC: Seima 1, Bobrinka II, Lamna I, Kisyachevo I and II, Zavyalovka, Sakhtysh I, II and VIII, Ivanovskoye III, V and VII, Somino II, Nikolo-Perevoz III, Yazykovo I, Volosov, Korenets I, Teren'kovo III, Zhabki III and Belivo II.

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Late Stone – Early Bronze Sites Age in the Western Dvina -Lovat Area

A.Mazurkevich,[1] P. Dolukhanov,[2] A. Shukurov,[3] and G. Zaitseva[4]

[1]State Hermitage Museum, St. Petersburg
[2]School of Historical Studies, Newcastle University
[3]School of Mathematics and Statistics, Newcastle University
[4]Institute for History of Material Culture, St. Petersburg

This area lies in the Russia's North-West, close to the Central Russian Upland, where the Russia's main rivers take their sources (Fig. 1). The surrounding terrain forms an evenly undulated sandy glacial outwash plain at the altitudes of 150-180 m, with isolated occurrences of morainic landforms (Malakhovsky and Markov 1969).

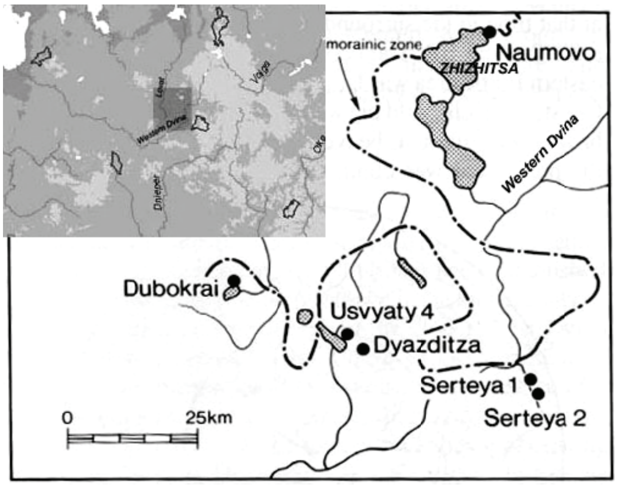

Fig. 1. Location of the sites

Starting with the maximum advance of the Valdai (Weichselian) ice-sheet at 20-18 ka, a system of ice-dammed lakes encompassed the entire catchment of the Upper Western River (Kvasov 1975). Their shorelines are visible at the heights ranging between 180 and 130 m above sea-level. The network of lakes collapsed following the abrupt fall of the Baltic Ice Lake at 11560 cal years BP (see Chapter). Numerous present-day lakes are the remains of huge Late Glacial basin.

The present-day climate here is moderately continental, with mean temperatures of –8°C in January and 17-18°C in July, and precipitation of 500-700 mm, mostly in summer. In geobotanical sense the area belongs to the East European mixed broadleaved-coniferous forests. Temperate deciduous formations consist of mixed oak forests, which are found mostly on the clayey soil of the morainic hills. Boreal evergreen conifer (mostly pine) forests cover the sandy outwash plain. Spruce forests are usually restricted to the lower levels of the morainic hills. An intensive felling of forests started in the 13th -14th centuries and became much enhanced after the 1860s. The woodland currently occupies less than 20% of the originally forested area. The secondary forests consist of birch, and alder with shrubs. Bottomland floodplain meadows, bogs and mires occupy about 40% of the total area. Agricultural plots take up the remaining 40%. Main staple crops are rye, wheat and flax.

In 1962 Alexandr Miklyayev discovered a submerged dwelling site of Neolithic age on the Usvyaty Lake (Miklyaev 1992). Since that time and until his tragic death in 1993, Miklyaev and his associates were systematically investigating that area, where a large number of new sites were brought to light. Since the initial discovery of pile dwellings, more than 40 prehistoric archaeological sites have been recorded and partly excavated in the Upper Western Dvina and Lovat river basins. These sites are now studied by several multi-disciplinary teams.

In current years, detailed studies were focused on the Serteya River valley and the catchment of the Zhizhitsa Lake. The Serteya is a small tributary of the Western Dvina River, 20 km east of the town Velizh and c 100 km north-north-west of Smolensk, the provincial capital. As will be shown later, during the Holocene this entire valley was taken up by the lakes that were drained during the subsequent development of the Western Dvina catchment. Another area of research, the Lake Zhizhitsa (Zhizhitskoe) is located in the south-eastern part of the Pskov Oblast, 70 km east of the town of Velikie Luki, on the Moscow-Riga railway line.

1 Mesolithic-Early Neolithic

The earliest sites belong to Mesolithic and Early Neolithic. This unit consists of several sites located in the northern part of the Serteya valley (Fig. 2). The Mesolithic sites are exclusively lithic-based. Early Neolithic sites are distinguished by the occurrence of early varieties of pottery wares. Stone tool assemblages at several sites located on elevated levels (Serteya 3-1, X, XIV and XIX) show affinities with Early Mesolithic Kunda Culture in Eastern Latvia, as exemplified by the 'Pulli-type' arrowheads, points and borers on sub-triangular flakes, sub-triangular axe-like tools, scrapers on flakes and (more rarely) blades, and micro-blades.

The sites Serteya X, XIV, VI, VII, 9, 10, and 11 include the artifacts attributable to Late Mesolithic. Two sites (Serteya X

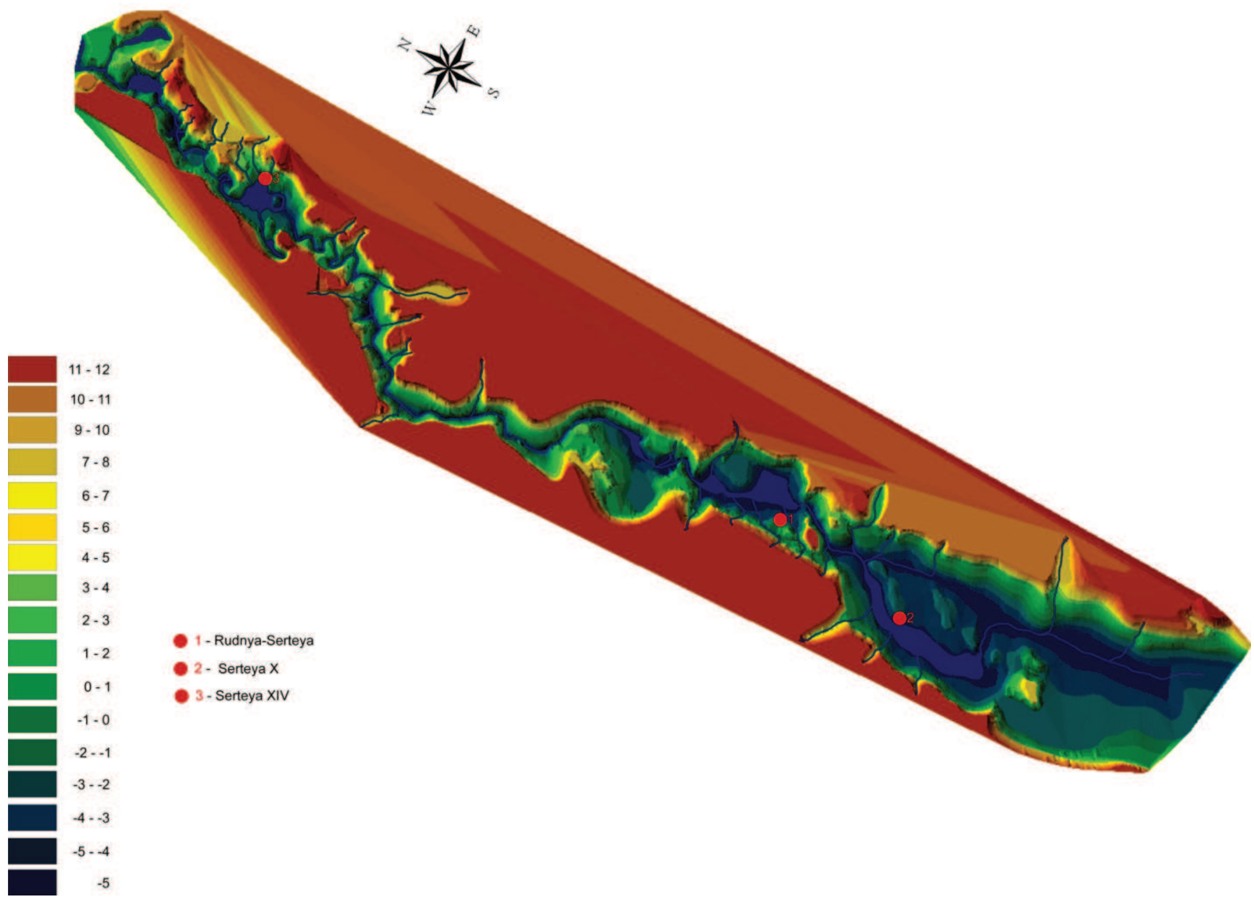

Fig. 2. Serteya Valley 7300-6000 cal BC.

and XIV) are considered as camp-sites; they included remains of circular dwelling structures with post-holes along the perimeter and the axis. Circular hearths were located in the middle part of the dwelling and close the entrance which faced the lake. Lithic industries included prismatic tanged arrow-heads, conic and unipolar cores, sub-triangular axe-like tools, blades and retouched blades. Their analogies are found in the later varieties of the Kunda Culture and the Dniepr-Dvina Mesolithic in Byelorussia.

The early pottery referred to as *Serteyan* can be subdivided into the varieties (phases), suggesting the occurrence of various (at least two) distinct stylistic and technological tradition of early pottery-making. The ceramic vessels of the earliest *Phase A* (Fig. 3) were manufactured using the coiling technique. The ceramic paste consisted of local clay tempered with organic matter, crushed shells and coarse sand. As show the analyses carried at out at the Porcelain Research Institute at St. Petersburg with the use of chemical, mineralogical and thin section analyses as well as scanning electron spectrography (Panteleyev, personal communication) the pottery was subjected to firing at less than 1000˚C, and, most likely, less than 500˚C. This has been confirmed by the analyses of early Neolithic Upper Volga pottery in Central Russia using time-of-flight neutron diffraction, which indicates 'absence of mullite reflections in the diffraction patterns indicates that the raw materials were generally fired below 800ºC' (Kockelmann et al. 2005). Apparently the low-temperature firing of ceramics was typical of the entire Early Neolithic in the boreal Europe. As Zaitseva (2000) notes the threshold of 900 C was with the development of kilns, which appeared in that area only in the Early Iron Age.

Fig. 3. Serteyan Phase A pottery

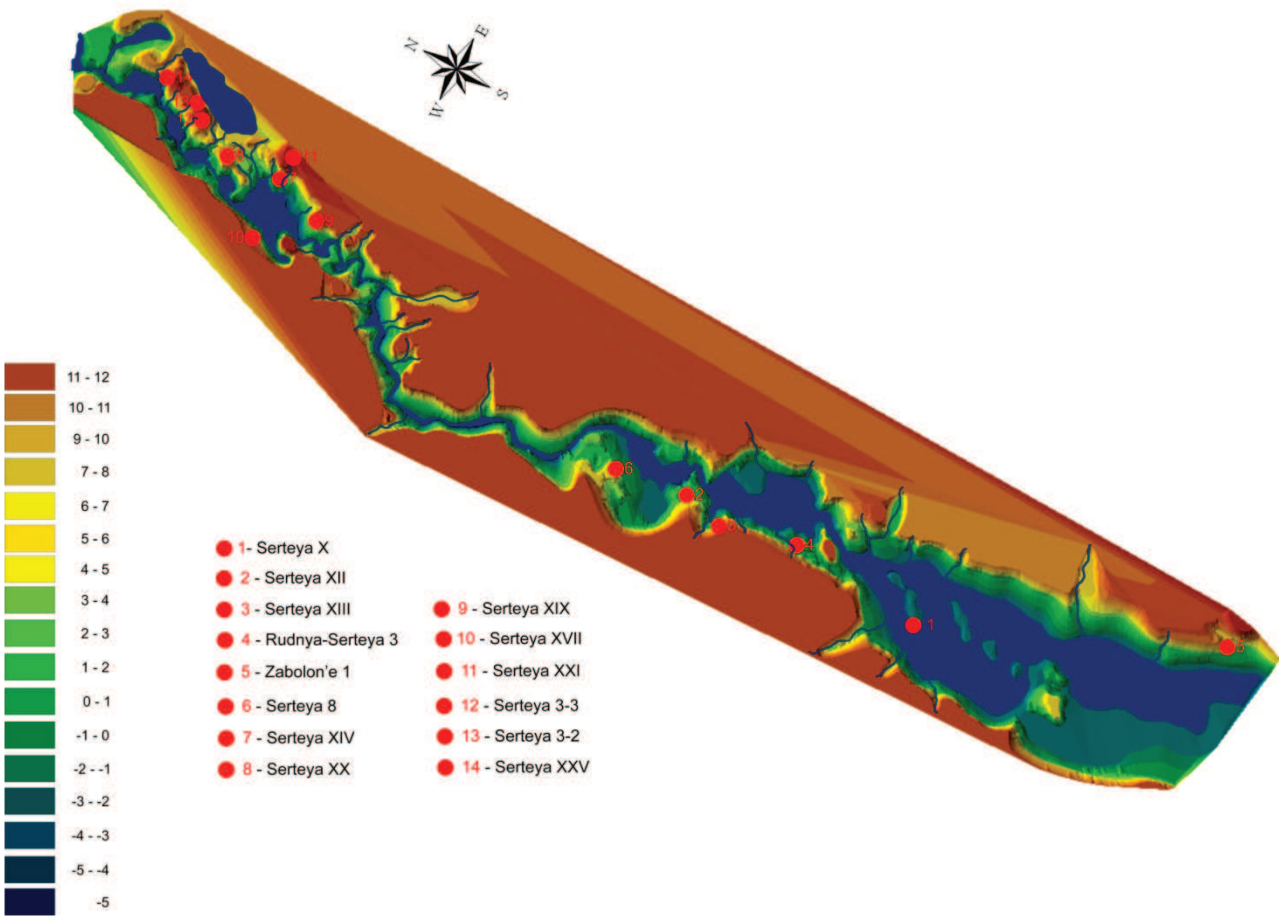

Fig. 4. Serteya Valley 6500-5700 cal BC.

The *Phase A* pottery has been identified at Rudnya-Serteya and layers A, 1, 2 and 3, and Serteya X. The sites of the *Phase A* include numerically poor flint industry: retouched blades, blade inserts; end-scrapers on flakes, bifacially retouched arrowheads with triangular edges and asymmetrical tanged arrowheads. Bone industry consists of tanged arrowheads, points, borers and pendants (perforated elk incisors). Remains of a sub-rectangular dwelling with a submerged floor have been identified in the Layer A of Rudnya–Serteya site. Its floor was deepened beneath the ground level, with ash planks supporting the walls. Several dwellings structures have been identified at Serteya XIV. They include a circular structure, 3.08 by 2.3 m, with a submerged floor, pot-holes along the periphery and one in its centre, and a heart in its north-eastern part.

The pottery *Serteyan, Phase B* is seen as a direct development of Phase A tradition. This type of pottery has been identified at several sites located on the sandy lake terraces (Serteya X, XI, XIV, XIX), as well as on the wind blown dunes on lake shores (Serteya 3–1, 3–2, 2–2, XX) (Fig. 4). The technology remains basically the same, the only innovation being the paddle and anvil technique used for smoothing the joins. The vessels were either conic or mitre-shaped, and rarely, flat-bottomed; the walls, 6–9 cm thick. The decoration restricted to the vessels' upper part, consists of notches forming either triangles or more complicated geometric patterns. Rims are straight with either flat of sharpened tips (Fig. 5).

Fig. 5. Serteyan Phase B pottery

In similar conditions were found the sites with that type of pottery in the Usvyaty area: Lukashenki I-1 and III-3. At Serteya X remains of an oval-shaped dwelling floor have been signalled, 2.5 by 3 m in size, deepened by 50–70 cm into the ground, with pot-holes along the perimeter and a hearth in the middle. The site includes several hearths surrounded by pot-holes and several oval-shaped 'workshops' with pot-holes along the perimeter and the central axis, and an entrance oriented to the south.

In recent years it became possible to distinguish a *Sub-phase B-1*. Its pottery features several drop-like notches, impressions of a hollow of toothed stamps. This variety of pottery occurs at several sites, Serteya XIV, 3-3 and XX, and at several sites in the Usvyaty area: Lukashenki I-1, III-3, Romanovskaya, Usvyaty II (site 1) and Uzmen'

The *Phase C* pottery consists of thick vessels (7–9 mm), manufactured with the use of a slightly different technique: docked coils, with the addition of clay rings. Both external and internal surfaces were smoothed by toothed stamps (Fig. 6). Undecorated cauldrons are either conic or flat-bottomed. This type pot pottery has been identified at Rudnya Serteya (point 3), Serteya X, XIV XII, X, XIV, XVII-XX, and several sites in the Usvyaty area: Uzmen', Romanovskaya, Usvyaty II (site 2). At Serteya XIV the corresponding layer includes an oval-shaped ground dwelling, 5.1 by 3 m, with pot-holes along the periphery and central axis, and a hearth in its western part. A more complex dwelling appeared at this site at later stage: a sub-rectangular structure, 8.8 by 6, 3 m, with two rows of pot-holes along the central axis, and a large oval stone-laid hearth it its northern part. The pot-holes surrounding the hearths suggest the occurrence of fire protective devices

Fig. 6. Serteyan Phase C pottery

The pottery of C-1 Sub-Phase is made of natural yellowish clay rich in organic matter, crushed shell and with a small amount of fine sand. The majority of vessels are not decorated. The decorated ones have horizontal or, rarely, diagonal notch impressions restricted to the upper part of the vessels. This pottery has been identified at Serteya X, XII-XIV, XVII-XIX, and in the Usvyaty area, at Uzmen', Usvyaty II (site 2) and Romanovskaya.

The earliest radiometric date has been obtained with the use of AMS method for food crust on the pottery sherd of Serteya XIV site (phase C): 7350-7170 calBC (Ua-37099). Several dates are available for Serteya X sites, layer A2 (phase A). They include two AMS dates for food crust: 7050-6500 calBC (Ua-37090) and 6160-5890 calBC (Ua-37100), as well as two conventional dates in the range of 6500-5750 calBC (Le-5261 and Le-5261). The existing data strongly suggest that the pottery-making showing apparent stylistic similarities both with North Caspian ('stroked') and Rakushechnyi Yar traditions appeared in the studied area at an early age (7300-6000 calBC), comparable to that of early pottery sites in the south East European Plain.

A new tradition of pottery-making appeared between 5300-4900 cal BC. Its technology remained basically the same: the combination of the coil and paddle and anvil techniques, the interior and exterior walls were smoothed with a toothed stamp. Three types of vessels are distinguished: those with 'S', 'CS' profiles and conic beakers. Rims are either rounded or bent inside; bottoms are conic, with thorn-like tips. Vessels with 'CS' profiles are decorated in their upper parts with either horizontal or diagonal rows of pits, nail notches and comb impressions. Conic beakers bear similar ornaments beneath the rims. Vessels with 'S' profiles are usually not decorated. The accompanying lithic industry is based on the flake blanks and includes end-scrapers, beaked burins, partially polished oval-shaped axes, triangular arrow-heads. Significantly, the stone tools were manufactured from low quality dark morainic flint, quite distinct from that that had been used previously. Bone and antler industry consist of a unilateral point, needle-like point, tanged arrowhead, borers, adzes and knives. These types of pottery, as well as the stone and bone-and-antler industries have direct analogies in the inventories of the Narva-types sites of the Lubanas Lake Lowland (Eastern Latvia). The sites with the age 4900-4500 cal BC include also the older types of pottery fired at low temperature with the surface decorated by horizontal rows of triangular notches, found in combination with the new types.

Several sites, Serteya 3-3, 3-2 and X, include small size vessels with the walls 4-5 mm thick, manufactured with the use of coil technique, straight or sharpened rims, and traces of smoothing by a toothed stamp on interior and exterior walls. The greater part of vessels was not decorated; several sharpened rims have rows of deep pits. This pottery finds direct analogies in the Yelshanian Culture.

The site Dubokrai V, on the Sennitsa Lake includes ca. 1000 pottery fragments of presumably Early Neolithic age that form a dense cluster on the off-shore sand bar. In several cases this type pottery has been found at the bottom of a sequence overlain by the Middle and Late Neolithic age. This pottery was manufactured from clay tempered by coarse lake sand, crushed shells and organic matter, with the use of coil, and, subsequently, coil and paddle techniques. The bottoms are either conic or flat-conic. Several conic or cauldron-like conic

Fig. 7. Pottery from Dubokrai V site

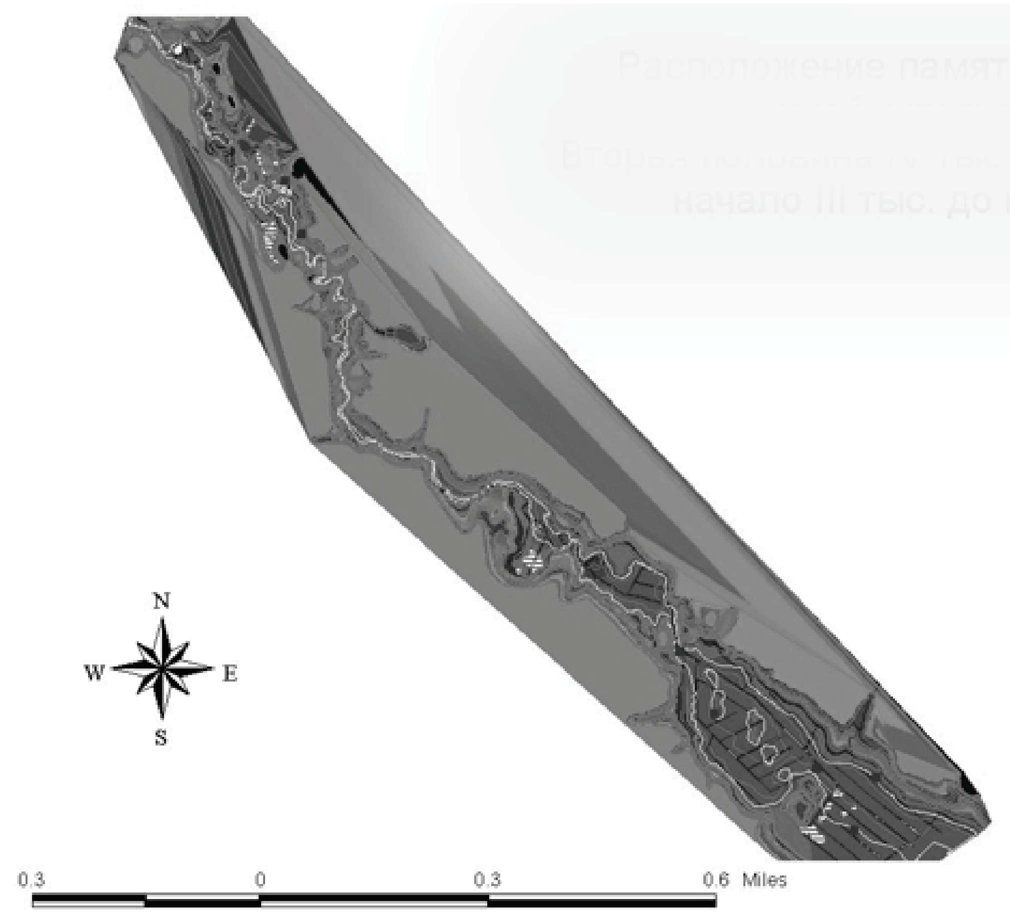

Fig. 8. Serteya Valley 4500 – 5700 cal BC

are 22 – 46 cm in diameter. One also notes smaller beakers with flattened bottoms and rings both around the rim and the body. The rim diameter is ca. 12 cm. The decoration consists of incised lines, pits and notches which form geometric curvilinear patterns. Rim tips and the adjusting interior surface are decorated with pits and notches (Fig. 7). Careful examination has shown that this type of pottery also occurred at such sites as Dubokrai I and Usvyaty IV, although its stratigraphic position is not precise. Analogies to this pottery may be found in some earlier varieties of the Linear Pottery in the areas of Lower Rhine, Maas, Elbe and Saale. This type of pottery in the investigated area is accompanied by lithic tools made on flake blanks: knives, asymmetric points, and a small oval, partly polished axe-like tool. Bon-and-antler industry includes biconical and needle-like points, knives and borers. One should particularly mention two flutes and pendants of Baltic amber.

2 Middle Neolithic.

The sites belonging to the Middle and Later Neolithic are found in the southern part of the valley (Fig. 8). Their common feature is the occurrence of dwellings built on the platforms supported by wooden piles (Fig. 10). The Middle Neolithic is exemplified by Usvyatian culture, first identified by Miklyaev on Usvyaty Lake, 50 km further north-west. Its rich decorated organic-tempered pottery includes varieties with 'curvilinear' patterns (Fig. 9). Other elements of material culture are variegated lithic industry, wooden implements, a human effigy (Fig. 11) and a bone wind musical instrument, a flute (Fig. 12). The samples of wood from the various construction periods at Usvyaty IV yielded the radiocarbon dates in the range of 4462-2200 cal BC.

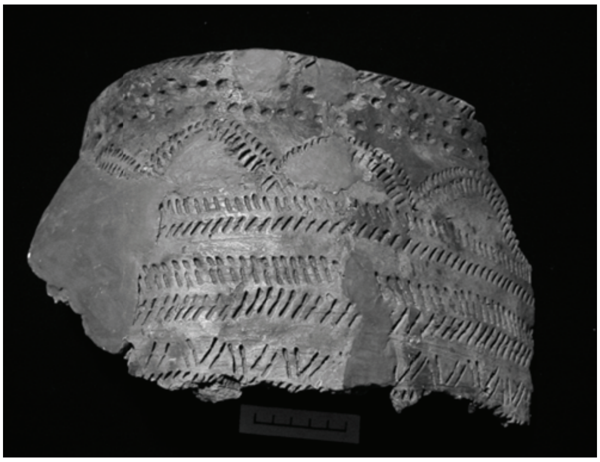

Fig. 9. 'Curvilinear' pottery

Fig. 11. Human effigy

Fig. 10. Pile settlement at Serteya II.

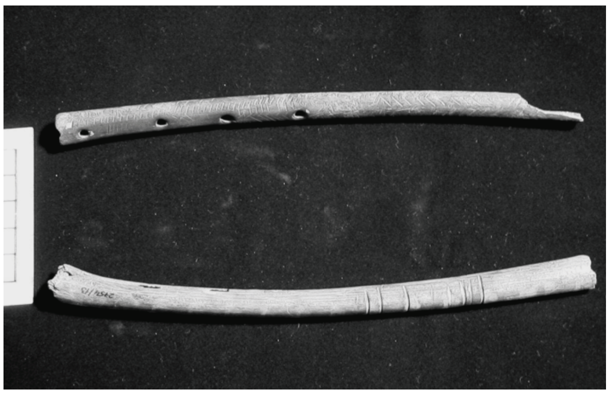

Fig. 12. Flute

Pile dwellings with the Usvyatian material were identified at several sites in the central and southern parts of Serteya valley: Serteya II, VIII, X and XI. These are large sites with the total areas varying between 300 and 1,000 sq.m. Three radiocarbon dates of wood samples from the Usvyatian layer at Serteya VIII show the average age of 3375±169 cal BC.

The Usvyatian deposits were identified in at Naumovo, in a lake settlement, located in the northern part of the Zhizhitsa Lake, in the mouth of the small river, Barabanovka. The initial pile settlement emerged at a low stand of the lake level and further developed in the course of its rise. This stage yielded the radiocarbon dates in the range of 3760-2004 cal BC.

Deposits of the Usvyatian sites contain 40 species of mammals: elk, brown bear and boar being the most common, and also fur animals: marten, otter and squirrel. Judging by the age groups, the elk was hunted throughout the year. Pike and perch were the most common among the fish. At least 30 edible wild plants were identified in the deposits of pile-dwellings; hazel-nut and water chestnut (*Trapa natans*) were allegedly the main source of plant protein.

3 Late Neolithic- Early Bronze Age

Two distinct cultures belong to this unit, both featuring the continued use of pile dwellings. The pottery of the earlier, Zhizhitsian, is basically similar to that of the Usvyatian with the addition of several novel ornamental patterns. Considerable changes are noted in the composition of the stone inventory. A total disappearance of bone and antler industry is remarkable.

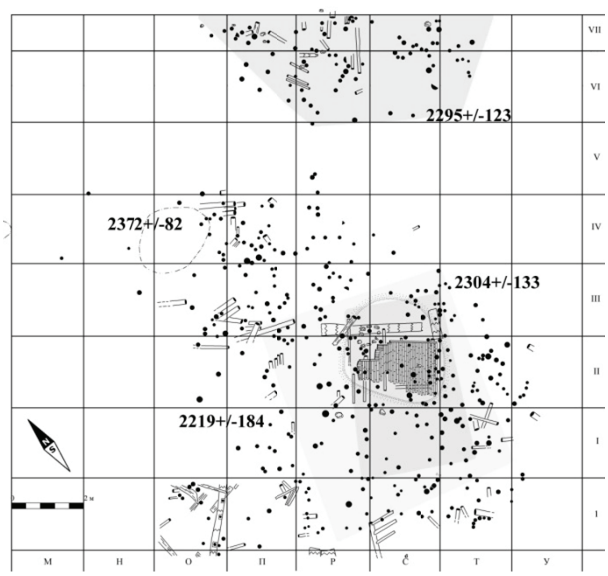

Fig. 13. Pile structures. Serteya II

Zhizhitsian levels have been identified at several sites in Serteya valley. Excavations in the drainage canal at Serteya II with the use of underwater technique have revealed six dwelling structures, consisting of platforms, resting on the piles (Fig. 13). Wooden structures were made of spurce, pine, ash, marple and, rarely, oak. The overall area of pile dwellings is c 600 sq. m.

The total of 35 radiocarbon dates has been obtained for wooden structures. They belonged to the houses each of which had apparently been constructed during a single season. Hence, the dates from each structure characterise a momentary event in the sense of radiocarbon dating. Several samples were taken from different sets of year-rings of a single pile. The empirical error has been calculated for four sets from Structures 1, 2, 3 and 6. In the case of Structure 1 all dates form a Gaussian-like distribution with one date obviously falling out. The mean age of the remaining dates is 2304 calBC with a standard deviation of 113 years. The corresponding values for the other structures are: 2372 ± 83 calBC for Structure 2; 2295 ± 129 calBC for Structure 3 (with one outlier), and 2219 ± 184 calBC for Structure 6 (with one outlier). The average age of all four structures is 2298 ± 127 BC. The standard deviation of 127 years is considered as a conservative estimate for the duration of a single pile dwelling.

At the site of Naumovo on the Zhizhitsa Lake, the appearance of dwellings belonging to the Zhizhitsian Culture coincided with the maximum rise of the lake level radiocarbon dated to c. 2200 BC cal. In certain areas the lake rose catastrophically damaging the pile structures. At a later stage, the lake level fell again.

5. Discussion

The initial settlement (‘Mesolithic-Serteyan’) occurred in the time-span of 7300-6000 calBC. As indicate the pollen and diatom analyses, at that time the entire valley was taken up by a mesotrophic – moderately eutrophic lake which included a body of free water and the macrophyte coverage (see Chapter 13). The level of the lake remained unstable, and experienced minor fluctuations. A considerable stability of the forest canopy is apparent. *Betula* remained dominant, and *Pinus* prevailed on sandy terrain. Broadleaved forests, restricted to the clayey soil in elevated areas, consisted predominantly of *Ulmus*, with the participation of *Quercus* and *Tilia* and *Corylus* in the undergrowth; *Alnus* was common along the water channels. Herb associations with Poaceae and Cyperaceae were restricted to forest meadows and the bottomland.

The sites of that age were located on elevated lake shores in its northern area. In several cases, the postholes, suggestive of light surface dwellings were identified. No human impact on the landscape at this stage is apparent. The pottery found at Serteyan sites has no recognisable similarities in the European Russia.

The next stage in the settlement covers the interval of 6000-5700 calBC. While the vegetation remained basically unchanged, a significant rise in the lake level is acknowledgeable. In its course the alkaline eutrophic lake reached the maximum depth. Apparently, this reflected a wider climatic signal. The maximum rise of lake level for that time has been recorded at the lakes of the Pre-Alpine zone (Magny et al. 2004) that time the high level The rise in lake was recorded also in southern Finland (Sarmaja-Korjonen 2001).

During this stage, the sites belonging to Rudnyaian culture appeared on the lake’s shore. Their type of settlement and the subsistence remained unchanged. A fishweir found at

Rudnya-Serteya site suggests an advanced technique of fishing. Material culture shows continuity in relation to the previous stage. At the same time, cultural liaisons with the eastern Baltic area became apparent. Suggestively, at this stage the Western Dvina started operating as a channel through which human and cultural contacts were conducted.

The stage between 4500-2200 calBC features the settlements of Usvyatian culture. Their appearance marks the interruption in cultural continuity and coincides with the major change in the environment. The diatom analysis signals a fall of the level of the alkaline eutrophic lake reflecting a wider climatic trend. The low water level has been recorded at 6000-5500 in the Pre-Alpine zone (Magny et al. 2004) and at c 4500 in southern Finland (Sarmaja-Korjonen 2001).

The pollen analysis (see Chapter 13) shows considerable fluctuations of the main taxa, apparently reflecting the anthropogenic signal. This stage begins with the rapid decrease of *Betula* and broad-leaved species, *Ulmus, Quercus, Tilia,* and also *Corylus*, together with the culmination of *Picea* and *Pinus,* and an increased rate of herbs, Poaceae and Cyperaceae. Subsequently, one notes an increase in the participation of broad-leaved species, *Ulmus, Quercus, Tilia,* and also *Corylus,* with the rise of *Betula* and *Alnus,* the general increase of herbs (Poaceae and Cyperaceae) with the appearance of heliophytic herbs, *Artemisia* and Chenopodiaceae. This pattern which repeats at least twice suggests a selective felling and the subsequent regeneration of forests. Similar pattern was observed in the pollen diagrams of North-Eastern Hungary and was viewed as a proxy evidence of the Neolithic 'woodland management' (Gardner 2002). Poska and Saarse (2002) report the first signature of agricultural impact on vegetation on Saaremaa Island, Estonia, as occurring at about the same time, 4500-4000 calBC.

The most spectacular feature of this stage was the emergence of settlements on the wet bottomland of the central and southern parts of the valley, which coincided with the fall in the water level. Dwelling structures included the platforms resting on posts thrust into the lake mud. In their construction *Picea, Pinus, Fraxinus, Acer* and, rarely, *Quercus* were used. These pile dwellings were of a considerable size reaching in one case an area of c 1000 sq. m. Remarkably similar structures appeared at that time in wetland landscapes of various parts of Europe; they became most common in the Alpine zone but existed also in other areas, including Scandinavia (Schichterle 1997; Göransson 1997).

The faunal and botanical records indicate that the livelihood of Usvyatian lake dwellers firmly relied on wild-life resources, with the round-the-year procurement of meat and fur animals and fishing. At least 30 edible wild plants were used for food. Processed hazel-nut and water chestnut (*Trapa natans*) became the surrogate of bread and the main source of plant protein. At the same time, isolated finds of *Cerealia* pollen suggest a familiarity with a primitive agriculture.

The pile dwellings reached their maximum size during the next stage which included the Zhizhitsian and North-Byelorussian cultures (2200-1880 calBC). This period coincided with the new rise in the lake-level. Detailed excavations and the statistical analysis have shown that each individual dwelling existed less than 170 years and each settlement included no more than two pile structures. The animal remains of North-Byelorussian sites include a limited amount of domesticates: cattle, sheep/goat and pig. Corresponding levels show the maximum frequency of *Cerealia*, and appearance of weeds (notably, *Plantago lanceolata*) and apophytes. All this may be viewed as a clear signal of an increased anthropogenic impact on the landscape in the conditions of initial agriculture.

Thus far the earliest evidence of agriculture in the basin of the Western Dvina came from the Iron Age hill-fort of Podgai (Petrov 1960). The finds included grains of bread wheat *(Triticum aestivum)* and naked six-row barley *(Hordeum vulgare* var. *nudum).* One may suggest that the same plants were cultivated in the Serteya valley at the beginning of the 2nd millennium BC.

Early agriculture was apparently of slash-and-burn (swidden) type. Ethnographical evidence cited by Russian (Petrov 1968) and Finnish writers (Sarmela 1987) show that in northern Russia, Finland and Karelia 'burn clearances' were cultivated on sloping and hilly terrain. In the case of Serteya the corresponding terrain could be found along the steep slopes of the valley, at a distance of less than 2 km from the site. The same writer states (p. 242), that swidden farming was well suited for the natural renewal of the natural forests. After the plots were abandoned, the area became populated by young birch, later by mixed forests dominated by deciduous forests, with the natural forests being restored in 100-170 years. Our pollen record is fully consistent with ethnographical evidence.

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Animal Remains from Neolithic Sites in Northwestern Russia

M.V. Sablin and E.V. Syromyatnikova

Institute of Zoology, Russian Academy of Sciences, St. Petersburg

The analysed faunal materials originated from several sites: Serteya II (1974, 1980-81, 1984-1985, 1993 excavation seasons,), Serteya VIII (1986), Serteya XI (1986), Rudya Serteya (1985-1987), Dubokrai V (1984-1986), Naumovo, layers B and A (1971-1972), and Usvyaty IV, layers B, A, and α, (1964-1967, 1974-1975 and 1989). According to the accepted criteria (Antipina 1999; Grayson, 1984) each studied assemblage includes no less than 400 bones, on which basis the subsistence dynamics for the time-span ranging from 6000 to 1000 BC has been assessed.

As show the animal remains, the subsistence of early Neolithic settlements in North-Western Russia was based on hunting supplemented by fishing (Table 1). Large ungulates, elk, boar, red deer and aurochs, constituted the preferred hunting prey (65.3% of the total amount), followed by fur animals, marten, beaver, wolf, marten, otter and polecat, with 29.9%. Judging from the age groups, both the adult and semi-adult beavers were procured in warm seasons, supposedly with the use of projectile weapons. Fur predators were hunted more likely in winter with the use of noose traps and crossbows. Marten fur was obviously preferred; its bones make up 21.1 % of the total number of recorded animal remains. The elk, with 43.5% , was the principle game amongst large ungulates in the early Neolithic, the boar came next with 17.2%. These animals were most efficiently procured in winter and autumn, during their seasonal migrations, but the hunting was undoubtedly carried out throughout the year. This conclusion is substantiated by the rate of elk's age groups: juvenile – 9.5%, sub-adult – 12.5%, adult – 78.5%. The same groups for boar feature: juvenile and sub-adult – 50%, adult – 50%. These figures are fully in accorfd with the age groups in present-day populations of these animals in North-western Russia (Vereshchagin & Rusakov 1979). The most common technologies of ungulate hunting were the traps (holes), and noose-snares set along the trails. Rarely procured bears were hunted mostly in winter, in their dens with the use of dogs and projectile weapons.

During the Middle and Late Neolithic the climate became cooler and drier, and the coniferous forests gradually replaced the mixed broad-leaved ones. Significant changes are notable in the composition of the hunting prey. The red deer disappeared being replaced by the fallow deer. Nonetheless, the rate of large ungulates versus fur animals procured by the pile dwellers remained practically unchanged as compared to the Early Neolithic, 60.0% and 26.9% respectively (Table 1). The elk remained the principle hunting prey (46.9%), followed by the bear (12/0%) and boar. The entire bodies of slaughtered animals were apparently transported to the dwelling site, where they were butchered, as the kitchen middens consist entirely of inedible parts of all hunted animals: hoofs, tail vertebra, teeth etc. Hence the butchering techniques were fairly similar for all large animals. Bear bones

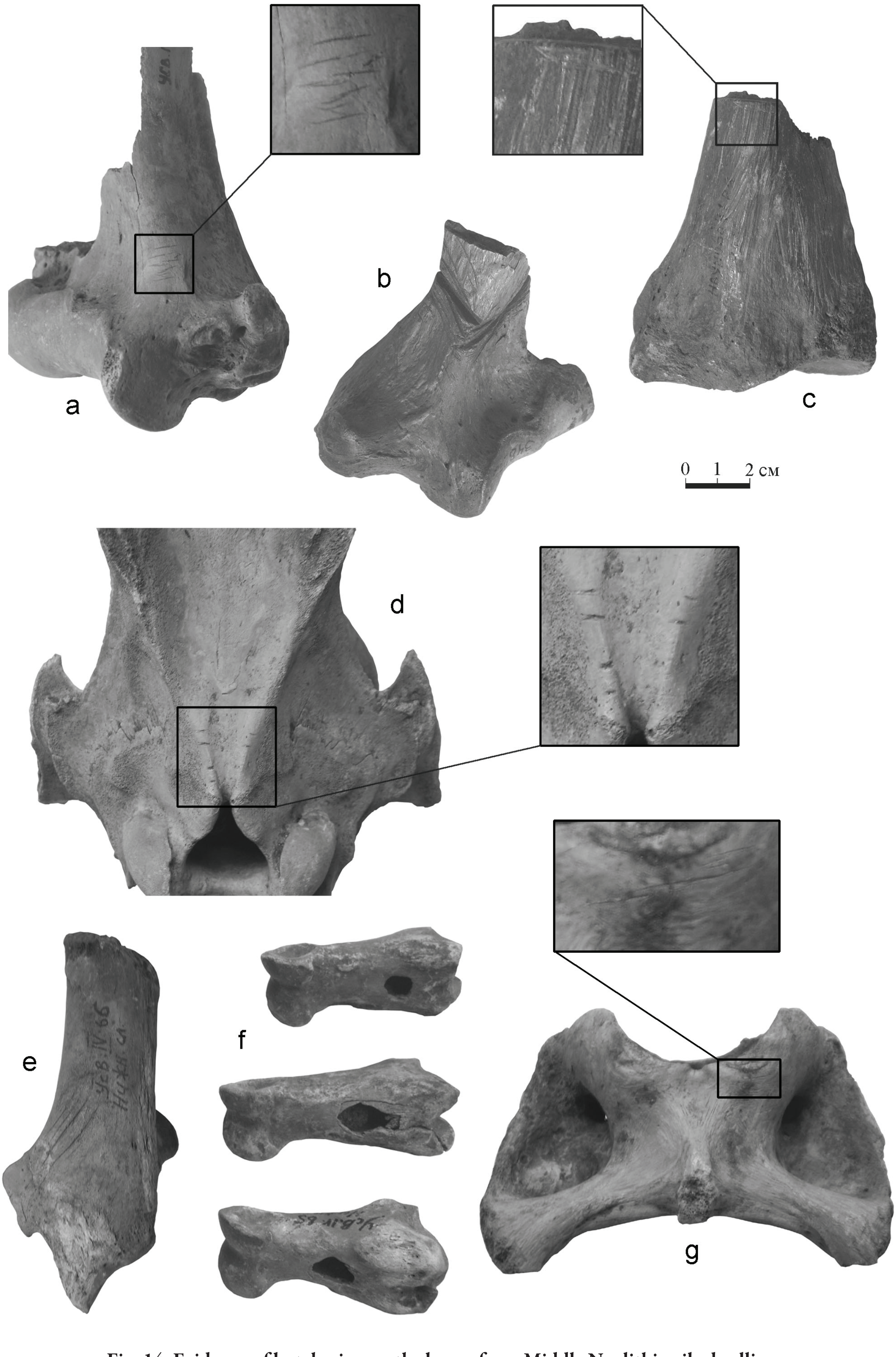

Fig. 14. Evidence of butchering on the bones from Middle Neolithic pile dwellings.
a, b - brown bear humerus, Usvyaty IV, layer B; c – brown bear tibia, Naumovo, layer B;
d – boar skull, Usvyaty IV, layer B; e – boar calcaneum, Usvyaty IV, layer B; f – boar toe phalanges; Usvyaty IV, layer B; g – boar atlas, Usvyaty IV, layer B.

Fig. 15. Remains of domesticated animals from Middle Neolithic pile dwellings.
a – horse upper molar M3, Serteya II; b – cattle lower molar M2, Usvyaty IV, layer B.

have numerous butchering marks (Fig. 14). Remarkably, the most nutritional parts of the bodies, humeral bones and halluces, were found in equal proportions. The Neolithic dwellers had no scruples to extract marrow from the ungulates' large phalanges. In other words, the bone assemblages are the remains of communal feasts, rather that those of simple butchering. The lack of antler apparently implies their use for antler carving. Incisions and deep cuts visible on bear bones equally show their utilisation for tool-making. Otter remains the preferred fur animal, although its rate in the bone assemblages diminished by a quarter, as compared to the Early Neolithic. By contrast, the fishing grew in importance. The bones of pike, perch, cat-fish, white fish and small-size fished were identified.

The forest fowl, including wood-grouse, black-grouse and willow-grouse, was hunted predominantly in autumn and winter with the use of noose-snares, while water-fowl, geese, ducks and swans, were hunter in warm seasons using projectiles.

The appearance of domesticates, the horse and cattle, was the most important feature, acknowledged in the sites of the mid-third millennium BC (Fig. 2; Fig. 15). Yet their rate did not exceed the decimals of one percent of the total faunal assemblage (Table 2). Apparently, the swampy lake shores were predominantly used as grazing areas. The small-size horse and cattle and practically identical to the medieval specimens. The horse's upper molar M2 is 22.3 mm long and 24.2 wide, the protocone (a central cusp of the upper molar), 11.0 mm long; M3 is 26.6 mm long and 21.2 wide. The cattle's lower molar M2 is 25.5 mm long and 12.2 mm wide. Neither pig nor sheep/goat could be identified among Middle Neolithic animal remains. This observation is rather surprising, as both at Naumovo (layer B), and Usvyaty IV (layer B) the swine coproliths filled in with bones and scales were found. Suggestively, the wild pigs caught in traps were not immediately slaughtered, but kept for some time at the site, and fed with small-size fish. At the same time, there is no evidence of pig rearing, as bones of piglets less than three months old were found. Pig rearing would have immediately resulted in the reduction of animal's size, yet all the boars identified at pile dwellings were exclusively large-size individuals. There is little doubt that the subsistence of pile dwellings was solidly based on foraging strategies, animal rearing being but a supplementary source of livelihood.

In the Late Neolithic (Table 3) the bear with 32.8% became the principle hunting prey, boar being second in importance with 23.7%. The rate of fur animals (9.7%) diminished threefold, as compared to the previous stage; the marten ceased to be the most popular fur animal. One remarks the growing importance of animal rearing, the rate of domesticates reaching 1-0.6%. At the stage all main domestic animals are ac knowledgeable, including the sheep/goat and pig, the latter supposedly being domesticated from the local boar (Larson et al., 2005). The rate of beaver (about 5%) remains unchanged throughout the Neolithic epoch.

The analysis of the faunal assemblages leaves one in no doubt that the Neolithic pile dwellings were habituated on the round-the-year basis. The occurrence of animal remains procured in the winter proves that these were sedentary and not seasonal settlements.

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Table 1. Animal remains from early Neolithic lake dwellings

	Serteya X			**Rudnya-Serteya**			**Serteya VIII**			**Serteya X**			**Total average**		
Species	**Ind**	**B**	%	**Ind**	**B**	%	**Ind.**	**B**	%	**Ind.**	**B**	%	**Ind.**	**B**	%
Beaver	4	28	6.1	2	3	8.8	1	1	2.1	7	32	5.9	4	28	6.1
Hare	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wolf	3	16	3.5	-	-	-	-	-	-	3	16	3.0	3	16	3.5
Fox	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polecat	-	-	-	-	-	-	1	1	2.1	1	1	0.2	-	-	-
Marten	16	106	23.0	1	3	8.8	-	-	-	17	109	20.1	16	106	23.0
Badger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Otter	1	3	0.7	1	1	2.9	-	-	-	2	4	0.7	1	3	0.7
Lynx	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brown bear	3	16	3.4	-	-	-	1	7	14.9	4	23	4.2	3	16	3.4
Boar	5	76	16.5	2	13	38.2	1	4	8.5	8	93	17.2	5	76	16.5
Fallow deer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red deer	2	21	4.6	-	-	-	1	4	8.5	3	25	4.6	2	21	4.6
Elk	6	192	41.6	2	14	41.2	4	30	63.9	12	236	43.5	6	192	41.6
Aurochs	1	1	0.2	-	-	-	-	-	-	1	1	0.2	1	1	0.2
Wild Total	41	459	99.6	8	34	100	9	47	100	58	540	99.6	41	459	99.6
Dog	1	2	0.4	-	-	-	-	-	-	1	2	0.4	1	2	0.4
Horse	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pig	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cattle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sheep/goat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Domesticates Total	1	2	0.4	-	-	-	-	-	-	-	2	0.4	1	2	0.4
Mammals Total	42	461	100	8	34	100	9	47	100	58	542	100	42	461	100
Fish		8			12			-			20			8	
Birds		16			13			-			29			16	
TOTAL		485			59			47			591			485	

Note. Ind – individuals; B – bones.

Table 2. Animal remains from middle Neolithic lake dwellings

	Dubokrai V			Naumovo 'B'			Usvyaty 'B'			Serteya XI			Serteya II			Total average		
Species	**Ind**	**B**	**%**	**Lev**	**B**	**%**	**Ind.**	**B**	**%**	**Ind.**	**B**	**%**	**Ind.**	**B**	**%**	**Ind.**		**%**
Beaver	3	18	8.2	1	6	2.6	3	22	1.5	1	3	15.8	3	55	26.8	11	104	5.0
Hare	-	-	-	-	-	-	3	66	4.6	-	-	-	1	1	0.5	4	67	3.2
Wolf	-	-	-	-	-	-	1	7	0.5	-	-	-	-	-	-	1	7	0.3
Fox	-	-	-	-	-	-	2	17	1.2	-	-	-	-	-	-	2	17	0.8
Polecat	-	-	-	-	-	-	1	7	0.5	-	-	-	-	-	-	1	7	0.3
Marten	1	3	1.4	6	66	28.7	22	253	17.8	-	-	-	1	3	1.5	30	325	15.5
Badger	-	-	-	-	-	-	5	22	1.5	-	-	-	1	1	0.5	6	23	1.1
Otter	-	-	-	-	-	-	4	12	0.8	-	-	-	1	1	0.5	5	13	0.6
Lynx	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0.5	1	1	0.05
Brown bear	2	19	8.6	1	24	10.4	5	199	14.1	1	2	10.5	3	7	3.4	12	251	12
Boar	3	26	11.8	1	6	2.6	5	185	13.0	1	5	26.4	1	9	4.4	11	231	11
Fallow deer	1	17	7.7	-	-	-	1	3	0.2	-	-	-	-	-	-	2	20	1
Red deer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elk	4	137	62.3	3	128	55.7	12	584	41.0	1	7	36.8	3	127	61.9	23	983	46.9
Aurochs	-	-	-	-	-	-	2	23	1.6	-	-	-	-	-	-	2	23	1.1
Wild Total	**14**	**220**	**100**	**12**	**230**		**66**	**1400**	**98.3**	**4**	**17**	**89.5**	**15**	**205**	**100**	**111**	**2072**	**98.8**
Dog	-	-	-			-	1	16	1.1	-	-	-	-	-	-	1	16	0.7
Horse	-	-	-			-	-	-	-	1	2	10.5	-	-	-	1	2	0.1
Pig	-	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-
Cattle	-	-	-			-	1	8	0.6	-	-	-	-	-	-	1	8	0.4
Sheep/goat	-	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-
Domesticates Total	-	-	-			-	**2**	**24**	**1.7**	**1**	**2**	**10.5**	-	-	-	**3**	**26**	**1.2**
Mammals Total	14	220	100	12	230	100	68	1424	100	5	19	100	15	205	100	114	2098	100
Fish		6			62			394			-			11			473	
Birds		6			57			300			-			32			395	
TOTAL		**232**			**349**			**2118**			**19**			**248**			**2966**	

Note. Ind – individuals; B – bones; Lev – levels.

Table 3. Animal remains from Late Neolithic lake dwellings

	Usvyaaty IV 'A'			Naumovo 'A'			Usvyaaty IV 'alpha'			Total average		
Species	**Ind**	**B**	**%**	**Ind**	**B**	**%**	**Ind.**	**B**	**%**	**Ind.**	**B**	**%**
Beaver	1	6	2.2	2	15	11.2	1	3	2.6	4	24	4.6
Hare	-	-	-	1	1	0.7	-	-	-	1	1	0.2
Wolf	1	1	0.4	1	3	2.2	-	-	-	2	4	0.8
Fox	1	1	0.4	1	2	1.5	-	-	-	2	3	0.6
Polecat	-	-		1	1	0.7	-	-	-	1	1	0.2
Marten	1	2	0.7	1	6	4.5	-	-	-	2	8	1.5
Badger	1	1	0.4	-	-	-	1	4	3.5	2	5	1.0
Otter	-	-	-	1	3	2.2	1	1	0.9	2	4	0.8
Lynx	-	-	-	-	-	-	-	-	-	-	-	-
Brown bear	3	113	41.9	2	45	33.6	1	12	10.5	6	170	32.8
Boar	2	51	18.9	2	25	18.7	3	47	41.2	7	123	23.7
Fallow deer	-	-	-	-	-	-	1	1	0.9	1	1	0.2
Red deer	-	-	-	-	-	-	-	-	-	-	-	-
Elk	3	52	19.2	1	21	15.8	2	34	29.9	6	107	20.7
Aurochs	1	11	4.1	1	1	0.7	-	-	-	2	12	2.3

Wild Total	14	238	88.2	14	123	91.8	10	102	89.5	38	463	89.4
Dog	-	-	-	1	8	6.0	1	1	0.9	2	9	1.7
Horse	1	1	0.4	-	-	-	1	4	3.5	2	5	1.0
Pig	1	2	0.7	-	-	-	-	-	-	1	2	0.4
Cattle	1	19	7.0	-	-	-	1	6	5.2	2	25	4.8
Sheep/goat	1	10	3.7	1	3	2.2	1	1	0.9	3	14	2.7
Domesticates Total	4	32	11.8	2	11	8.2	4	12	10.5	10	55	10.6
Mammals Total	18	270	100	16	134	100	14	114	100	48	518	100
Fish		24			125			8			157	
Birds		14			10			2			26	
TOTAL		308			269			124			701	

Note. Ind – individuals; B – bones.

The beginning of farming in the Eastern Baltic

Aivar Kriiska

Introduction

Choosing the Eastern Peribaltic as an object of the regional analysis, it is necessary first to clearly define this area, since there is no unanimity in the use of this term and its scope remains ill-defined. Most commonly this term refers to the Baltic countries, Estonia, Latvia and Lithuania, often including the region of Kaliningrad (Königsberg) now belonging to Russia (e.g. Лозе 1991; Antanaitis 1999; Girininkas 2002). Sometimes the term also comprises the Karelian Isthmus and historical Ingria in north-western Russia or even the southern part of Finland (e.g. Kriiska *et al.* 2006) but in other cases confined to Latvia and Lithuania only (e.g. Witczak 2006). In the current study we discuss the area in its classical sense, i.e. embracing Estonia, Latvia, Lithuania and Kaliningrad region, an area of more than 185,000 sq. km covering the eastern coast of the Baltic Sea, and extending up to 400 km inland**.**

During the Last Glacial Maximum, approximately 20,000–18,000 years BP the Scandinavian ice-sheet covered practically the entire Eastern Baltica Sea only a small part on the sourthern border of Lithuania being ice-free (e.g. Raukas *et al.* 1995, Fig. 3). In the discussed area the recession of continental ice-sheets that followed the cold peak was completed slightly before 10,000 years cal BC (e.g. Rosentau 2007, Fig. 1 and the references therein) when the area's southern part already became in all respects suitable for human settlement (Fig. 1). The beginning of Late Palaeolithic settlement phase in the Eastern Baltic area is usually dated to approximately 11,000 years cal BC – i.e. the second half of Alleröd (Rimantienė 1998, 145). Three archaeological cultures, Bromme, Ahrensburg[1] and Świdry (e.g. Šatavičius 2004; 2005; Zagoska 1996; 1999; 2001) are distinguished within this stage. Assemblages of flint artifacts i dentified in southern Lithuania are attributed to the Hamburgian and Federmesser Cultures (Šatavičius 2002; 2005), thus being probably older than 12,000 yeas cal BC. The majority of Final Palaeolithic sites of in southern Lithuania were found on the banks of the Nemunas and Neris Rivers and their tributaries. Similar sites also known further to the north in the valleys of the Lielupe and Daugava Rivers in Latvia (Fig. 1).

The continuity of the material culture provides some clues regarding the settlement and economy of the Final Palaeolithic. As estimated on the basis of the site location,

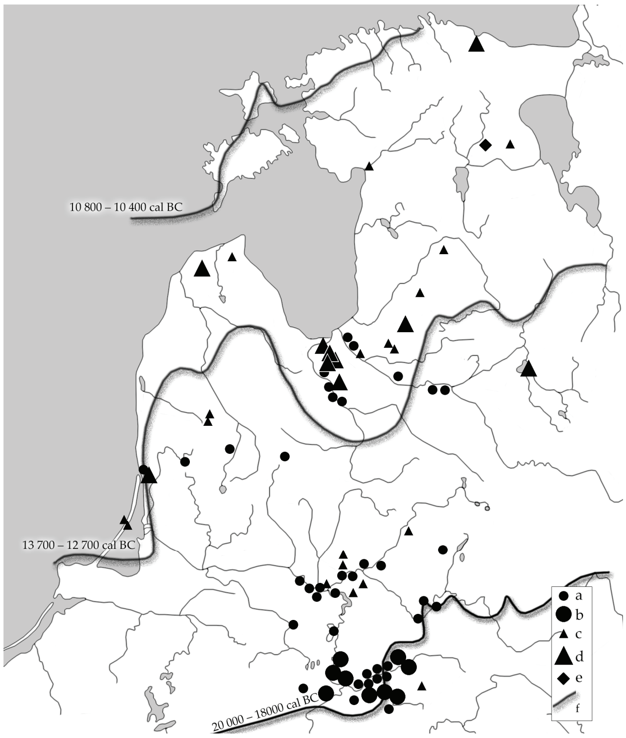

Fig. 1. A simplified scheme of Brandenburgian (Grunda), Luga (North-Lithuanian, Linkuva and Haanja) and Palivere ice-sheet marginal zones (after Rosentau *et al.* 2007 Fig. 1 and the references therein), Final Paleolithic sites (after LTAA 1974; Rinantienė 1996 Fig. 5; Zagorska 1999; Šatavičius 2002; 2004) and the find places of bones/antlers of Late Glacial reindeer (Ukkonen *et al.* 2006, Fig. 1) and mammoths (Lõugas *et al.* 2002, 1353) in the Eastern Baltic.
Key: single site, b – two or more sites, c – single Late Glacial reindeer bone/antle findsr, d – two or more Late Glacial reindeer bones/antlers finds e – two Late Glacial mammoth teeth, finds f – ice-sheet marginal zone.

their natural setting and limited number of animal bones and antlers gathered at the sites as well as stray finds, the subsistence was basically oriented on hunting reindeer (Ukkonen *et al.* 2006). This implies the exploitation of relatively large catchment areas, i..e.hunting, fishing (?) and gathering territories – and the occurrence of seasonal settlements within them. However, there is evidence suggesting the occurrence mammoths in the Eastern Baltic area at the final stage of the Palaeolithic (Lõugas *et al.* 2002, 1353).

[1] Rimutė Rimantienė discusses the Bromme and Ahrensburg cultures under the common name *Group of Baltic Magdalenian Cultures* (e.g. Римантене 1971, 19).

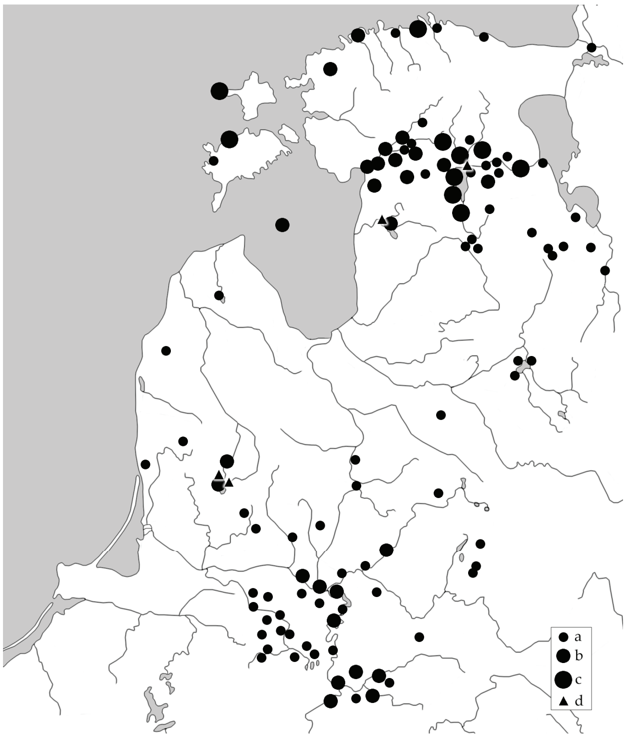

Fig. 2. Settlements and burial sites of (pre-pottery) Mesolithic in the Eastern Baltic (after Apals *et al.* 1974, Fig. 2; Joudagalvis 2005, Fig. 15; Kriiska *et al.* 2007, 8). *Key*: single settlement site, b – two or more settlement sites, c – burial site.

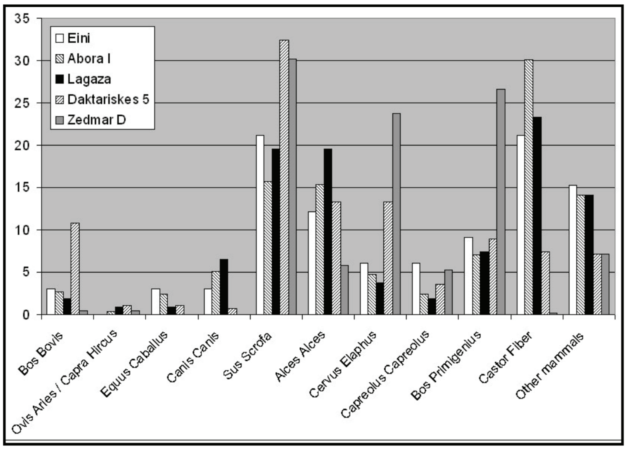

Fig. 3. Occurrences of animal species in the palaeofauna of the eastern Baltic region. Steady line – occurrence as proved by subfossil finds and/or written evidence; dashed line – probable occurrence (Lõugas & Maldre 2000, Table 2).

During the Postglacial period several archaeological cultures are distinguishable in the Eastern Baltic: Kunda, Kudlaevka, Janisławice, Narva (Proto-Narva) (e.g. Jaanits *et al.* 1982, 33; Лозе 1988, Tab 17; Ostrauskas 2002a; 2002b; Larsson & Zagorska 2006; Kriiska & Tvauri 2007, 20). In conrast to the earlier settlements, the Mesolithic sites sites were focused on the boreal forest zone. The settlements were predominantly concentrated on the lake shores and river terraces (Fig. 2), although the areas further afield were also settled (Jussila & Kriiska 2006). Food was procured by means of hunting, fishing and gathering. Game apparently depended on the natural environments (Fig. 3): elk and beaver were the major game animals at the beginning of the Mesolithic, later wild boar and auroch played a notable part as well (e.g. Lõugas & Maldre 2000; Kriiska & Tvauri 2007, 36). Among the fish the bones of pike, pike-perch and perch were most commonly found (Lõugas 1996, Table 1; 1997, 25) but the choice was probably considerably larger. Bones of duck, swan, goose, pochard, capercaillie, black grouse and other water fowl were commonly reported from the Mesolithic contexts (e.g. Glück 1906; Lõugas 1996, Table 1).

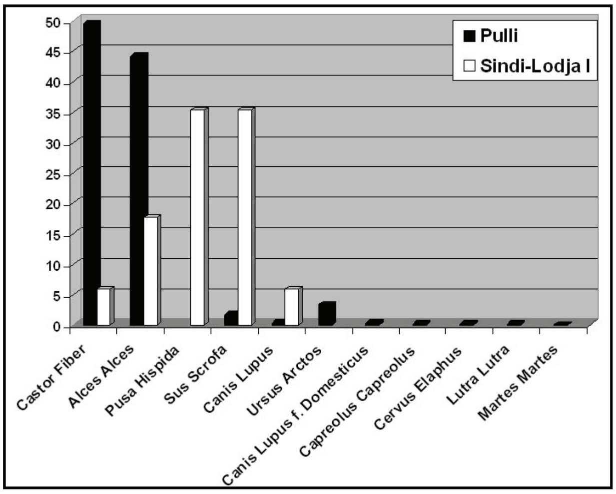

Fig. 4. Mesolithic changes in the procurement of game: Early Mesolithic Pulli site (south-western Estonia) as compared to Late Mesolithic Sindi-Lodja I settlement site (after Veski *et al.* 2005, Table 2 and 3).

From the viewpoint of the impendng Neolithic, the most important processes took place in the Late Mesolithic when an extensive foraging settlement network emerged in the entire Eastern Baltic area. Its main features such as the– settlement pattern, foraging strategy, the use of resources and others remained intact (although in a slightly amplified manner) for thousands of years to come surviving in some cases until the Late Neolithic. Approximately 7000 years BC a dual settlement pattern started to develop, with an inland and coasal areas becoming distinct. In the inland areas the river valleys and lake depressions became predominantly settled, while the river estuaries were mostly chosen for settlements in the coastal area. Often the contact zones of various habitat types were exploited as the biota in those areas being particularly rich and diversified. . The Baltic Sea which salinity at the Litorina Sea phase was higher than today apparently increasing the biomass of sea life, and particularly the population of seals (Nuñez 1996, 24). The new opportunities offered by nature was taken to their full advantage by human groups settled in the coastal area

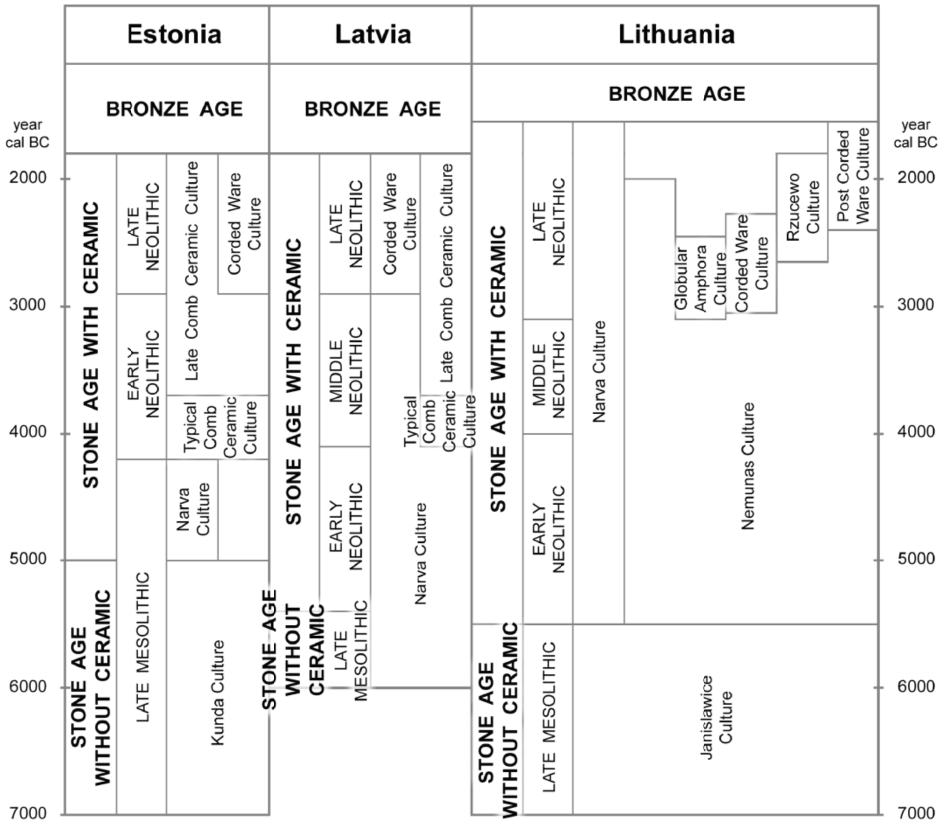

Fig. 5. Formal chronology and periodization of the Eastern Baltic Late Mesolithic and Neolithic period (Estonia – Aivar Kriiska, Latvia – Zagorska 2003/in English Larsson & Zagorska 2006; Lithuania – Džiugas Brazaitis , oral communication from4.04.2008).

(Kriiska 2001b) (Fig. 5). Approximately at the same time the coastal settlements appeared in Southern Scandinavia (Andersen 1993, 66-67; Christensen 1993, 21; Larsson 1997, 14). Probably during the seal hunting expeditions the Eastern Baltic islands were discovered and colonized (Kriiska 2003, 27). An extensive settlement of both the coast and islands occurred at that time over the entire the Baltic Sea basin, with the settlement of the island of Gotland (Larsson 1997, 14) and at least seasonal inhabitance of several islands off Finnish coasts (e.g. Purhonen & Ruonavaara 1994, 91; Nuñez & Gustavsson 1995, 233; Asplund, 1997, 218).

By this time the settlement system based on 'mother' villages had probably emerged in the Eastern Peribaltic. This system generally consisted of relatively small catchment areas, each used by a single community. The dimensions of catchment areas started to diminish in the Baltic area probably around 7000 cal BC. The reason for that might reside in the population growth On a more general Balto-Scandinavian scale the shrinking of the exploitation areas was suggestedly due to the increased emergence of dry land (initially triggered by the ice-sheet recession and the high-rate isostatic crust rebound). This, jointly with the population growth and environmental changes occurring during the Atlantic period, led to the modifications in the settlement pattern (Halinen 1999, 38). Decreased possibilities to sustain livelihood inevitably necessitated an intensification and divercification of foraging strategies. This in its turn enhanced the role of the central residence in the settlement pattern and hence sedentary settlements started to form. From this period on, the intensification of human impact becomes conspicuous in pollen diagrams obtained for the Eastern Baltic bog and lake sediments (Veski 1998, 93; Poska 2001). Forests around the sedentary villages, rarified by tree felling were colonized by ruderal The Late Mesolithic was the period of novelties in the entire Northern Europe. The modifications of settlement and economy as well as demographic processes took place are noted in various areas affecting the entire human society. A sedentarization can be generally observed in Europe. This was probably a reason why large (and in rare cases long-term) burial sites started to emerge in Eastern and Northern Europe, such as Oleni Ostrov in Russian Karelia, Zvejnieki in Latvia, Skateholm in Sweden –. The same reason most likely stood behind the development of the rock art at Vingen fiord in Western Norway (Lødøen 2002, 198).

In the 4th millennium cal BC the craft of pottery-making reached the Eastern Baltic. The earliest reliable radiocarbon dates have been obtained for the sites Eastern Latvia showing the age of approximately 5500 cal BC (Loze 1988, 101). This has been generally interpreted in terms of a cultural borrowing (e.g. Jaanits 1970, 86; Zagorskis 1973, 65; Girininkas 1994, 259) as universally other manifestations of the material culture show a clear continuity in relation to local traditions. During the first thousand years which followed the introduction of pottery-making two principle types of pottery with several local varieties are distinguishale in the Eastern Baltic. The two major pottery types were those of Narva and Nemunas which also form the basis for the identification of the Narva and Nemunas archaeological cultures (Fig. 6).[2] According to the currently used formal scheme, the Neolithic period in Latvia and Lithuania starts

[2] The Early Neolithic stage in Southern Lithuania has lately been distinguished under Dubičiai Culture (Girininkas 2005, 138).

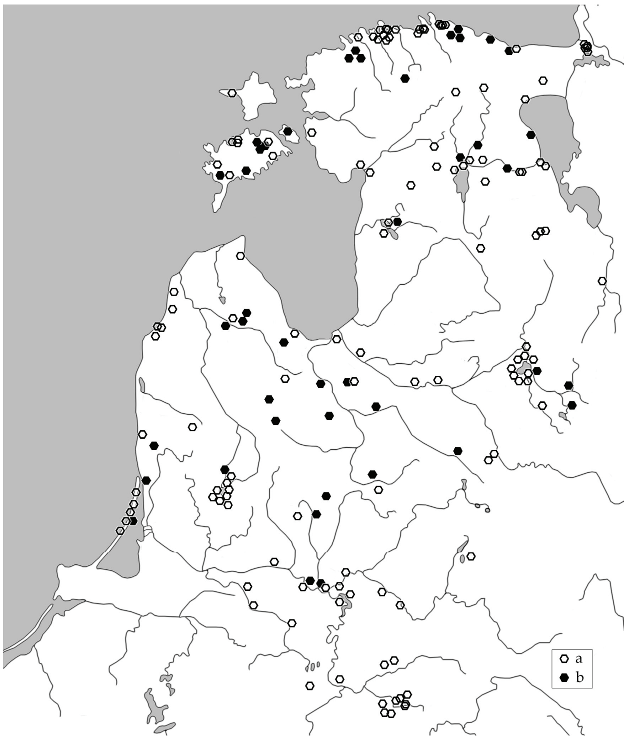

Fig. 6. The sites of Narva and Nemunas Culture (the Dubičiai stage) dated the end of the 6th and the 5th millenniia cal BC (after Loze & Liiva 1989, Fig. 1; Piličiauskas 2002, Fig. 22; Girininkas 2005, Fig. 37; Kriiska *et al.* 2007, Fig. 10).
Key: a – one settlement site, b – two or more settlement sites, c – burial site.

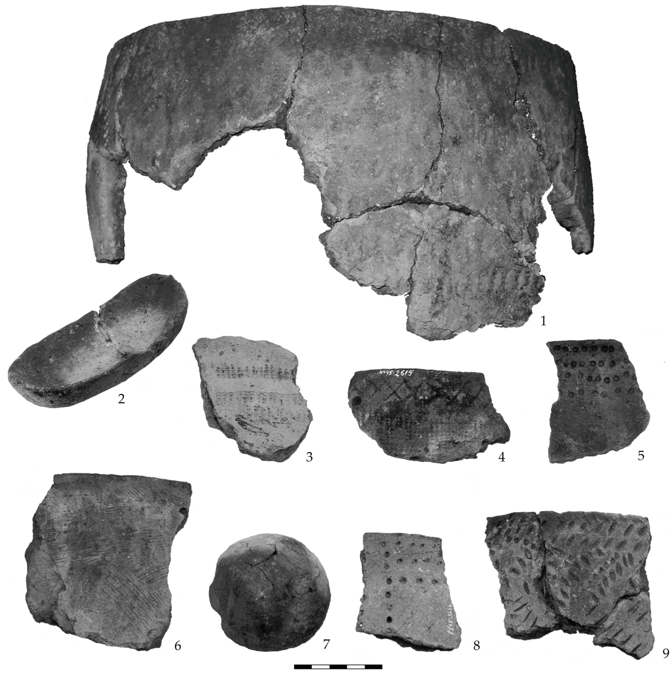

Fig. 7. Narva type pottery from the Kääpa settlement site in south-eastern Estonia (collection of the Institute of History of the Tallinn University, AI 4245: ?, 1419, 1573, 2615, 2038, 3642, 1275, 1491, 1351).

with the use of ceramic vessels. According to the recently developed periodization scheme in Estonia the initial Stone Age period with pottery is connected with the Mesolithic (Fig. 5), the earlier schemes , however, being similar to those of other Baltic countries (e.g. Jaanits *et al.* 1982, 61; Lang & Kriiska 2001, 89) distinguishing both the foraging Neolithic and one with the incipient animal husbandry and plant cultivation (e.g. Jaanits 1955, 191-192).

Several local cultural varieties (e.g. Jaanits 1984; Loze 1985; Timofeev 1989; Girininkas 1985; 1994) or styles (Brazaitis 2002) have been distinguished amongst the Narva type pottery. This has been interpreted either in terms of the direction of foreign influences (Jaanits 1985, 356; Jaanits et al. 1982, 67; Girininkas 1985, 121-123) or as local specific features that had existed prior to the introduction of pottery (Kriiska 1997, 17; Brazaitis 2002, 70).

Narva type ceramic vessels were usually manufactured from narrow, often only up to 1-2 cm wide clay coils. The contact surfaces of the clay coils were predominantly convex-concave (U-type), rarely oblique (N-type) or straight (H-type) (Гурина 1967, 34; Лозе 1988, 48 49; Kriiska 1995b, 66-67). The bottoms of the vessels were pressed from single clay lumps. Relating to the form of the containers , the vessels with pointed (including nipple-shaped bottoms) (Fig. 7) or rounded bottoms, thus resembling a halved egg, are distinguishable. There were the pots either with straight or slightly profiled walls (Fig. 7: 1) or oblong (Fig. 7: 2) or round bowls (Vankina *et al.* 1973, 211; Loze 1988, 49; Kriiska 1997, 18). The edges were of the same thickness with the walls or slightly thinning, more seldom thickening (Kriiska 1997, 18; Brazaitis 2002, Fig. 2-4). The tempering of moulding mass shows local differences:crushed shells (*Unio tumidus* and *Anodonta cygnea* distinguished in Estonia – Kriiska 1996, 374) (Fig. 8), minced plant remains (Vankina *et al.* 1973, 211; Kriiska 1996, 374) and rarely rock debris (Jaanits 1984, 20; Loze 1988, 48; Kriiska 1995a, 412). The surface treatment was also varied, often even within a single site: the surfaces could be striated (e.g. Fig. 7: 6, 7), smoothed or even slightly polished (Loze 1988, 48; Kriiska 1995b, 71). The ornamentation of Narva type pottery comprises regional specific characteristics. The vessels were more often ornamented in Latvia and Southeastern Estonia where the decoration petterns were more varied. The early pottery of the Western Estonian archipelago was decorated less often. A part of pottery vessels were decorated with imprints of a tooth stamp (the so-called comb impressions) and various notches, pits and grooves (e.g. Vankina *et al.* 1973, 211; Loze 1988, 49-52; Kriiska 1995b, 65). The ornamentation was usually restricted only to the upper part of the vessels with a single ornamental; element used on the entire surface (Vankina *et al.* 1973, 211; Kriiska 1995b, 72). In Eastern

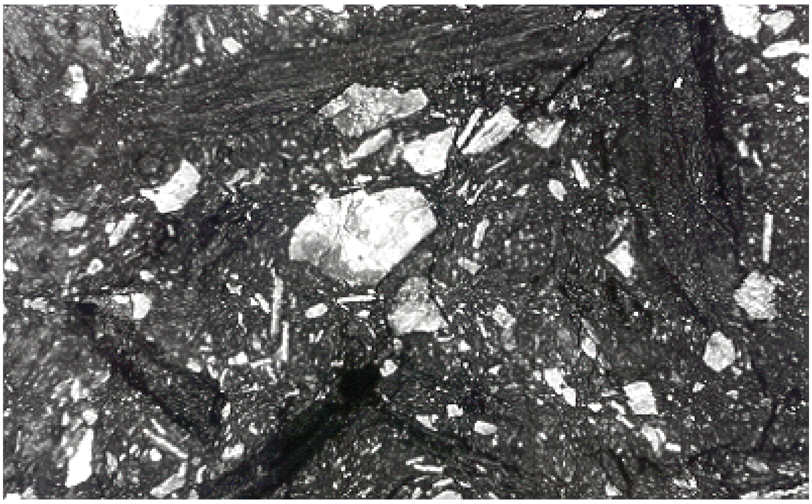

Fig. 8 Shell temper in Narva type pottery sherd from Riigiküla site north-eastern Estonia (collection of the Institute of History of the Tallinn University, AI 4198:41).

Latvia small regular notches and pits forming belts and simple geometric patterns were the dominant ornamental motives. (e.g. Loze 1988, 49-52). In Estonia comb impressions were often used whereas the so-called stepping comb motive were more common in the Narva type pottery of Northern Estonia than elsewhere (Kriiska 1995b, 73). The 'stepping comb' impressions were made by step-by-step, alternatively fixing one end of the stamp and slightly moving the other. While comb impressions were still present on the Narva type pottery in eastern Latvia, notches became clearly dominant in more southern areas (Loze 1985, 14-15). A row of deep pits along the rim of the vessels was the unique feature of Estonian islands (Jaanits 1984, 20). In Northeastern Estonia comb impressions were often made by denticulated edges of river mollusk shells. It is possible that the outer surfaces of some vessels were coloured with red ochre (Kriiska & Tvauri 2007, 53). Firing temperature was in most cases below 800°C (Kriiska 1995, 74). Narva type vessels were used for storage as well as cooking purposes. The latter is sometimes confirmed by the occurrence of charred organics crust on the inner surfaces of the vessels (e.g. Loze 2000, 213).

The Nemunas type vessels were also relatively diverse Initially (at the so-called Dubičiai stage) organic matter, plant remains,were used for tempering; later mineral admixture was intoduced.. The vessels were made from considerably wide (3 cm and more) coils with N-type contact surfaces (Rimantienė 1996, 123; Piličiauskas 2002, 134) and the bottoms were pressed from a single clay lump (Rimantiene 1996, 123). The vessels were conical, the pots, with pointed or rounded bottoms (Rimantienė 1996, 127; Piličiauskas 2002, 134) the height to the upper diameter rate being predominantly 1 to1.5 (Rimantienė 1996, 127). During the early stage the vessels were usually capacious, with a straight or more rarely slightly outward protruding rims (Piličiauskas 2002, 134). The ornamentation was relatively rarem and restricted to the upper part of vessels (Rimantienė 1996, 127). The ornament elements included notches and pits(Piličiauskas 2002, 134).

In the southern part of the Eastern Baltic area the initial plant cultivation dates to theperiod of Narva and Nemunas cultures. Later it spread over the entire discussed territory.

The sources of evidence regarding early Eastern Baltic farming

A limited amount of sources of evidence is available for the studies of early farming and animal husbandry in the Eastern Baltic area area . The most suitable for this purpose are so-called direct evidences: grains, bones of domestic animals, implements connected with farming and animal husbandry or processing farming products and fossil field remains.

The remains of fossil fields that emerged as a result of past land management as well as ploughing and recogniseable in the present-day landscape in the form of banks, stone cairns or ard marks, are studied in the Eastern Baltic since the 1920s (e.g. Laid 1928; Lõugas 1972, Mandel 1982). Thei surveyng, mapping and excavations became especially intense during the last fifteen years (e.g. Lang 1994; 2000; 2007b; Kriiska 1998a; Merkevičius & Nemickienė 2003). The earliest fossil field remains from the Eastern Baltic are known from the Bronze Age, the oldest of these have been excavated in Northern Estonia, Saha-Loo (Fig. 9), and radiocarbon dates obtained for tree charcoal collected under the stones show the age of c. 1500 cal BC (Lang *et al.* 2005, 125). The ard marks found under the cultural layer of the Dievukalns Late Bronze Age site have been dated to 1300/1100–500 cal BC[3]

[3] All dates are in solar calender. ^{14}C dates are calibrated by computer program CAL40.DTA OxCal v2.18 cub r:4 sd:12 prob[chron]. Reference to the publication with original data has been given in brackets or in footnote.

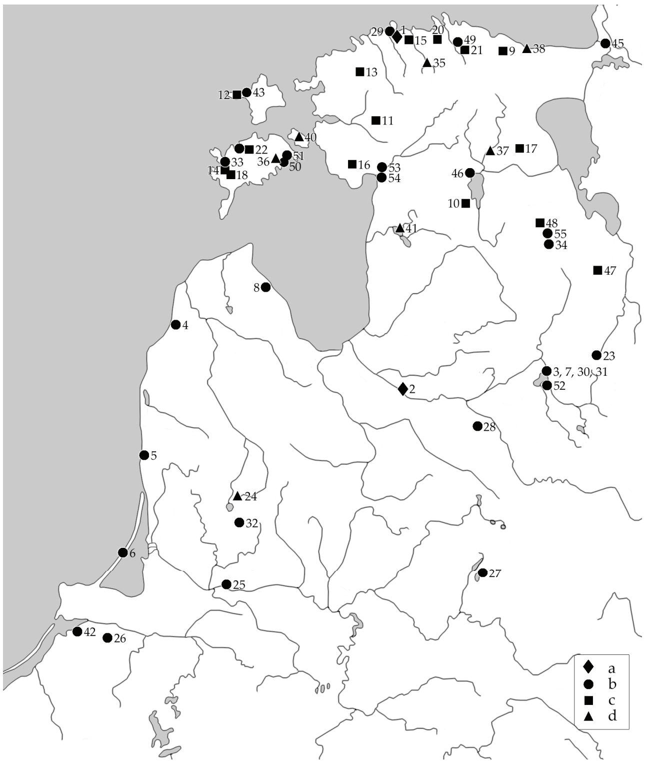

Fig. 9. Archaeological sites and bog- and lake sections with evidences of Stone Age *Cerealia* pollen.

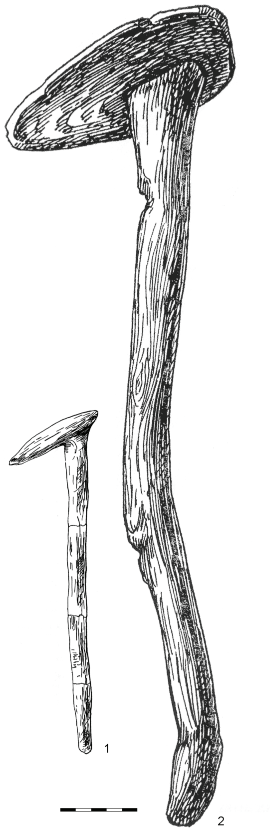

Fig. 10. Wooden artefacts from Zvidze,and Sventoji 1B sites voewed as hoes related to food- gathering and/or cultivation acitivities (after Loze 1988, Platte, XXXVII; Rimantienė, 1979, Fig. 32).

Key: a – fossil field remains, b – sites, and bog- and lake sections. *Sites*: 1 – Saha-Loo, 2 – Dievukalns, 3 – Zvidze, 4 – Sārnate, 5 – Šventoji, 6 – Nida, 7 – Abora, 8 – Gipka, 9 – Kunda Arusoo, 10 – Akkali, 11 – Velise, 12 – Kõivasoo, 13 – Mustjärv, 14 – Vedruka, 15 – Maardu, 16 – Tõhela, 17 – Kõrenduse, 18 – Pitkasoo, 19 – Saha, 20 – Kahala, 21 – Viitna Pikkjärv, 22 – Surusoo, 23 – Kreiči, 24 – Dounkalnis, 25 – Zedmar, 26 – Utinoje Boloto, 27 – Kretuonas, 28 – Piestiņa, 29 – Iru, 30 – Eiņi, 31 – Lagaža, 32 – Daktariškės, 33 – Loona, 34 – Tamula, 35 – Ardu, 36 – Tika, 37 – Kunila, 38 – Sope, 40 – Külasema, 41 – Zvejnieki, 42 – Pribrezhnoye, 43 – Kõpu, 44 – Võhma, 45 – Riigiküla, 46 – Valma, 47 – Hino and Mustjäev, 48 – Ala-Pika, 49 – Ilumäe, 50 – Asva, 51 – Ridala, 52 – Brikuļi, 53 – Pulli, 54 – Sindi-Lodja I.

– e.g. Lang 2007a, 25) A fortified settlement in Central Latvia, has been attributed to the Early Bronze Age (Zariņa 1982, 10).

Some wooden and stone tools can be associated with early farming. The oldest of these belong to the second half of the 4th millennium cal BC. Wooden tools have been found at the sites of Zvidze and Sārnate in Latvia and Šventoji 1B, 2B, 3B and 23 in Lithuania (Fig. 10) and have been interpreted as hoes used for farming and/or gathering (1970, 95, Tab. XIX; Rimantienė 1979, 32, Fig. 32; Rimantienė 1993-1994, 93; Loze 1988, 41). Cross-bladed stone artefacts, usually referred to as hoes as well, were used in the Eastern Baltic by the end of the Stone Age (e.g.s Kriiska & Tvauri 2002, 90, Bagušienė & Rimantienė 1974, 101-103; Apals *et al.* 1974, Plate 14). Stones with ground surface and the shape suitable for ard blades were also used (Lang 1995, 159). Several of these tools (including all specimens from Estonia) were collected as stray finds, therefore it is hard to date them precisely. However, some of these 'hoes' were found within habitation sites, for example tens of specimens weret collected at the settlement of Nida in Western Lithuania, dated to the time span between 3200-1800 cal BC (Rimantienė 1989, 68 pp). So-called grinding stones and mortars were also found at Nida (Rimantienė 1989, 76-77). There is probably no reason to doubt that at least part of these tools were used for processing of farming products but they were apparently suitable for gathering activities as well.

The identification of tools connected with farming in the Eastern Baltic area becomes clearer only starting with the Bronze Age. Only rarely bronze sickles were found, the oldest of these are dated to the 15th-14th centuries cal BC (Jaanits *et al.* 1982, 132, 152; Laul & Tõnisson 1991, 76). Plenty of grinding stones with mortars, supposedly bone bridle-bits, horn artefacts interpreted as hoes or ard blades and bone items considered swingles or sickles based on ethnographic parallels are dated to the Bronze Age, mostly its recent part (e.g. Indreko 1939, 27; Apals *et al.* 1974, 363, Tab 15; Jaanits *et al.* 1982, 144, 156; Grigalavičienė 1986, Fig. 13; Lõugas 1992, 58, 61; Mandel 1993, 21; Vasks 1994, 115;

Table. 1. The pollen of *Cerealia* dated to the Stone and Early Bronze Age identifiable in the pollen diagrams of Estonian bog and lake sediments

Location	**Area**	**Plant**	**The median value of the data (cal BC)**	**Reference**
Kunda Arusoo Bog	Northeast Estonia	*Cerealia*	4300*	Poska 1994
Akkali Bog	East Estonia	*Tritckum t.*	4000	Poska *et al.* 2004
Velise Bog	West Estonia	*Avena t.* *Hordeum t.* *Triticum t.*	4000 1900 1600	Veski 1998
Kõivasoo Bog	Hiiumaa Island	*Hordeum t.* *Avena t.*	3900 3200	Königsson *et al.*1998
Mustjärv Bog	West Estonia	*Avena t.* *Triticum t.*	3800 3500	Veski 1998
Vedruka Bog	Saaremaa Island	*Avena t.*	3700	Poska & Saarse 2001
Maardu Lake	North Estonia	*Tritckum t.* *Secale t.*	3500 2000	Veski 1998
Tõhela Lake	Southeast Estonia	*Cerealia*	3500	Veski 1998
Kõrenduse Bog	East Estonia	*Cerealia*	3200	Pirrus & Rõuk 1988
Pitkasoo Bog	Saaremaa Island	*Cerealia*	3000	Königsson & Poska 1998
Saha Bog	North Estonia	*Cerealia*	2200	Kihno 1996
Kahala Lake	North Estonia	*Cerealia*	1800	Poska & Saarse 2001
Kahala Bog	North Estonia	*Cerealia*	1800	Poska & Saarse 2001
Hino Bog	Southeast Estonia	*Hordeum t.* *Tritikum t.*	1700 1700	Laul & Kihno 1999b
Viitna Pikkjärv Lake	North Estonia	*Hordeum t.*	1600	Saarse *et al.* 1998
Surusoo Bog	Saaremaa Island	*Avena t.*	1600	Veski 1996

* Date inprecise.

Lang 1996, 49, 177). These implements were mostly found at fortified settlements, more rarely in graves.

In the Eastern Baltic area the earlier finds of bones of domesticated animals identified in rare cases at Neolithic sites were dated to between 5900 and 3000 years cal BC (Loze 1988, 114-115; Antanaitis, 1999, 94; Daugnora & Girininkas 2004b, 285), the finds of domesticates and related implements became more common by the end of the Stone Age, originated from graves and settlements dated to 3000-2000 years cal BC (e.g. Kriiska 2003a, 17; Lõugas *et al.* 2007).

The oldest, and so far unique find of cereal grains and their imprints on pottery is known in the Eastern Baltic area from Stone Age sites dated to, the 4th and 3rd millennia cal BC (Levkovskaya 1987, 76; Jaanits 1992, 49). A large number ofof pottery sherds with grain imprints are known from the Bronze Age (e.g. Indreko 1939, 26-27; Lõugas 1992, 61).

Fossil field remains are not known from the transition period to farming anywhere in Europe. The situation is no better with artefacts connected with farming. At the early stage of the economic change these are often missing as clear-cut categories. On the one hand the old tool types were probably used with a noval function, on the other, one cannot rule out the use of tools from organic and perishable materials (Lang 1995, 119 and the references therein).

The scarcity of the archaeological evidence is compensated by scientific, predominantly palynological proxy evidence. Pollen can be preserved in the ground even after hundred thousands years. Especially good preservation conditions are in anaerobic or slightly acidic bog and lake environments. Among other elements, the pollen grains deposited in the ground reflect the changes in vegetation concommited with farming activities like the presence of *Cerealia* and other agriculture-related edvidence. Thus palynology has become one of the most important instruments for the studies of incipient farming economy.

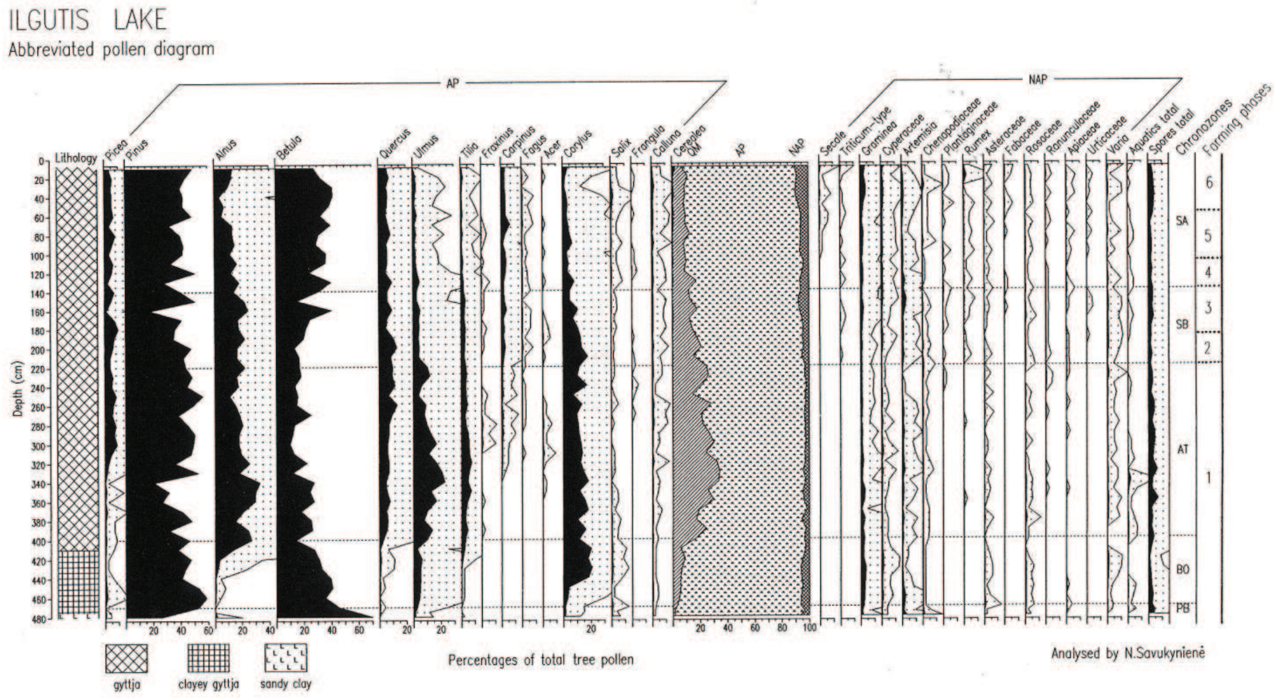

Fig. 11. Pollen diagram from the sediments of Lake Ilgutis, Southeastern Lituania. Triticum-type pollen occurs around the shift of Atlantic and Subboreal chronozones (by Sebutis & Savukynienė 1998, Fig. 2).

The pollen analysis, developed by Swedish scientists at the beginning of the 20th century (Robertson 1989) was introduced into the Eastern Baltic scholarly practice in the 1920s (Thomson 1928; 1929; 1930). It was first used mostly as an instrument to indirectly date archaeological material and obviously in order to obtain additional information about the natural enviroment (climate, vegetation etc). In the 1980s the trend to investigate the human impact on natural environment gained in importance, in addition to the attempt to ascertain the history of vegetation.[4] The research intensified in early 1990s (Moe *et al.* 1992; Saarse & Königsson1992) when pollen analyses techniques were improved, resulting in the identification of a larger amount of pollen grains from a single specimen: 1000, orf even 2000, instead of 500 (Veski 1998, 4). While earlier the pollen of cereals were determined under the common family name of *Cerealia*, now different species of cereals started to be distinguished.

Until now more than a thousand pollen diagrams reflecting the post-glacial period have been obiained in the Eastern Baltic area. Yet not all of them are representative enough. Some diagrams are (1) selective, i.e the identifications were made only to follow upthe general trends in the history of vegetation, (2) the amount of pollen grains identified was too small or (3) the sequences were inadequately dated. For example, considering the number of pollen grains counted as well as the existing radiocarbon dates, it was suggested that out of the approximately 400 pollen diagrams in Estonia only 30 are on state-of-the-art level (Poska *et al.* 2004, 39). However, sufficient results were obtained sheding light on of human acitivities in a wider sense and farming in particular.

The beginning of farming

The first signals of cereals in the Eastern Baltic, pollen grains of gramineous plants – originating from the sites dated to c. 4900-4700 cal BC[5] and have been identified in Southern Lithuania (Antanaitis-Jacobs & Stančikaitė 2004, 265).

A more recent, but a sufficiently more representative group of gramineous pollen has been obtained from bog and lake sediments and the cultural layer of habitation sites radiocarbon dated to between c. 4400-3000 years cal BC. Gramineous plants of a comparable age have been found at ten sites in Estonia (table 1; Veski 1998; Poska *et al.* 1999; Kriiska 2000, 2003a, 2007; Poska 2001) as well as in several bog and lake sites in Southern Lithuania (for example Seibutis & Savukynienė 1998, 54-55; Antanaitis-Jacobs & Stančikaitė 2004, 253, 255) (Fig. 11) and Eastern Latvia (Seglinš *et al.* 1999, 125), whereas wheat (*Triticum*), barley (*Hordeum*) and oats (*Avena*) are all represented.[6] According to the typology of pottery, the pollen of barley has been found

[4] For the associations of palynology and archaeology in the Eastern Baltic see in detail for example Kriiska & Lõugas 2006.

[5] The basis for the calibrated dates in Antanaitis-Jacobs & Stančikaitė 2004, 265.

[6] According to the research made elsewhere in Europe it can be suggested that oats could have been the weed of barley fields at that time and not an independent grain species. Moreover, in case of oats determination faults may occur (Siim Veski orally to the author 13.02. 2002).

from the cultural layer of the Eastern Latvian Abora IB settlement site (Levkovskaya 1987, 77) and Western Latvian Gipka B settlement site (Jakubovska 2006, 206) used approximately from 4000 to 3000 years cal BC.

Naturally one cannot fully exclude a possibility that the cereal pollen had been brought into the Eastern Baltic by winds from afar. Yet an abundant evidence collected from the sites in the interval of 4400-3000 years cal BC by now makes this explanation unlikely. Importantly, numerous pollen diagrams in Estonia, show considerable changes in vegetation: decrease in the pollen of trees and increase in the pollen of herbaceous plants, occring in a wide area–(Veski 1998; Poska 2001). This may be interpreted as a asignal of firest clearence aimed at ob aining arable land.

The fact that cereals were known in the Eastern Baltic area is substantiated by the finds of cereal grains dated to the same period. The earliest of these grains were identified at the cultural layer of the Kreiči site in eastern Latvia (Levkovskaya 1987, 76). According to the typology of pottery the age of this site lies between 4000-3000 years cal BC.

The early stage of farming has provided so far little evidence related to animal husbandry. Ever since the Early Mesolithic the dog was the only recogniseable domestic animal (e.g. Jaanits *et al.* 1982, 32). The earliest bones of livestock in the Eastern Baltic, a few cattle teeth, were collected at Duonkalnis cemetery (graves ## 4 and 5) in eastern Lithuania. The cattle skeleton from one of the graves has been radiocarbon dated to c. 5900 cal BC (Antanaitis 1999, 91). All other dated domesticates' bones are at least 1500 years younger. A few sheep/goat teeth and possiblly a bovine tooth, have been found at the site Zedmar A in Kaliningrad region, which has been radiocarbon dated to 4200-3700 years cal BC (Timofeev 1991, 18; Daugnora & Girininkas 2004b, 285). A few sheep/goat bones have been collected from the Utinoje Bologo 1 site in Kaliningrad region dated to c. 3700 years cal BC (Timofeev 1991, 22). It should be mentioned that , at Zedmar A site the penetration of the bones from the , Corded Ware Culture or even Early Iron Age layers cannot be excluded (Timofeev 1991, 18).At Kretuonas 1B site in eastern Lithuania dated to c. 4400-2900 years cal BC the bones of domestic animals make up up nearly 7% of the total faunal remains (Daugnora & Girininkas 1996, 177; Daugnora & Girininkas 2004b, 81, 285-286).

At the Neolithic Zvidze site in eastern Latvia radiocarbon dated to about 3500-3100 cal BC,[7] pig, cattle and goat/sheep bones make up 4,5% of mammal remains (Loze 1988, 114-116). At the majority of Neolithic sites in Latvia yielded no bones of livestock whereas at Estonian sites of that period they are completely missing. Taking into account that the faunal material from Estonian Stone Age sites were studied almost completely (Paaver 1965 and Lõugas 1997) this evidence should be considered as totally reliable.

Leaving aside unnumerous finds of cereal pollen and animal bones at early Neolithic sites, the early farming in the Eastern Baltic area coincides with the Comb Ware Cultures[8] in Estonia, Comb Ware and Narva cultures[9] in Latvia (e.g. Loze 1984) and Narva and Nemunas cultures in Lithuania and Kaliningrad region[10] (e.g. Rimantienė 1998, 151-153) (Fig. 6, 7). Rare artefacts associated with Comb Ware Cultures have been reported from western Lithuania (Rimantienė 1996, 152–153) and a few pottery sherds are known from eastern Lithuania (Girininkas 2000a, 103) and Kaliningrad region (Kulakov & Timofeev 1992, 14-15) but the latter are still exceptions in the context of contact areas of an alien Narva culture.

As had already been mentioned by this time the settlement system based on 'mother' villages had probably emerged in the Eastern Balticum.eme. The Stone Age villages reached the peak during the Neolithic. Several habitation sites attained a considerable size, with numerous artefactual finds and thick cultural deposits; and numerous faunal remains indicative of highly successful hunting-and-fishing strategies allegedly carried out in opportune seasons..One may add to that large solidly built dwelling structures with sunken floors (e.g. Gurina 1967, 22-23; Kriiska 2002, 137) can probably be added to this list as well. The emergence of longer-term sedentary villages and the established system of procurement areas apparently stimulated the spread of farming activities.

Another important factor resided in large-scale trade and exchange networks. While raw material and in some cases accomplished artefacts already previously moved over hundreds of kilometres (e.g. Jussila *et al.* 2006), starting from approximately 4000 years cal BC the trade distances in some cases more than doubled, extending over 2000 kilometres (e.g. Halén 1996, 288-291). Flint from Central Russia (Galibin & Timofeev 1993) and Lithuania and Belorussia, slate from Onega Lake in Russian Karelia (Edgren 1984, 38; Kriiska & Lõhmus 2005, 39) and amber from the coastal areas of Latvia and Lithuania (Loze 1980; Ots 2003) and even copper from the Ural mountains (Halén 1996, 288–291; Pesonen 1998, 26) and arolla pine (Edgren 1984, 57) were distributed over wide areas.

The importance of farming in the economy of that time is not sufficiently clear. However, cultivation during the early

[7] The basis of calibration Лозе 1988, 101.

[8] Typical (4200-3700 cal BC) (Fig. 13) and Late Comb Ware (3700-1800 cal BC) Cultures are discerned. In Russian, Lithuanian and Latvian archaeological literature typical comb ware is called also comb-pit ware (e.g. Лозе 1984) and typical pit-comb ware (Zagorskis 1963, 34) and late comb ware is called Eastern Baltic ware (e.g. Лозе 1988, 106), late pit-comb ware (Zagorskis 1963, 34) or Piestiņa-type pottery (Ванкина *et al.* 1973, 214).

[9] If the material from Sārnate is joined with it.

[10] If so-called Zedmar-type sites are treated as the variation of Narva or Nemunas Culture.

stage probably remained an exceptional activity less important as compared to hunting and fishing, failing to bringing along notable changes either in the settlement pattern or material culture. Their relatively continuous development without any abrupt changes makes valid a suggestion that agriculture initially began without large-scale migrations, and the use of various species of cereals was mastered by the local populations.. At the same time there is no reason to completely exclude the movements of small groups of people.

It is equally difficult to assess the role of animal husbandry in the economy. The earliest (ca 5900 cal BC) bone finds are bovine tooth pendants found in graves as part of funerary goods. It is not enough to suggest the occurrence of cattle-breeding.. As gifts the pendants could have travelled over long distances from their production site. As another example from the Eastern Baltic area one may quote seal tooth pendants which have been found in Central and Southeastern Estonian Stone Age sites at a distance of a hundred or more kilometres from the sea (Bolz 1914, 32; Kriiska *et al.* 2004, 40; Lembi Lõugas orally to the author 10.03.2008). Pendants have been found on Saaremaa Island which have been made from the teeth of animal species who never habitated this isolated island (Eriksson *et al.* 2003, 54). Domestic animal bones in the are rare even at Eastern Baltic which are 2000-3000 years more recent, giving rise to a suggestion that the meat was obtained via exhange, for example from the area of Funnel Beaker Culture. Rare of funnel beaker sherds found mat Zvidze in Latvia together with bones of domestic animals may confirm this suggestion (Лозе 1988, 115). At the same time the occurrence of animal husbandry cannot be completely excluded at least for Lubanā Lake region in eastern Latvia and Kretuonas region in eastern Lithuania.

We have no inforlation regarding the fields during that period. It can be suggested that the lack of fossil field remains visible on the ground until today stems from the fact that the cultivated land was initially not cleared of stones. Cultivated plots were cleared supposedly by slash-and-burn technique and the soil was loosened manually, without the use of ploughing ards.

Agriculture during the Final Stone and Early Bronze Ages

More evidence of agricultural economy in the Eastern Baltic area can be found from the end of the Neolithic and the Early Bronze Age, in the 3rd and the early 2nd millennia cal BC. Pottery sherds with grain imprints have been collected at the sites of this period. At the site of Iru in northern Estonia a corded pottery sherd was found with a charred barley grain embedded in its surface (Jaanits 1992, 49). An imprint of another grain was found on the other side of the same sherd (Valter Lang orally to the author 7.09.2007). Grains have been found also in archaeological deposits (for example a wheat grain from the cultural layer of the settlement site of Šventoji 6 (Rimantienė 1993-1994, 97).

Several bogs and lakes (Fig. 12) and the cultural layers of the sites of that age (for example Eiņi, Lagaža, Abora I; Zedmar A; Zvidze, Šventoji – (Levkovskaya 1987, Tab. 6, 77-78) have yielded *Cerealia* pollen which indicates the cultivation of barley and wheat (e.g. Veski 1998; Kriiska 2000, 73; Antanaitis *et al.* 2000, 49; Poska 2001; Antanaitis-Jacobs & Stančikaitė 2004, 265; Daugnora & Girininkas 2004b, 287) (Tab. 1). Oats is continually present in pollen diagrams but as indicated above, it could have been weed in barley fields. The first known pollen of rye (*Secale*) in Eastern Baltic dates to about 2000 cal BC and originated from from Maardu Bog in northern Estonia (oral communication by Siim Veskito the author 13.02.2003). At that time,. rye probably also occurrred as a weed in other cereal crops.. The regular presence of *Cerealia* pollen in diagrams is indicative of a more intensive farming by the end of the Stone Age. The increased abundance of herbaceous plants, especially photophilous species characteristic of meadows (*Chenopodiaceae, Melampyrum, Plango spp, Polygonum aviculare, Rumex spp.*, etc) is conspicuous. Fragments of tree-charcoal occur more often than previously which can also be connected with human-initiated fires aimed at forest clearance to obtain fields and pastures. While rich botanic evidence from southern Scandinavia (charred grains, grain imprints on pottery and pollen), is clearly indicative of barley-dominated agriculture the Corded Ware Culture (Andersen 1993, 88; Ahlfont *et al.* 1995, 154), the data available for the Eastern Baltic area are not sufficient for making similar prononcements.

Millet (*Setaria italica*) was also grown in the Eastern Baltic areaby the end of the Stone Age. The earliest finds of millet seeds – were obtained from the cultural layer of Šventoji 6 site in western Lithuania radiocarbon dated to c. 2600 years cal BC (Rimantienė 1993-1994, 95). Hemp (*Canibis ruderalis Jan C. Sativa L.* and *Canibis ruderalis Jan C. Sativa var. Indica, Lam.)* was cultivated as technical plant and it has been identified in the form of seeds, pollenand macro remains in the cultural layer of Šventoji 1A, 3B, 9 and 23 site (Rimantienė 1979, 168; Rimantienė 1980, 75; Rimantienė 1993-1994, 97)

The bones of livestock – sheep/goats, pigs, bovines and horses – and artefacts made of them were found both at settlements and burial sites (Table 2; Fig. 13). These includes such habitation sites as Lagaža, Eiņi and Abora I in in Lubāna Lake depression (eastern Latvia) (Лозе 1979, 125; Лозе 1991, 19), i Sārnate in western Latvia (Vankina 1970, 134), Šventoji 1A, Šventoji 3B and 23, Daktariške 5 and Nida in western Lithuania (Rimantienė 1979, 168; Rimantienė 1980, 74; Rimantienė 1989, 181; Rimantienė 1993-1994, 99; Daugnora & Girininkas 1996, Tab. 23), Kretuonas 1A and

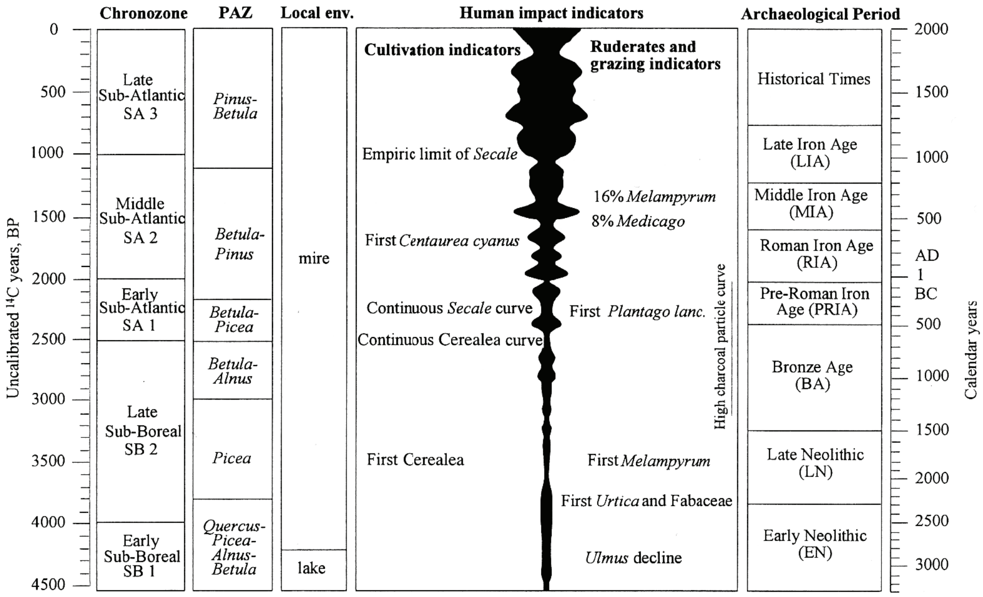

Fig. 12. Simplified diagram showing human impact, based on the biostratigraphical evidence from Kahala mire, northern Estonia (after Saarse *et al.* 1999, Fig. 10).

Table 2. Burial sites in the Eastern Baltic area radiocarbon dated to the end of the Stone Age with the remains bones of domesticated animals and related artefacts.

Burial site	**Area**	**The Median value of the data (cal BC) from human bones**	***Ovis aries/ Capra hircus****	***Sus domesticus***	***Bos taurus***	**Publication**
Zvejnieki	Northern Latvia	2900	+			Eriksson *et al.* 2003
Sope	Northeastern Estonia	2700	+	+ (?)	+	Янитс 1952
Ardu	Northern Estonia	2700	+			Indreko 1938
Tika	Saaremaa Island	2700	+			Янитс 1952
Kunila	Central Estonia	2500		+		Янитс 1952
Karlova	Southeastern Estonia	2200			+	Lõugas *et al.* 2007

* The bones of goats and sheep are difficult to distinguish wherefore they are usually treated as a single group.

Fig. 13. Awls of sheep or goat bone from the grave at Sope (collection of the Institute of History of the Tallinn University, AI 2607:1, 3175:1).

Kretuonas 1D in Western Lithuania (Daugnora & Girininkas 1996, Tab. 19 and 20), Zedmar D in Kaliningrad region (Timofeev 1991, 19) and Loona in Western Estonia (Paaver 1965, 440; Lõugas et al. 1996, 405). Animal bones have also been collected from settlements in Southeastern Estonia (for example Tamula and Akali) (Паавер 1965, 440, 438; Jaanits 1992, 48; Maldre 1999, Tab. 1). Although the later age of these sites cannot be excluded in view of the adsence of radiocarbon dates, their Final Stone Age dates cannot be ruled out either. As a rule the total amount of the bones of livestock of the settlement sites of Final Stone Age is relatively small (Fig. 14), being less than ten per cent of all the total mammal assemblage: for example 5.5% in Abora I,

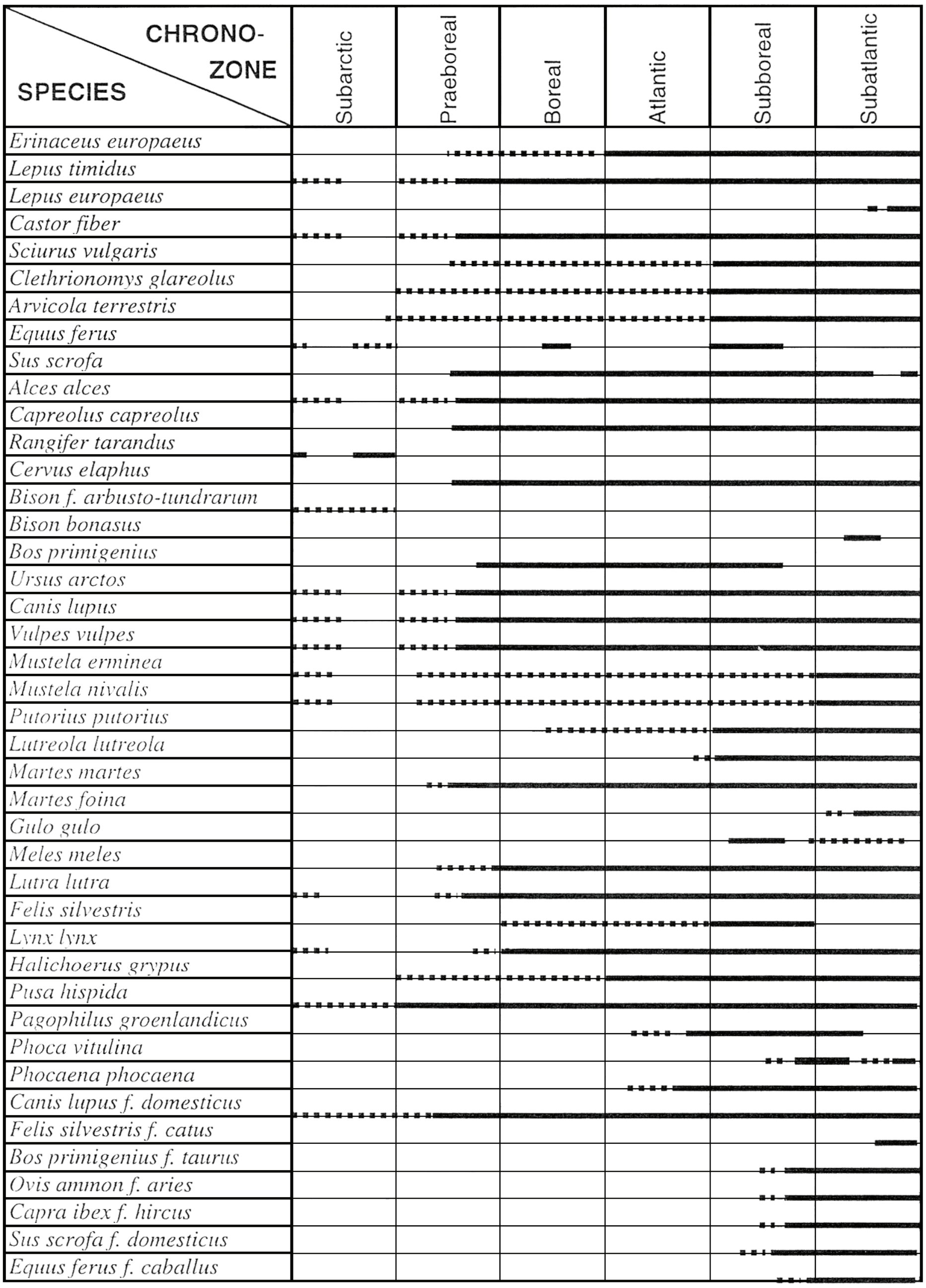

Fig. 14. Rates of mammal bones, including bones of livestock, in the osteological assemblages of five sites in Latvia, Lithuania and Kaliningrad region dated to the end of the Stone Age (Loze 1979, 125-126; Timofeev 1991, 19; Daugnora & Girininkas 1996, Tab. 23).

3.7% in Lagaža and 6% in Eiņi (Loze 1979, 125-126 after the determination of Paaver). Unfortunately at the majority of the Eastern Baltic Late Neolithic sites the bones were not preserved and the cultural layers wereat least partly distorted by later human activities. There exists a theoretical possibility that animals were not raised locally but the bones have reached the habitants of the Eastern Baltic area via exchange either as ready-made artefacts or raw material and meat even at the end of the Stone Age. Considering the occurrence of large-scale animal husbandry in the Eastern and Northern European context during this period, the assumption does not seem plausible. At the same time the scarcity of domestic animals clearly indicates at the marginality of animal husbandry in the local economy.

In any case the hunting and fishing retained a significant role during that time. The bones of wild animals and fish prevail in the faunal assemblages at all Final Stone Age and Early Bronze Age sites (Rimantienė 1980, 75; Ostrauskas 1998, 271; Kriiska 2000, 74). Hunting and fishing activities are indicated by the bones of elk (Ardu and Tika burial sites), beaver (Kunila burial site) and wild boar (Sope and Kunila burial sites) (Lõugas *et al.* 2007, 25) and a head of a bone fishing spear (Tika and Külasema – Jaanits *et al.* 1982, 107) found at the graves dated to the end of the Stone Age in Estonia. Tools connected with hunting and fishing, such as flint arrow- and spear-heads, wooden spear etc., are relatively common at habitation sites, especially in the coastal area of western Lithuania: (Rimantienė 1980, 74). The remains of a fishweir have been unearthed at Šventoji in western Lithuania (Rimantienė 1980, 14 pp).

Several synchronous archaeological cultures have been recognised in the Eastern Baltic area during the final Stone Age millennium (Fig. 5). Likewise in Northern, Central and Eastern Europe (see for example Carpelan 1999, 261, Fig. 4; Kruk & Milisauskas 1999, 334; Włodarczak 2001), Corded Ware Cultures Spread into that area. In the Eastern Baltic the so-called 'pure' Corded Ware Culture with regional distinctive features (e.g. Rimantiene 1984, 35; Girinikas 2002) and in western Lithuania and Kaliningrad region Rzucewo culture[11] is commonly recognised (Rimantienė 1980; Kulakov & Timofeev 1992, 15). The Corded Ware Cultures formed following the Late Comb Ware Culture in Estonia and Latvia and Nemunas and Narva Cultures in Lithuania and Kaliningrad region (Rimantiene 1984, 34). The latter 'cultures' are a common denomination for the material traditions which lasted for and, even thousands years,The sedentary village remained the principle settlement unit all that time. According to radiocarbon dates the Corded Ware Cultures in the Eastern Baltic dates between 3000-2000 years cal BC (e.g. Rimantienė 1980, 74; Loze 1992; Eriksson *et al.* 2003; 50; Lõugas *et al.* 2007).

Altogether about 150 Corded Ware Culture settlements and 50 burial sites are known in the Eastern Baltic area (Girininkas 2002, 75-77) (Fig. 15**).** In most cases they were found occasionally in the course of excavations of other sites (Kriiska 2000, 70). Only in rare cases the remains of Corded Ware Culture settlements were not mixed up with finds from other periods or destroyed by ploughing. The cultural layers of Corded Ware Culture settlements are usually thin and poor in finds. They usually include no more than a few thousands of pottery sherds, and a small number of stone tools and flakes from flint and quartz primary splitting (Jaanits 1966, 61-63; Kriiska 2000, 70; Girininkas 2002, 92). The sites of Rzucewo Culture in western Lithuania (such as Nida and Šventoji) and Kaliningrad region (for example Pribrezhnoye where cultural layer extends over at least 15 000 sq m (Saltsman 2004, 135) are quite distinct.

The people of the Corded Ware Cultures, had different motives when choosing their dwelling sites, than those of the preceeding or the contemporary Late Comb Ware, Narva Nemunas, or Rzucewo Cultures. For them it was no longer

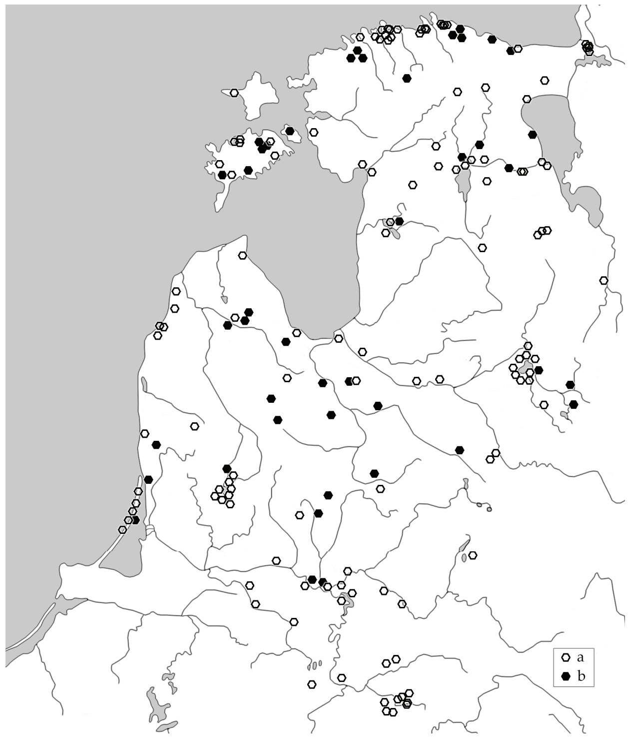

Fig. 15. The Corded Ware Cultures sites in the Eastern Baltic (Girininkas 2002, Fig. 1; supplemented and checked by Vankina 1980, Fig. 1; Loze 1992, Fig. 1; Žukauskaitė 2004, Fig. 1; Kriiska & Tavuri 2007, 79).

important to dwell in the close vicinity of large waterbodies. In the coastal area and on islands several previously known sites now situated further inland were re-inhabited (e.g. Kriiska 1998b, 18; 2000, 72). For example at Kõpu on the island of Hiiumaa off western Estonia the Corded Ware Culture settlement was located at 1 km from the seacoast, at Võhma in the northwestern part of Saaremaa island that distance was about 1.5 km and inthe Riigiküla XIV site in north-eastern Estonia was located on the lower stretches of the Narva River at 1.5 km from the sea.. Similar changes sporadically occurred on the shores of Võrtsjärv Lake in Central Estonia. In Northern Estonia people preferred to live a plateau near the 'Clint' escarpment (Lang 1996, fig. 101, 120; Lang & Konsa 1998; Lang 2000, 77, 79) where easily arable humus-rich rendzinas soils were spread. In south-western, south-eastern and eastern Estonia the Corded Ware Culture sites remained in the vicinity of river valleys (Kriiska 2000, Kriiska & Saluäär 2000) but these were the areas with the best agricultural potential in otherwise swampy terrain. At the time when practically the entire Estonia was covered with forests and bogs, flooded meadows were the only areas with rich herbaceous vegetation and seasonally flooded patches of land suitable for agricultural use (Järvekülg 2000, 56).

The natural resources of livelohood were directly controlled by natural environments in which the Stone and Bronze Age people had existed. . Thus, it could be suggested that the

[11] Also called Coast Culture and Vilnius-Nemunas Culture (Rimantienė 1980, 74).

economy and the type of prehistoric landscape defined ithe choice of habitation sites as well as the dietary base. This location of sites probably also met the requirements of the farming economy since the catchment areas of these sites included good natural pastures for animal husbandry as well as soils suitable for plant cultivation. Similar shifts in the settlement pattern in connection with the development of farming is recogniseable in several areas of Europe as well as the Finnish Corded Ware sites (e.g. Pohjakallio 1994, 65) where no clear evidence of cultivation has been found so far.

In the Eastern Baltic area small-size settlements and burial sites with one or rarely two skeletons, had been previously considered the indices of peripathetic type of settlement typical of the Corded Ware Culture (Jaanits 1966, 65; Daugnora & Girininkas 2004a, 285). Mobility (possibly a seasonal one) was suggested to have been conditioned by the needs of seeking new feeding and hunting areas (e.g. Jaanits 1966, 64-65). Ever since the 1920s animal husbandry has been considered as one of the main branches of the economy of the Corded Ware Culture around the Baltic thin cultural layers and the location of sites being considred as the arguments supporting this interpretation. This has been done even when the bones of domestic animals were actually missing in the osteological assemblages, like in the case of Finland (Salo 2005, 26). We are actually dealing with the so-called local reconfiguration of the hypothesis advanced already in the early 20th century, suggesting that the Corded Ware Culture emerged as a result of the migration of Indo-European nomadic herders from the steppes. This idea has been shared by many archaeologists, including prominent Eastern Baltic archaeologists (e.g. Gimbutas 1963).

The concepts of the development of the Corded Ware Culture via migrations, *par excellence* remained valid for decades (e.g. Moora 1956, 55; Jaanits et al. 1982, 102; Римантене 1984, 34), while an important role of local groups was only recognised in the case of the'hybrid' Rzucewo Culture (Rimantienė 1980, 76). This concept has been brought into question both in the Eastern Baltic (e.g. Lang 1998; Kriiska & Tvauri 2002, 84) as well as Scandinavia (e.g. Malmer 1962; Bådenholm 1967; Damm 1999). Also DNA studies formly suggest that in global sense no remarkable movements of genes accompanied the spread of farming in Europe (e.g. Haak 2005).[12] At the same time there is no reason to exclude the moivements of smaller groups of people, for example, families.

[12] True, while studying the genes of modern people information of possible migrations have been obtained. Several very different versions have been suggested wherefore the problem is far from being solved. 10-20% of the present European female lines (Richards 2000, 1271) and 22–50% of male lines (Semino *et al.* 2000) have been considered as the result of the Neolithic immigration from Near East whereas it is the strongest in the Mediterranean (Richards *et al.* 2002). As a result these studies refer to the very important contribution of the Mesolithic people in the development of European agricultural settlement.

As indicated above, the Eastern Baltic palaeozoological material does not demonstrate an intensive animal husbandry in the Final Stone Age. Limited practice of raising domestic animals does not presume, and has probably never presumed in the past, nomadic lifestyle. Therefore it is difficult or even impossible to imagine a nomadic herding in the Baltic area during the Late Neolithic period. Considering the travelling possibilities in the forest zone with the established settlements, and the fact that farming seems to have been associated with the use of highly specialised terrains, the small-size settlements and burial sites could rather be viewed as a signal of the settlement patterns focused on farmstead of individual families (Lang 1996, 444; Kriiska 2000, 74). The idea that people used to live in scattered farmsteads during the Corded Ware Cultures, is supported by the research in Vihasoo-Palmse region in Northern Estonia where the distribution of sites allows the suggestion that the basic settlement units of the Corded Ware Cultures were small one with an area under 10 sq m in size(Lang 2000, 80) i..e. 10-20 times smaller than the supposed catchment areas of the Comb Ware Cultures (Kriiska 2001a, 9).

It could be suggested that certain social links existed between the groups of farmsteads and common activities were taken up, for example seasonal fishing, seal hunting etc. It is possible that the remains of a fishing camp at Valma on the shore of Lake Võrtsjärv in Central Estonia were shared by three farmsteads at this site where the remains of hearths indicate at three buildings (Jaanits *et al.* 1982, 67-68). Three acitivity areas, the buildings and their surroundings , are recognised at Riigiküla XIV (Kriiska & Nordqvist 1987, 33 pp). Unfortunately the material from either of these settlements is insufficient to judge on the simultaneity of these buildings.

In rare cases larger communities inhabitated the stationary villages. This interpretation is certainly valid for the settlement sites of Nida and Šventoji in Lithuania. Šventoji 1A site was surrounded by wooden palisade (Rimantienė 1980, 75).

Only a limited number of sites dating from the end of the Stone Age and the beginning of Bronze Age are known in the Eastern Peribaltic (Lang 2007b, Fig. 3), and only a few sites have yielded a considerable amount of animal bones (Ostrauskas 1998, 269). At the same time numerous stone shaft-hole axes mostly stray finds, belong to this period. Their distribution together with *Cerealia* pollen in several bog and lake sediments (Veski 1998; Poska *et al.* 1999, Fig 1, Tab. 2; Poska 2001; Kriiska 2000, Tab. 1) indicates at the in creased density of settlements during that period.

While the Corded Ware Culture people already used the higher areas with heavy soils, the Bronze Age finds – mostly the so-called late shaft-hole axes were particularly common in these areas. In Estonia stone axes have been found in the entire highland areas (Kriiska 2003a; Johanson 2005, 172) and *Cerealia* pollen has been identified in the Bronze Age layers of highland lakes (in Estonia for example lakes of Hino, Mustjärv and Ala-Pika – Laul & Kihno 1999a, 246; Laul & Kihno 1999b, 9; Kihno & Valk 1999, 233-234).

Slash-and-burn agriculture was probably continuely practiced but the marks of crosswise ploughing[13] found under the cultural layer of a fortified settlement in Dievukalns, Latvia, radiocarbon dated to c. 850 cal BC (Zariņa 1982, 10), and the earliest so-called Baltic fields in Estonia are indicative of the use of ploughing ard (Lang *et al.* 2005, 125).

The importance of animal husbandry remained relatively modest in the Early the Bronze Age. For example at the settlment of Kretuonas 1C, (c.1950-1650 cal BC according to the radiocarbon dates) (Daugnora & Girininkas 2004a, 250), the bones of bovine, pig, horse and sheep/goat form 10 % of the total mammal assemblage (Daugnora & Girininkas 2004a, 250). At the settlement of Dusija 8 the rate of domesticates is 18,7 % respectively (Остраускас 1998, 269 and the references therein). The importance of animal husbandry in the economy rapidly increased or experienced an abrupt change during the Early Bronze Age and the beginning of Late Bronze Age. Since the Late Bronze Age the meat of bovine and sheep/goat consituted a significant part of the diet in the Eastern Baltic area (for example the bones of livestock form 63,7 % of the mammal bones of Asva fortified settlement and 78,1 % of the mammal bones of Ridala fortified settlement (Paaver 1965, appendix II; Lõugas 1994, 74) in Estonia and 75 % of the mammal bones of the Brikuļi fortified settlement in Latvia (Vasks *et al.* 1999,300). Animal husbandry during the Late Bronze Age was diverse and oriented to the production of meat as well as wool and dairy products. The bone remains of Ridala make it possible to assess the slaughtering age of animals. It shows that the majority of bovines were slaughtered as juvenile animals and thus raised for meat, whereas in the case of sheep and goats there are bones of juvenile as well as mature individuals which on the one hand suggestsw their keeping as meat animals as well, but on the other suggests the raising of sheep for wool and goats for dairy products (Maldre 2008, 271-272).

Acknowledgements

The author is thankful to archaeologists Džiugas Brazaitist, Valter Lang and Kristiina Johanson, palynologists Siim Veski, Anneli Poska and Kersti Kihno, palaeozoologist Lembi Lõugas for good advice and comments and artist Kristel Külljastinen for completing the drawings.

[13] The oldest ard marks from Estonia (under the cultural layer of Ilumäe II and IV settlement sites) are younger than the Late Neolithic and older than the 4th-6th century AD – Lang 2002, 178–179.

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Abbreviations

KSIA – Kratkie soobshcheniya Institute arheoilogii Akademii Hauk SSSR;
LTAA - Lietuvos TSR archeologijos atlas, I. Akmens ir žalvario amžiaus paminklai. Vilnius.

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Early Farming and Metal Working in Boreal Russia (Zhizhitsa Lake Sites Case Study)

B.S. Korotkevich,[1] A.N. Mazurkevich[1] and G.I. Zaitseva[2]

[1] *State Hermitage Museum, St. Petersburg, Russia*
[2] *Institute for History of Material culture, Russian Academy of Sciences, Russia*

Introduction

The appearance and early development of agriculture and stock-breeding and metallurgy in the boreal forests of northwestern Russia remains a controversial and insufficiently studied issue. The present article focuses on the area of Zhizhizsa Lake in North-western Russia (Fig. 1). First archaeological sites of Iron Age were discovered by Stankevich in the course of archaeological surveys conducted in the 1940s and 1950s (Stankevich 1976). Naumovo, a stratified Late Neolithic-Early Bronze Age lake settlement was discovered by Miklyayev and Semenov in 1996 and systematically excavated since that time (Miklyayev and Semenov 1979). The Early Iron Age, Anashkino, is being systematically excavated since 1991. In 2001 and 2002 multidisciplinary field studies of both archaeological and environmental sites have been conducted by the INTAS-sponsored expedition.

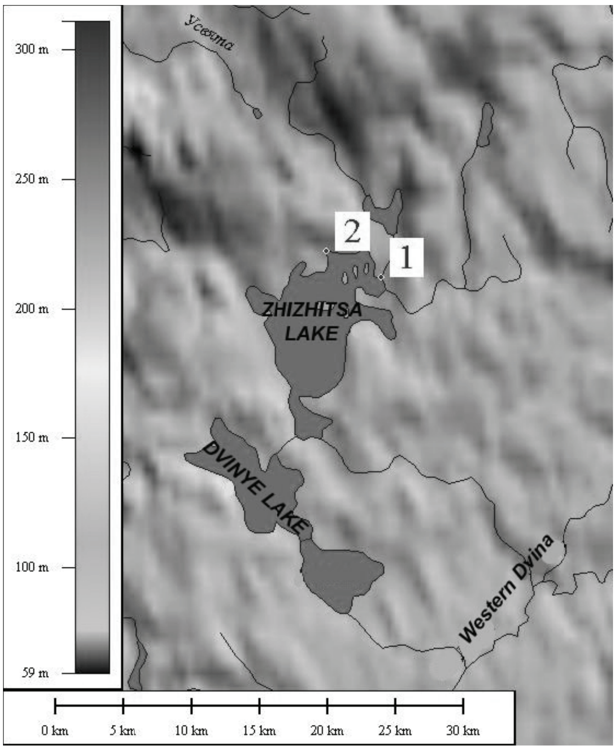


Fig. 1. Zhizhitsa Lake. General setting
Key: 1 – Naumovo site; 2 – Anashkino hill-fort.

Present-day environment

The Lake Zhizhitsa (Zhizhitskoe) is located in the south-eastern part of the Pskov Oblast, 70 km east of the town of Velikie Luki, on the Moscow-Riga railway line (Fig. 1).

This area lies in the distal zone of the Last (Valdai-Weichselian) glaciation, on the southern edge of the limit of the terminal morainic zone (Fig. 2). The surrounding terrain includes the terminal morainic hills reaching 190-200 m in the north and the west, flanking the evenly undulated sandy fluvio-glacial terrain at an altitude of 166-180 m, in the east and the south (Malakhovsky & Markov 1969).

Starting with the maximum extension of the Valdai (Weichselian) ice-sheet at 20-18 ka, a system of ice-dammed lakes encompassed the upper catchment of Western Dvina and Dniepr Rivers (Kvasov 1975). Their level dropped as the glaciers retreated, opening new thresholds. Following the glacial recession, the Orsha-Surazh basin emerged with an threshold at 180 m. After the abrupt fall of the Baltic Ice Lake at 11560 cal years BP (Agrell 1979; Andren *et al.* 20020, the entire hydrological area in the Western Dvina catchment collapsed. A chain of small lakes emerged in the place of the ice-dammed basin. The present-day lakes in that area are the remains of huge Late Glacial lakes. The Lake Zhizhitsa is connected with the small lake Kodosna in the north. In the south hrough the system of lakes Zhekto – Dvin'ye – Velinskoe and the river Dvinka, the Lake Zhizhitsa is connected with the Western Dvina River.

Quaternary deposits vary in thickness between 25 and 100 m, and consist predominantly of fluvio-glacial sand and gravel with the boulder clay forming the morainic hills. The soils are podzolic; soddy-podzolic on fluvio-glacial sands; superficially podzolic on morainic uphills.

The present-day climate in that area is moderately continental, with a temperature, -7÷-10°C in January and 17-18°C in July, and a rainfall of 500-700 mm, mostly in summer. This area belongs to the East European mixed broadleaved-coniferous forests (or 'cool-mixed forest biome' according to Prentice *et al.*, 1992).

Temperate summer-green formations are represented by mixed oak forests, which are found mostly on the clayey soil of the morainic hills. Boreal evergreen conifers consisting mostly of pine forests cover the sandy outwash plain and glacio-lacustrine landforms. Spruce forests are usually restricted to the lower levels of the morainic hills and outwash plain. An intensive felling of forests started in the 13th -14th centuries and was much increased after the 1860s. The woodland currently occupies less than 20% of the originally forested area. The secondary forests consist of birch, and alder with shrubs (Lubimova 1967). Bottomland and dry meadows, bogs and mires occupy about 40% of the total area. Agricultural plots take up the remaining 40%. Main staple crops are rye, wheat and flax.

Methods

Our field investigations were carried out in the summer of 2001 and 2002. They included a detailed archaeological survey with the use of GPS equipment. The coordinates and altitude of all archaeological sites and major landforms were measured and recorded. Subsequently, the recorded data were processed with the use of GIS technology (ArcView package) and presented in the form of digitized electronic maps and 3D projections.

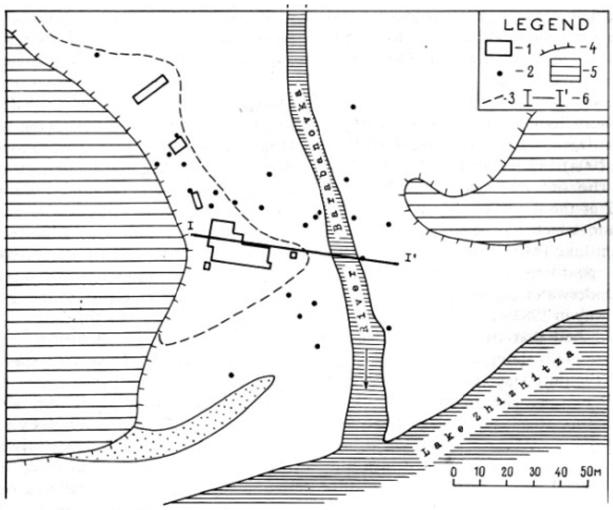
Anashkino, an Iron Age settlement is systematically excavated by archaeological teams of the State Hermitage since 1991. The samples taken at this settlement were ^{14}C dated at the Radiocarbon Laboratory of the Institute for History of Material Culture at St. Petersburg. The environmental evidence, obtained for that area is discussed in the Chapter X.

Results

1. Late Neolithic – Bronze Age.

The deposits of Late Neolithic – Bronze Age were identified in the course of the excavations of Naumovo, a lake settlement, located in inshore area of the northern part of the Zhizhitsa Lake, in the mouth of the small river, Barabanovka (Fig. 2). Archaeological layers were found in the context of lacustrine and alluvial mineral and organic deposits which reflect considerable changes in the depositional environment (Fig. 3).

The earlier pile structures, found in the layers of lake mud, at 3 m below the surface, belong to the Usvyatian culture. The initial settlement pile settlement emerged at a low stand of the lake level and further developed in the course of its rise. This stage yielded the radiocarbon dates in the range of 3760-2004 calBC.



Naumovo. General setting.
Legend: 1 – excavation blocks; 2 – bore-holes; 3 – limits of the cultural layer; 4 – limits of the flood-plain; 5 – morainic heights; 6 – cross-section I–I'.

Fig. 2. Naumovo site. General location.

Rich pottery assemblage consists predominantly of conic vessels with the rare appearances of flat-bottomed varieties. Pots were manufacturing by pinching the coils and the subsequent smoothing of the surface. The paste was tempered with crushed shells, sand and crushed pottery. The decoration consisted of the impressions of pits, strokes, dots, combs and incised lines, forming simple geometric patterns.

The Usvyatian strata contain 40 species of mammals: elk, brown bear and boar being the most common, and also fur animals: marten, otter and squirrel. Judging by the age groups, the elk was hunted throughout the year. Pike and perch were the most common among the fish. At least 30 edible wild plants were identified in the deposits of pile-dwellings; hazel-nut and water chestnut (*Trapa natans*) were supposedly the main source of plant protein.

The maximum rise of the lake level coincided with the appearance of pile dwellings belonging to the Zhizhitsian Culture (c. 2200 calBC. The main characteristics of the material culture remain unchanged, with the lithic industry becoming more numerous and varied. Flat-bottomed vessels became more numerous, and the sand in the pottery tempering, more common.

In certain areas the lake rose catastrophically and damaged pile structures. Later, the lake level falls again. At this stage new pile dwellings arose, which belonged to the North-Bielorussian culture. The quality of sand-tempered pottery improved, and the number of flat-bottomed vessels increased still further. The common use of the cord impressions as well as the shapes of the vessels find similarities in the Corded Ware and Globular Amphorae assemblages further west. The radiocarbon dates fall into the time-span of 2200-1880 calBC

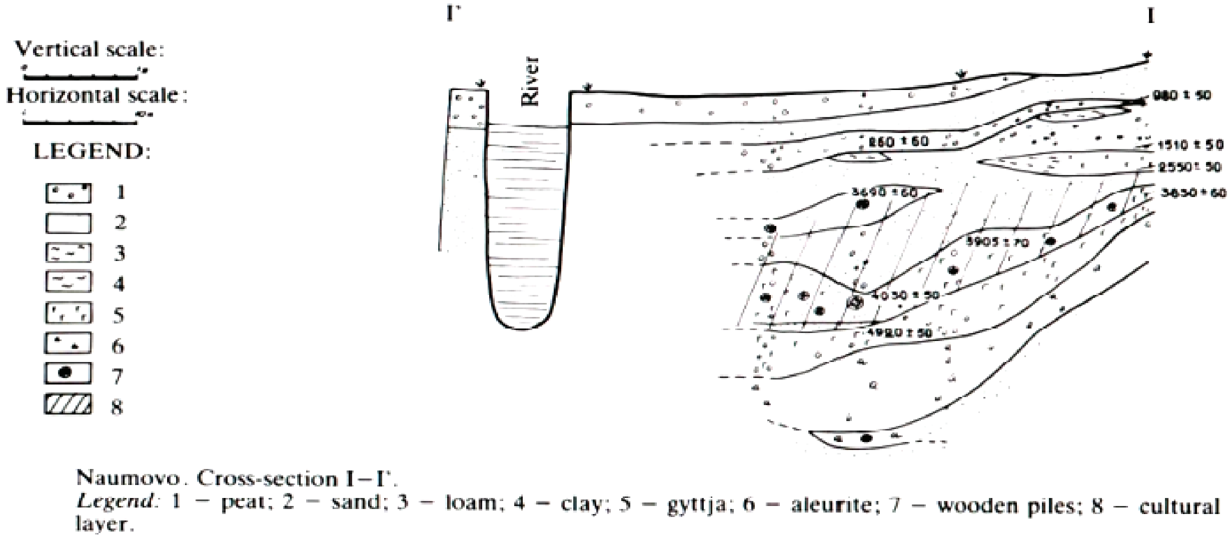


Fig. 3. Naumovo site. Cross-section.

The animal remains of North-Byolorussian at Naumovo include a limited amount of domesticates: cattle, sheep/goat and pig. The corresponding levels at Serteya 2 site (Dolukhanov et al. 2003) include the signals of a swidden-type agriculture. The subsequent rise of the lake level led to the abandonment of the site. After that the tradition of pile dwelling was suspended and never resumed.

2. Iron Age

Following an interval, new sites appear on elevated levels in the vicinity of the lake; they belong to the Uzmenian Culture. Visech, site of that type, is located on the slope of a morainic plateau, facing the mouth of the river Vesecha, 1 km south of Naumovo. The pottery and stone industry has analogies in the North-Bielorussian levels at Naumovo. Several Uzmenian sites yield evidence of iron metallurgy in the form of slag and remains of furnaces.

The subsequent period of the Early Iron Age saw the appearance of the settlements located on top of the morainic hills, traditionally referred to as 'hill-forts' (*gorodishche*). These hills are usually 10 – 15 high with at least one abrupt slope; there is no evidence of artificial fortifications, at least at the initial stage.

Anashkino, hill-fort, located on the top of the southern extremity of a long promontory, stretching into the lake (Fig. 4), part of the terminal morainic hummock terrain, along the northern shore of the Zhititsa Lake. The hill, 15 m high over the lake level, consists of the pebbly morainic till, and flanked on both sides by the creeks flowing in deep valleys.

The excavations of 1991-2001 have exposed 2-meters of archaeological deposits over an area of 144 sq. m. They include three levels of fires, one in the upper, and two, in the lower stratigraphic units.The lower level includes numerous fragments of course hand-made sand-tempered vessels, and bone and antler implements (one-sided harpoons, polishers, awls etc.).

Fig. 4. Anashkino hill-fort. General view.

The next level includes remains of four dwellings located parallel each other in the middle part of the settlement. These were two-chamber rectangular houses deepened into the ground, 10 to 3 m in size, with the post-supported wooden walls. Wooden planks with the traces of supporting posts were found along the longer walls. The posts also divided the houses' interior into two chambers, each having a rectangular open oven, 0.5 by 1.5 m in size, slightly uplifted over the floor. Both the chambers and the ovens were repeatedly rebuilt. One of the reconstructions apparently followed a fire which had partly destroyed the building (Fig. 5).

Material remains found inside the houses included flint flakes, iron and bone arrowheads, flint 'sickle-knives', curved iron knives, bone awls, stone pestles. Among personal adornments were found iron bracelet, iron pin, pendent with an engraved swastika, a bronze plaque with two holes, and perforated animal bones. More than 10,000 fragments of pottery were recorded, they belonged, predominantly, to straight-walled and straight rimmed jars. A boulder wall, 20-30 cm tall and 70-80 cm wide, surrounded the settled area.

Fig. 5. Anashkino hill-fort. Burnt structures.

Greater part of animal remains found at this site, was retrieved from this level. The bones were fragmented, implying that the bodies of slaughtered animals were butchered at the site. Mammal bones were often affected by fire. The bones of wild animals outnumber the domesticates at the rate 58:62. Beavers and cattle dominate the assemblage; elk, marten and bear, as well as fish bones, were also numerous. All dwelling structures of this level perished in a catastrophic fire.

Domesticated animals, mostly cattle, became dominant in the faunal remains of the third period , in the aftermath of the fire. Hunting at this stage was oriented exclusively towards the procurement of fur animals, and probably were intended for long-distance trade. Judging from the number of fish bones, fishing retained its importance. No direct evidence of agriculture is available, except a single find of a stone mortar.

The upper level of the Anashkino settlement includes remains of a blacksmith workshop. They include the furnaces, blacksmith's equipment, ore and slag. The poles and logs from the wooden roof were found in between the rows of furnaces. Among the finds one note both the blacksmith's instruments and accomplished products: 'knives-sickles' and curved knives with wooden handles, iron hooks, chisels with a narrow blade and a broad butt, and other implements.

The nodules of iron ore were collected on the shores of lakes and banks of streams, and ground to powder on special grinding stones. These stones were found at the sites, and the traces of ferric oxide were found in their fissures. Stone hammers and anvils were used for forging. Various rocks were used ass whetstones for sharpening the iron implements. A large plate with three chiseled hollows was supposedly used as an oil-stone; the hollows contained the traces of solver, ferric oxide, as well as copper and tin oxides, and calcium carbonate; the traces of natural fat were identified on the severely scrapped surface.

The last major fire occurred shortly before the blacksmith shop ceased to exist. Following it two rectangular structures arose, a dwelling house and a workshop. The dwelling house, 6,8 by 3 m in size, was built of wooden logs about 10 cm wide, and included two chambers. The living room included a stone oven in one corner 1.6 m in diametre. The workshop included three furnaces, of the same construction as the old ones, which were built exactly above them.

Animal remains from this level are still more fragmented and 67 % of the total asemblage were unidentifiable. In the workshop's deposits sheep and goat became dominant, with the hare coming nest, and much lesser percentage of other wild animals and fish.

Another IA settlement, Mikhailovskoye, is located on the even top of the morainic ridge stretched along the Vesecha river, close to its mouth in the north-eastern part of he Zhizhitsa Lake. The excavations by Stankevich (1960) exposed 188 sq. m. of archaeological deposits, with the thickness of 1.5-2 m. The Early IA which was partially preserved includes two oval hollows which were identified as 'ground dwellings'.

Khmelevo is situated on the morainic ridge on the eastern shore of the Kodosna lake, north of the Zhizhitsa Lake connected with the later by a sinuous strait. Archaeological deposits were found in an area of 30 by 40 m, on the upper durface and the lake-oriented slope. Stankevich's sondage has produced the bluff-colour thick-walled hand-made pottery and numerous animal and fish remains (Stankevich 1960).

Yamishche, the settlement located on a sandy morainic ridge elevated above the surface of evenly undulated fluvio-glacial plain south of the Zhizhitsa Lake. The settlement faces the river Zhizhitsa which flows from the interconnected Zhizhitsa and Zhekto Lakes into the Western Dvina river. The settlement was never excavated. Iron Age pottery was collected on a circular surface 40 b in diameter. A wall in clearly vivibke at the bottom of the hill.

Discussion

The initial appearance of a lake settlement belonging to the Usvyatian culture occurred at ca. 5000 and 4000 uncal BP. Their appearance marks the interruption in cultural continuity and coincides with the major change in the environment. The diatom analysis signals a fall of the level of the alkaline eutrophic lake. Likewise the previous stage, this likely reflects a wider trend. The low water level at c 4500 has been recorded in southern Finland (Samaja-Kojonen 2001).

The pollen analysis shows considerable areas taken up by the broad-leaved forests apparently restricted to the morainic upland. Sandy fluvio-glacial plains were taken up by the pine forests which content markedly increased. At this stage one note a considerable decrease in the abundance of *Ulmus,* and a gradual decline of other broad-leaved species, *Quercus, Tilia, Fraxinus* and also *Corylus.* Withis goes together with an increased rate of herbs, Poaceae and Cyperaceae, and the occurrence of heliophytic herbs, *Artemisia* and Chenopodiaceae. This may be viewed as a proxy evidence of swidden-type agriculture.

The faunal and botanical records indicate that the livelihood of Usvyatian lake dwellers firmly relied on wild-life resources. Yet at least 30 edible wild plants were used for food. Processed hazel-nut and water chestnut (*Trapa natans*) became the surrogate of bread and the main source of plant protein. It is likely that this was combined with swidden-type agriculture on the slopes of the morainic hills.

Grains of cereal pollen were identified in the Usvyatin layers in the Serteya Valley, 80 km to the south (Dolukhanov et al. 2003).

Stratigraphic evidence shows that the settlement emerged in the northern shallow coastal area of the lake at the time when its level was low. As the lake level rose, the subsequent constructions were made on elevated levels. The level reached its peak at 3800-3700 BP, when the pile dwelling belonging to the Zhizhitsian culture. The diatoms show that this was a mesophitic lake with a body of free water and a macrophyte coverage. At this stage the settlement reached its maximum size.

After a fall, a new rise of the lake level occurred. It coincided with a new stage of the lake settlement attributed to the North-Byelorussian culture (3700-3200 BP uncal). According to the diatom evidence this settlement existed in a mesophitic lake with an intense macrophyte coverage

The animal remains of North-Byolorussian sites include a limited amount of domesticates: cattle, sheep/goat and pig. Corresponding levels at Serteya sites (Dolukhanov et al. 2003) show regular occurrences of the pollen of *Cerealea*, weeds (notably, *Plantago lanceolata*) and apophytes. This may be viewed as a proxy evidence of swidden-type agriculture.

The entire sequence comprising the Usvyatian, Zhizhitsian and North-Byolorussian levels shows a considerable degree of cultural continuity. As no earlier sites were found in this area, it seems likely that the Yusvyatian population penetrated into the Zhizhitsa Lake from the south and the west via numerous water channels. Based on the similarities of pottery ornamental patterns Miklyayev (1972) argued that the Usvyatian forms an easternmost variety of the Central Europe's Funnel Beakers Culture.

The later levels reflect an increased impact of the Corded Ware and Globular Amphorae cultures. The elements of corded ornamentation appeared already on the Usvyatian wares.

In the 1980s an entire corpus of the Naumovo pottery was analysed with the use of Principal Components analysis (Dolukhanov and Fonyakov 1984). The total of 108 ornamental patterns forming 16 groups and 32 groups were processed. This analysis identified two clear clusters corresponding respectively to the Usvyatian and North-Byolorussian entities, and loose intermediate one, the Zhizhitsian. Based on this evidence, we reached a conclusion that the pottery reflects a gradual penetration of new (Corded Ware/Globular Amphorae) population that became gradually absorbed by the indigenous one.

Following an interval, new sites appear on elevated levels in the vicinity of the lake; they belong to the Uzmenian Culture. So far no radiocarbon dates for these sites are available. Using indirect evidence, they age may be assessed as between 3500 and 2500 BP uncal.

The pottery and stone industry having direct analogies at North-Byelorussian sites, continuity both in culture and subsistence seems apparent. A new element consisted in iron metallurgy. Iron slags and the remains of furnaces were identified at several Uzmenian sites. Iron metallurgy was based on the outcrops of 'bog iron ore', hydrated iron oxide minerals formed by precipitation of groundwater flowing into wetlands. In many parts of northern Europe and Northern America bog iron ore was mined from the banks of the streams until the mid-19th century.

The most spectacular changes in the settlement pattern occurred in the mid-1st millennium BC with the appearance of early Iron Age hill-forts. In contrast to the preceding settlements, these sites were located on the elevated ridges of morainic uphills. The hill-forts which at their initial stage had no artificial fortifications, were invariably strategically located on the elevations, which controlled the surrounding terrain.

The settled area on the top of the hill was protected by the stone wall and consisted of standared two-chamber rectangular houses. These housed were made of wooden planks and supportted by posts, with stone laid ovens inside and allegedly had gable roofs.

The animal remains from the lower levels of Iron Age settlements are dominated by wild animals which outnumber the domesticates by 58:62. Beavers and cattle dominate the assemblage; elk, marten and bear, as well as fishbones were also numerous.

Domesticated animals, mostly cattle, became dominant in the faunal remains of the later period. Hunting at this stage was

Table 1. Animal remains from Anashkino Hill-Fort

Animal species	Layer 1 'Workshop'		Layer 2 Settlement	
	Bones/ individuals	%	Bones/ individuals	%
Hedgehog	--	--	1/1	0.05
Beaver	160/12	17.3	446/21	27.0
Squirrel	1/1	0.1	1/1	0.05
Hare	228/11	24.7	112/8	6.8
Polecat	4/3	0.4	11/2	0.7
Marten	31/10	3.4	106/11	6.4
Badger	3/1	0.3	12/4	0.7
Otter	2/1	0.2	11/2	0.7
Wolf	--	--	1/1	0.05
Fox	48/4	5.2	84/3	5.1
Brown bear	18/2	1.9	76/2	4.6
Lynx	--	--	2/1	0.1
Wild boar	--	--	6/2	0.3
Elk	28/2	3.0	93/5	5.6
Wild species total		56.5		58.2
Sheep/goat	233/13	25.2	277/15	16.8
Cattle	143/6	15.5	350/13	21.2
Pig	6/2	0.7	--	--
Dog	8/3	0.9	21/4	1.3
Horse	11/1	1.2	41/5	2.5
Domesticated total		43.5		41.8
Mammals total	924	100	1651	100
Fish	383		1560	
Brids	25		22	
TOTAL	1332		3233	
Undefined large animals	460		1064	
Undefined small animals	2229		3608	
Undefined total	2689		4672	

oriented exclusively towards the procurement of fur animals, and probably were intended for long-distance trade. Judging from the number of fish bones, fishing retained its importance.

No direct evidence of agriculture is available, except rare finds of stone mortars and iron 'knives-sickles'. Evidence of agriculture in the basin of the Western Dvina came from the Iron Age hill-fort of Podgai, 30 km to the north-east, which belonged to a younger stage (Petrov 1960). The finds included grains of bread wheat *(Triticum aestiovum)* and naked six-row barley *(Hordeum vulgare* var. *nudum)*. One may suggest that the same plants were cultivated in the Zhizhitsa area. Early agriculture was apparently of slash-and-burn (swidden) type. Ethnographical evidence cited by Russian (Gromov 1968) and Finnish writers (Sarmela 1987) show that in northern Russia, Finland and Karelia 'burn clearances' were cultivated in sloping and hilly terrain. In our area, the may have been slopes of the morainic hills.

The Iron Age sites of the Zhizhitsa Lake bear evidence of the developed iron metallurgy: with the remains of blacksmith workshops identified at Anashkino and other sites in that area. They include the furnaces, blacksmith's equipment, ore and slag, accomplished products. The blacksmith workshops were protected by artificial structures erected above. Remarkably the faunal remains fond at the workshop are different from the rest of the site and consist predominantly of ovicarpids.

Hence the available materials demonstrate considerable changes in the cultural affiliation and economic structure that occurred in the middle of the 1st millennium BC that was at least partly due to the influx of a new population stemming from the south-west.

Cultural continuity apparent in the pottery types shows that the bulk of the population was of a local origin. A new and highly successful economic strategy combined the developed iron metallurgy based on the local iron bog ore, with swidden-type agriculture with hunting and fishing. The subsequent development saw a gradual development of stock-breeding based on rich lake meadows. The common occurrence of fires implies the incidents of warfare. The naturally and artificially protected hill-forts were apparently reserved for rapidly developing local elite, which consisted of the military and craftsmen.

Acknowledgements

The writers express they deep appreciation to Professor Tony Stevenson, Provost, School of Humanities and Social Sciences at the University of Newcastle upon Tyne, who carefully read the manuscript and made valuable suggestions. The work was supported by the INTAS (Project 00-0016).

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Mesolithic and Neolithic in North Eastern Europe

P. Dolukhanov,[1] M. Lavento[2] and K. German[3]

[1] *School of Historic Sciences, Newcastle University, UK*
[2] *Department of Archaeology, University of Helsinki, Finland*
[3] *Department of Archaeology, Kizhi National Park and Museum, Karelia, Russia*

The initial human settlement of Fennoscandia, including the Baltic Sea basin, occurred during the final stages of the Last Ice Age, resulting from the collapse of extensive Upper Palaeolithic networks. It had been shown (Dolukhanov 1986; Dolukhanov et al. 2002) that during the Last Glacial maximum (LGM), 25-21 ka BP, the Palaeolithic population in northern Eurasia massively declined. The surviving population concentrated in two major refugia. One of these was located in the west and included Cantabria and south-western France. Another one was focused on the 'periglacial' areas of Eastern Europe and encompassed the basins of the Dniestr, Dnepr and Don rivers. As the distribution of the frequencies of the radiocarbon dates suggests (Dolukhanov et al. 2001) during the LGM the population densities in the 'periglacial' areas increased whereas large areas of Central Europe were populated sparsely (Terberger and Street 2002).

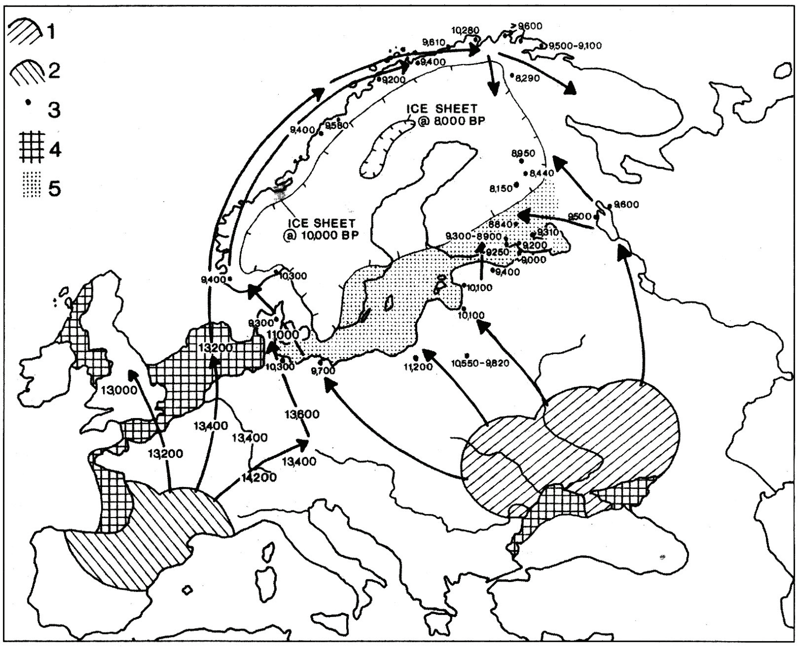


Fig. 1. Postgalacial colonisation of Northern Europe (Zvelebil 2008)

The colonisation of Northern Europe (Fig. 1) proceeded during the Late Glacial period in an environment of rising temperature and humidity combined with hunting pressure, caused by the depleted big game resources on which the livelihood of Palaeolithic groups basically depended (Housley t al. 1997). After c. 12,000 Cal BC, the principal hunting prey, first the mammoth and later the bison, disappeared, and large sites vanished in the Upper Palaeolithic core area of the Dniepr and Don Basins. Gamble et al. (2006) based on the frequencies of radiocarbon dates, identified several stages in the Late Glacial human dispersion:

Initial: 19.5 – 16 kyr;
Main expansion: 16 – 14 kyr;
Population stasis: 14 – 13 kyr;
Population contraction: 13 – 11.5.

It has been suggested (Dolukhanov 1986, Nuñez 1997, Bjerck 2008; Zvelebil 2008), that the colonization of the Europe's North proceeded via two ways (Fig. 1). The groups that pursued the western route advanced from the north-central Europe following the ice-free corridor all along the western Norwegian coastline. On the ground of typological similarities the Ahrensburg 'technocomplex' in northern Germany is attested as its centre of origin. The northbound movement proceeded at a high speed (supposedly with the use of boast) and resulted in the emergence of early Komsa industries at around 10200-8900 BP (9500-8900 cal BC) (Bjerck 2008). Originally based on reindeer hunting, the expanding groups subsequently turned to the exploitation of marine resources, primarily, seal hunting.

Another route of colonisation stemmed from the periglacial area on East European Plain. During the Late Glacial period, a new network consisting of smaller sites arose along the river ways that linked numerous lakes that arose in the ice-freed areas. The subsistence was apparently oriented on the pursuit of seasonally migrating ungulates (the reindeer, in the first place). These movements are documented in the distribution of industries with a component of tanged points (the Ahrensburgian and Swiderian), which are present over the entire area of East European Plain, extending as far as the Crimea.

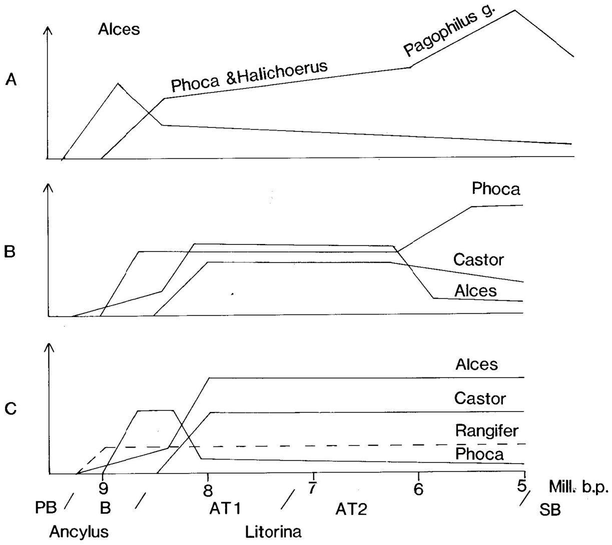


Fig. 2. Time trend in the Mesolithic hunting (Matiskainen 1989)

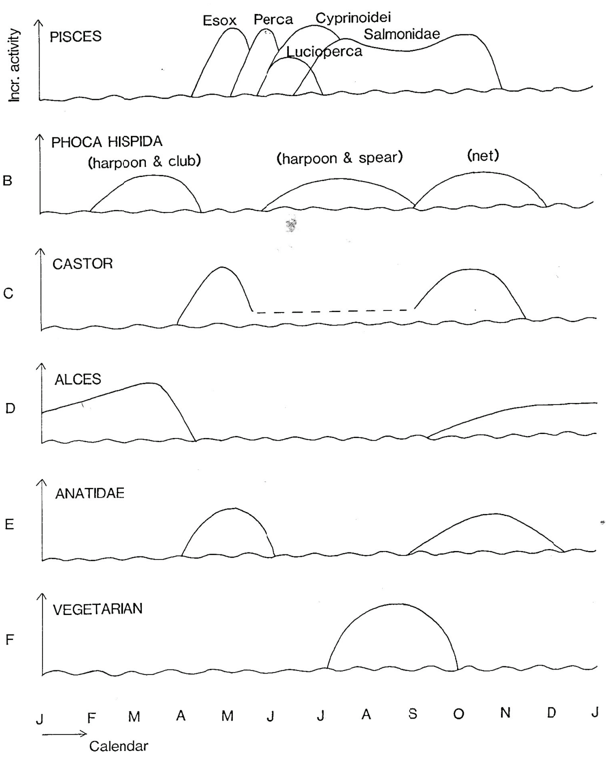


Fig. 3. Seasonal changes the Mesolithic hunting (Matiskainen 1989)

The earliest penetration of humans into the north-eastern Baltic basin, apparently from the north-east, is documented by the site of Antrea-Korpilahti near Vyborg (Pälsi 1915/1920). Remains of a willow bark net, and bark net floats from this site were later radiocarbon-dated to 9200-8250 BC (Matiskainen 1989, 71). Judging from the location of the site and its geological context, the Mesolithic artefacts were originally deposited in a shallow lagoon, or in a shallow

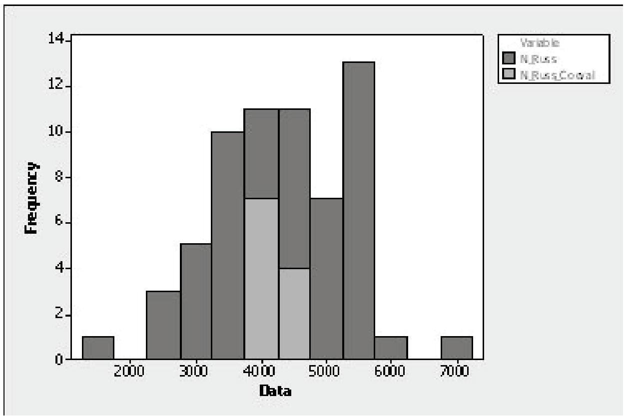


Fig. 4. Frequencies of radiocarbon dates for early Neolithic sites

channel which was part of the Ladoga-to-Baltic drainage system. A comparable date (9300±75 BP or c 8600 c al BC) has been obtained for Saareneoja dwelling site in Joutseno (Jusila et al. 2007). The subsequent development of early settlers in Finland and adjacent areas in the east resulted in the emergence of a new network of sites with distinct typological affinities, which had been traditionally classified as 'Suomusjarvi' Mesolithic culture, consisting of communities which Zvelebil (2008, 41) views as 'delayed-return foragers'.

Existing faunal records suggest that these communities were based on seasonally-adjusted broad-spectrum subsistence with a definite time trend (Matiskainen 1989, (Figs 2, 3).

The hunting of seals (which appeared in the Baltic Sea and the connected water systems no later then 9500, Ukkonen 2002), played an important part in the Mesolithic economies. It acquired even gained in importance with the appearance of pottery-bearing cultures, when the ringed seal (*Phoca hispida*), was supplemented by harp seal *(P. groenlandica*).

Large Mesolithic cemeteries, such as Oleni Ostrov and Popovo in Russian Karelia (Gurina 1956, Oshibkina 1996) imply the occurrence of 'descent-based societies organised into sequential hierarchies' (O'Shea and Zvelebil 1985; Zvelebil 2008, 38).

The early pottery-bearing sites in Finland classified as the Early Comb Ware (Ka I:1 style or Sperrings 1) have been first identified on the south Finnish coast by Europaeus-Äyräpää (1925). Based on their relation to the raised coast-lines, this writer suggested their relative chronology as the oldest pottery-bearing culture in that area. Later these sites were correlated by Hyyppä (1937) with the Litorina II shore-line. Siiriäinen (1970, 1982) linked it up with the maximum transgression of Pajänne Lake that occurred at c. 5,200 BC. The highest frequencies of radiocarbon dates (Table 1, Fig. 4) fall within the time-span of 6500-5500 cal BC.

Table 1. Radiocarbon dates of early pottery sites in Finland and northern Russia.

Site	N. lat	E. long.	Index	Material	Age bp	*si* [yr]	Age BC
Heppo-Jarvi	60°11'	30°35'	Le-1411	charcoal	6380	60	5480-5250
Kurkijoki	60°11'	29°53'	Le -6928	charcoal	6400	600	5900-4600
Kurkijoki	60°11'	29°53'	Le -6929	charcoal	7900	80	7030-6640
Ust-Rybezhna	60°22'	32°53'	Le -405	charcoal	6380	220	5560-5060
Prilukskaya	61°18'	42°21'	Le -4814	charcoal	6350	60	5372-5230
Prilukskaya	61°18'	42°21'	Le -4813	charcoal	6680	70	5598-5488
Tudozero 5	61°09'	36°26'	Le -6699	charcoal	6075	20	5000-4850
Tudozero 5	61°09'	36°26'	Le -6700	charcoal	6600	25	5610-5480
Sheltozero 10	61°21'	35°21'	TA-1311	charcoal	4330	80	3088-2788
Sheltozero 10	61°21'	35°21'	TA-1308	charcoal	6400	80	5428-5270
Sheltozero 10	61°21'	35°21'	TA-1313	charcoal	5960	70	4924-4782
Sheltozero 10	61°21'	35°21'	TA-1312	charcoal	6480	70	5446-5413
Chernaya Rechka I	61°45'	36°02'	Le -3745	charcoal	4185	150	2920-2500
Chernaya Rechka I	61°45'	36°02'	TA-1633	charcoal	4700	80	3622-3378
Chernaya Rechka I	61°45'	36°02'	TA-1651	charcoal	5500	100	4460-4250
Chernaya Rechka I	61°45'	36°02'	TA-1550	charcoal	5800	100	4770-4540
Chernaya Rechka I	61°45'	36°02'	TA-1648	charcoal	5950	100	4950-4720
Chernaya Rechka I	61°45'	36°02'	TA-1634	charcoal	6200	100	5250-5000
Chernaya Rechka I	61°45'	36°02'	TA-2203	charcoal	5420	100	4360-4090
Chernaya Rechka I	61°45'	36°02'	TA-2353	charcoal	5930	80	4980-4722
Shettima 1	62°20	37°03	TA-1152	charcoal	6400	150	5520-5090
Pegrema 1	62°35'	34°26'	Le -1029	charcoal	4980	60	3906-3696
Pegrema 1	62°35'	34°26'	TA-493	charcoal	4200	50	2882-2668
Pegrema 1	62°35'	34°26'	TA-492	charcoal	4780	50	3638-3392
Pegrema 1	62°35'	34°26'	TA-541	charcoal	5145	110	4080-3790
Pegrema 2	62°35'	34°26'	TA-808	charcoal	4550	90	3370-3096
Pegrema 2	62°35'	34°26'	TA-811	charcoal	5070	120	3980-3710
Pegrema 3	62°35'	34°26'	TA-813	charcoal	4240	90	2918-2624
Pegrema 9	62°35'	34°26'	TA-1161	charcoal	6510	90	5559-5328
Chernaya Guba 3	62°49'	34°52	TA-1890	charcoal	4950	100	3920-3640
Chernaya Guba 4	62°49'	34°52	TA-2024	charcoal	4580	60	3492-3110
Cernaya Guba 9	62°49'	34°52	TA-2140	charcoal	4340	80	3088-2880
Cernaya Guba 9	62°49'	34°52	TA-2023	charcoal	4840	80	3706-3394
Cernaya Guba 9	62°49'	34°52	TA-1315	charcoal	6530	80	5563-5340
Yerpin Pudas	63°21'	34°29'	TA-795	charcoal	5240	50	4216-3984
Yerpin Pudas	63°21'	34°29'	TA-800	charcoal	5460	80	4446-4168
Yerpin Pudas	63°21'	34°29'	TA-413	charcoal	5825	80	4782-4588
Yerpin Pudas	63°21'	34°29'	TA-472	charcoal	5860	100	4840-4590
Yerpin Pudas	63°21'	34°29'	TA-799	charcoal	5990	100	4934-4810
Yerpin Pudas	63°21'	34°29'	TA-344	charcoal	6510	120	5565-5380
Besovy Sledki	64°23'	34°26'	TA-471	wood	4495	60	3334-3048
Besovy Sledki	64°23'	34°26'	TA-431	wood	5000	60	3926-3706
Besovy Sledki	64°23'	34°26'	TA-522	wood	5180±60	60	4078-3820
Besovy Sledki	64°23'	34°26'	GIN-129	wood	5430	50	4336-4244
Choinovty 1	64°25'	49°57'	Le -5164	charcoal	4640	25	3496-3362
Choinovty 1	64°25'	49°57'	Le -1729	charcoal	5320	60	4230-4044
Choinovty 2	64°25'	49°57'	Le -6050	charcoal	4880	20	3693-3644
Choinovty 1	64°25'	49°57'	Le -4495	charcoal	5750	70	4700-4522
Chavanga	66°06'	37°05'	Le -1222	charcoal	5560	80	4468-4336
Tsaga I	67°42'	35°04'	Le -4293	charcoal	3090	75	1426-1218
Tsaga I	67°42'	35°04'	Le -4292	charcoal	5020	250	4220-3520
Tsaga I	67°42'	35°04'	Le -971	charcoal	4690	70	3616-3370
Tsaga I	67°42'	35°04'	Le -1087	charcoal	5760	160	4790-4400

Ust-Drozdovka	68°17'	38°28'	Le -1332	charcoal	5510	100	4460-4250
Mayak 2	68°27'	38°22'	Ле-1992	charcoal	4630	50	3502-3346
Mayak 2	68°27'	38°22'	Le -1994	charcoal	5190	60	4214-3828
Mayak 2	68°27'	38°22'	Le -2632	charcoal	5390	60	4330-4154
Mayak 2	68°27'	38°22'	Le -1995	charcoal	5760		4690-4536
Ostra Jansmyra	60°16'	20°00'	Ua-17856	charred crust	6185	120	5500-4800
Ostra Jansmyra	60°16'	20°00'	Ua-7856	charred crust	6100	75	5260-4800
Ostra Jansmyra	60°16'	20°00'	Ua-17855	charred crust	6065	80	5300-4700
Vargstensslatten	60°16'	20°00'	Ua-17859	charred crust	6165	75	5300-4850
Vargstensslatten	60°16'	20°00'	Ua-17857	charred crust	5990	90	5250-4600
Vargstensslatten	60°16'	20°00'	Ua-17858	charred crust	5990	110	5070-4690
Kraviojankangas	61°15'	22°20'	Hel-1380	charcoal	6060	170	5400-4500
Kraviojankangas	61°15'	22°20'	Hel-1382	charcoal	5550	100	4700-4050
Kraviojankangas	61°15'	22°20'	Hel-1381	charcoal	5310	110	4400-3800
Konjonperä	60°59'	23°02'	Hel-2376	charcoal	5790	140	5000-4300
Jokkavaara	66°27'	26°04'	Hel-1619	charcoal	5860	110	5000-4450
Jokkavaara	66°27'	26°04'	Hel-1620	charcoal	6120	110	5350-4750
Kiikarusniemi	64°09'	28°23'	Hel_1750	charcoal	6150	110	5350-4750
Tainiaro	65°51'	25°29'	Hel_2107	charcoal	5780	110	5900-4350
Tainiaro	65°51'	25°29'	Hel_2108	charcoal	5800	100	5900-4400
Tainiaro	65°51'	25°29'	Hel_2109	charcoal	5850	100	5900-4400
Mylläri	62°39'	21°48'	Hel_2112	charcoal	5350	110	4450-3950
Mylläri	62°39'	21°48'	Hel_2113	charcoal	5220	140	4350-3700
Räätäkangas	64°01'	28°44'	Hel_2294	hearth	5440	100	4460-4000
Nellim	68°42'	25°45'	Hel_2678	hearth	6000	120	5300-4550
Tainiaro	65°51'	25°29'	Hel_2977	charcoal	5410	120	4500-3950
Tainiaro	65°51'	25°29'	Hel_2978	charcoal	5760	120	4950-4350
Tainiaro	65°51'	25°29'	Hel_2979	charcoal	5430	120	4500-3950
Jokkavaara	66°27'	26°04'	Hel_3025	charcoal	5930	150	5250-4450
Jokkavaara	66°27'	26°04'	Hel_3026	charcoal	6200	110	5500-4800
Jokkavaara	66°27'	26°04'	Hel_3027	charcoal	5620	130	4800-4100
Jokkavaara	66°27'	26°04'	Hel_3028	charcoal	5650	140	4850-4150
Jokkavaara	66°27'	26°04'	Hel_3029	charcoal	5940	100	5100-4500
Jokkavaara	66°27'	26°04'	Hel_3030	charcoal	5660	130	4800-4200
Latokangas	65°04'	26°09'	Hel_3255	charcoal	3970	130	2900-2100
Latokangas	65°04'	26°09'	Hel_3256	charcoal	3880	110	2700-1950
Latokangas	65°04'	26°09'	Hel_3257	charcoal	4120	110	2950-2350
Latokangas	65°04'	26°09'	Hel_3258	charcoal	2360	110	800-150
Saha	64°42'	28°10'	Hel_3259	charcoal	6300	120	5500-4900
Kultisalmi	66°05'	27°07'	Hel_3655	charcoal	5360	90	4350-3980
Multavieru	62°55'	29°21'	Hel_3911	charcoal	5550	120	4700-4000
Rönkönraivio	68°36'	27°24'	Hela-38	charred crust	5830	85	4860-4490
Turpeenniemi 5	66°04'	25°32'	Hela-40	charred crust	5520	185	4800-3950
Latokangas	65°04'	26°11'	Hela-42	charred crust	5790	105	4900-4350
Jokkavaara	66°27'	26°03'	Hela-57	charred crust	5070	80	4040-3690
Tainiaro	65°52'	25°34'	Hela-79	charred crust	5920	110	5050-4500
Tainiaro	65°52'	25°34'	Hela-80	charred crust	5940	100	5100-4500
Latokangas	65°04'	26°11'	Hela-146	charred crust	5795	90	4850-4450
Pyhänniska	64°48'	26°15'	Hela-148	charred crust	6140	105	5350-4800
Roinila	64°46'	26°19'	Hela-149	charred crust	5975	105	5250-4455
Vepsänkangas	64°59'	26°14'	Hela-128	charred crust	5995	65	5050-4710
Vepsänkangas	64°59'	26°14'	Hela-129	charred crust	6020	80	6080-4710
Vepsänkangas	64°59'	26°14'	Hela-235	charred crust	6065	75	5210-4770
Vepsänkangas	64°59'	26°14'	Hela-312	charred crust	5990	60	5070-4710
Kuorikkikangas	3568346	7326818	Su-2681	charred crust	5750	110	4810-4350

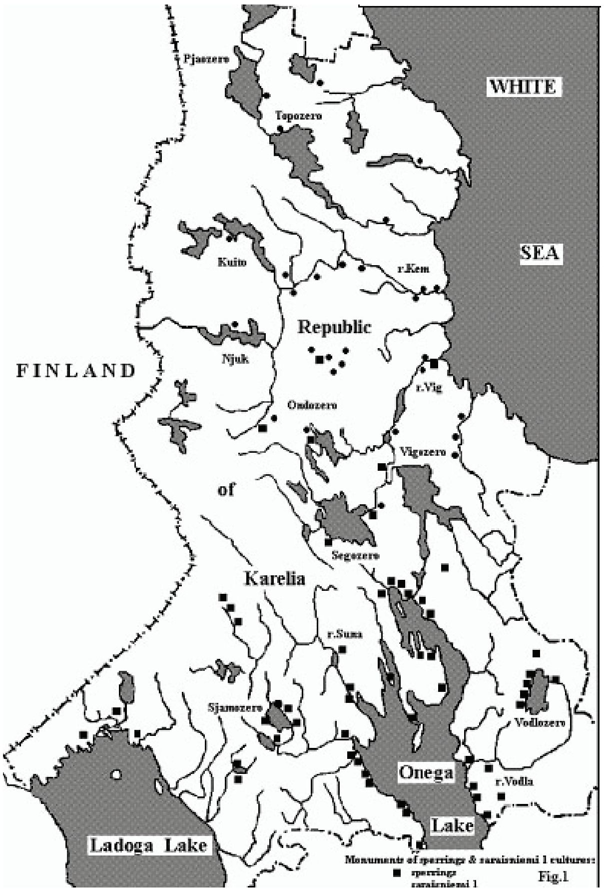


Fig. 5. Sperrings and Säräisniemi sites in Russian Karelia (German 2006)

The distribution area of sperrings-type site concentrates in Southern Finland, the Åland Islands, and Russian Karelia (**Fig. 5**).

The settlement pattern remained basically the same as in the preceding Mesolithic period. The sites were located along the sea and lake shorelines and the connecting waterways.

As show the analysis of faunal remains and the stable isotope analysis of human bones from the related sites in Sweden (Fornender 2006), the diet of early pottery-making communities was based on the consumption of seals supplemented by marine fish.

German (2002) distinguished several types amongst the early Sperrings ware (Figs 6 a-d):

1. Large vessels with the mouth diameter of 30-50 cm, the walls 0,8-1,3 cm thick, either rounded or pointed bottoms;
2. Smaller vessels with the mouth diameter of 20-30 cm, the walls 0,4-0,7 cm thick, either straight or slightly profiled (bent outside or inside) and slanting or pointed bottoms (most common variety);
3. Small round-bottomed cups with the mouth diameter of 20 cm, walls 0,4-0,6 cm. thick, rims strait and flattened, more rarely, rounded or cut inside;
4. Miniature round-bottomed saucer-like pots with the mouth diameter of 12 cm., walls 0,3-0,5cm (rarely, up to 0,7 cm) thick.

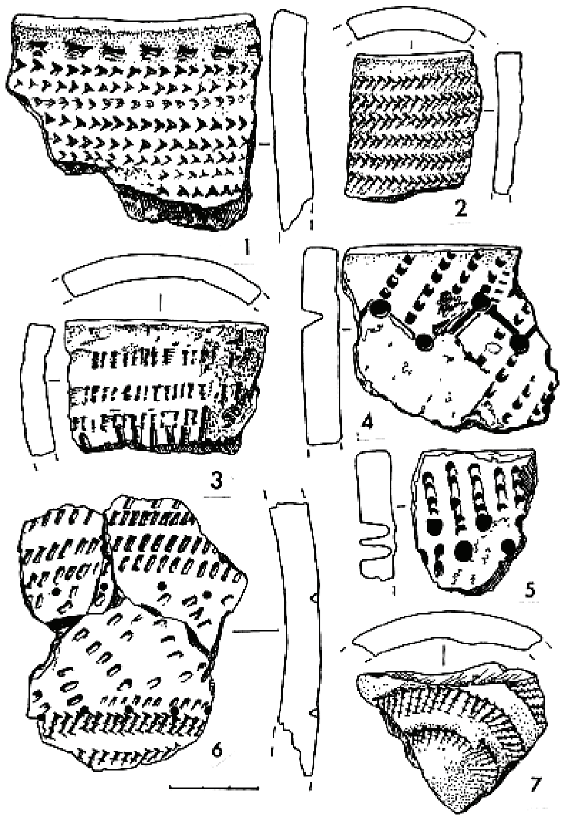
Tempering is usually acknowledgeable in the larger vessels only, and consists of particles of sand, granite and quarts. Organic matter was more commonly used in the western areas. The pottery was hand-made and open-fired. The low temperature firing is suggested based on the observed colours varying from dark to grey-brown and the brittle character of pottery sherds.

The ornaments most commonly consist of the impressions of fish vertebra, amongst which those of pikes, bream, perch, small fry, coregonus could be identified. The second common ornamental element consists of vertical, horizontal, or oblique incised lines. Large number of vessels were ornamented with impressions of comb, or 'interwoven cord' (*wickelschnur*). Pit impressions were usually placed at the final stage of ornamentation (Figs. 6 a-d).

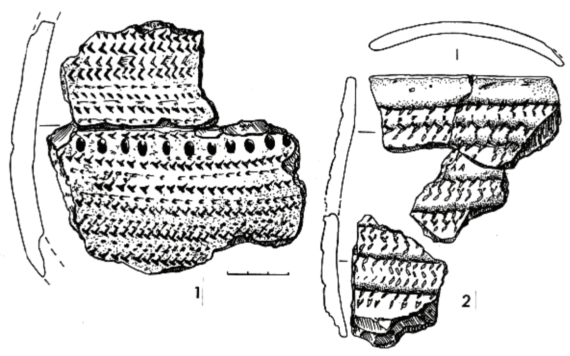
The sites with Säräisniemi 1-type ceramics (Sär 1) are found in Northern and North-eastern Fennoscandia including Russian Karelia. Existing radiocarbon measurements and the dates based on shoreline displacement lie in the time range of 6100-5500 BP (Torninen 1997, 1998, 2000). Hence these sites were either roughly contemporaneous or slightly younger than the Sperrings sites further south. Säräisniemi 1 pottery appeared in northern Norway at the Late Stone Age period I (5800-5000 BP) and coincided with the changes in the stone industry, notably the disappearance of microblade technique (Bjerck 2008, 83).

The Säräisniemi pottery is generally similar to the Sperrings and is often considered as its northern variety. Distinctions are acknowledgeable in the paste admixtures, which often include organic matter and mica. The ornamental patterns are slightly more complicated and cover the entire surface of the vessels (German 1997) (Figs. 7 a,b).

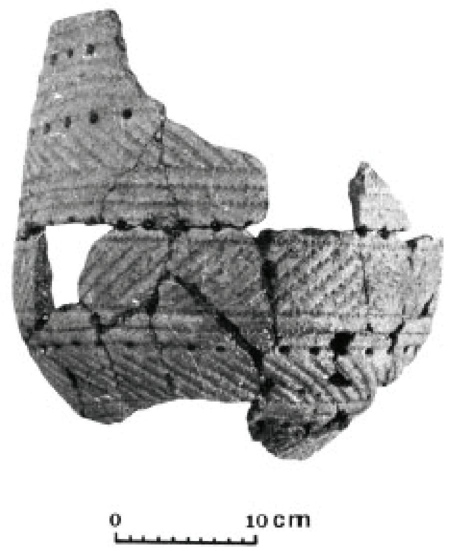
Existing data suggest that the Kola Peninsula was settled by about the same time as the neighbouring areas of northern Fennoscandia (Shumkin 1996; Gurina 1997). The sites are usually found on the elevated coastlines, inside the fjords and further inland along the river valleys (Fig. 8). The largest sites are Ust-Drozdovka (5510±100 BP) and Nerpichya (4630±100 BP), both found on the elevated coastline of the Drozdovka Fjord on the Kola's Northern coast, Chavanga (5560±80 BP), on the southern coast, and Tsaga (5760±160 BP, the oldest date) near Lovozero Lake in the central part of the Peninsula.



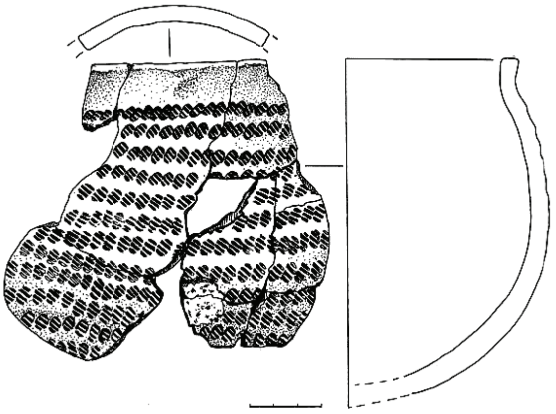
a



c



d



b

Fig. 6 a-d. Sperrings pottery (German 2006)

Both Mesolithic and Neolithic sites of the Kola Peninsula include very few organic remains. Nonetheless, the rich varieties of bone and antler fishing tools (particularly, harpoons), and the abundance of seal remains (mainly of harp seal) in Early Metal sites, leaves one in do doubt that the subsistence of coastal pottery-making communities was mainly focused on hunting sea mammals.

The early varieties of pottery were essentially similar both to Sperrings and Säräisniemi, yet displayed specific features in the ornamental patterns. Based on the observed specificity in the pottery, as well as stone and bone-and antler industries, Gurina (1997) identified a distinct Kola Neolithic culture.

The specimen of rock art discovered on the northern coast include stylistic effigies of animals (mostly elk), humans (allegedly performing ritual dances), as well as purely abstract symbols.

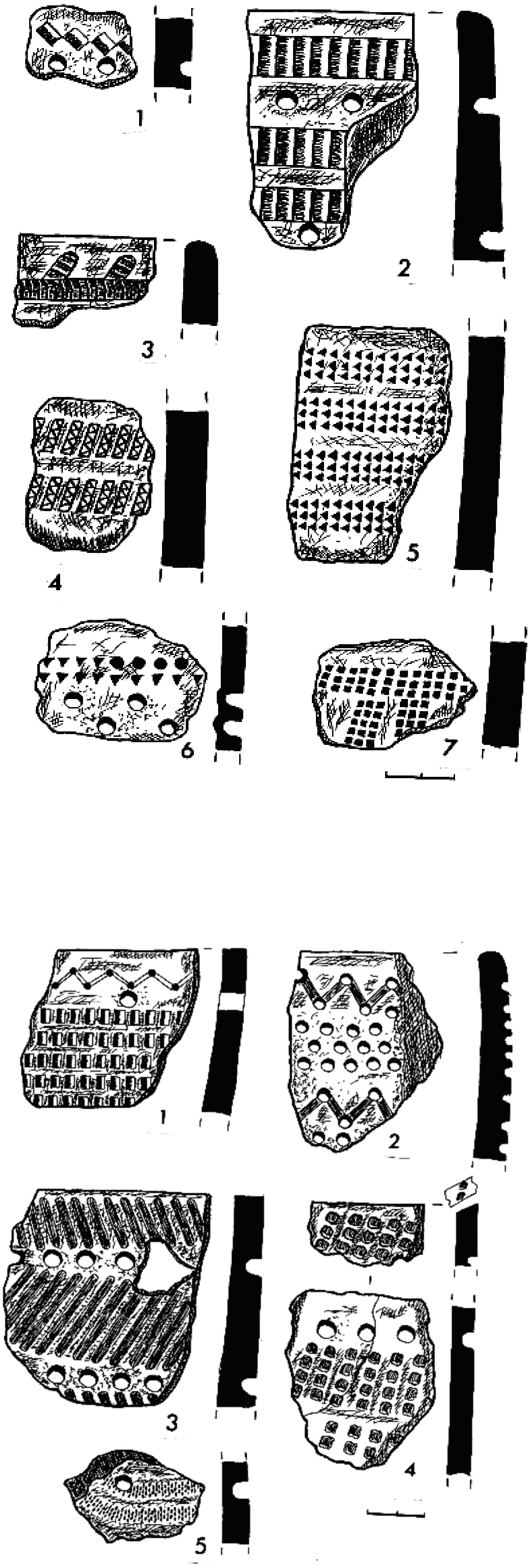


Fig. 7 a,b. Säräisniemi pottery (German 2006);

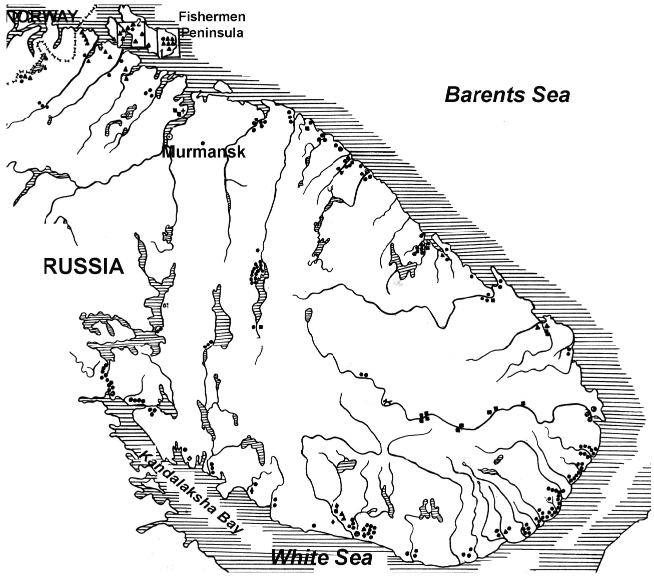


Fig. 8. Mesolithic and Neolithic sites on the Kola Peninsula (after Gurina 1997).

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Multiple Sources of the European Neolithic: Mathematical Modelling Constrained by Radiocarbon Dates

Kate Davison,* Pavel M. Dolukhanov,† Graeme R. Sarson,*
Anvar Shukurov* and Ganna I. Zaitseva‡

* *School of Mathematics and Statistics, University of Newcastle upon Tyne, NE1 7RU, UK*
† *School of Historical Studies, University of Newcastle upon Tyne, NE1 7RU, UK*
‡ *Institute for the History of Material Culture, Russian Academy of Sciences, 18 Dvortsovaya Nab., St. Petersburg, 191186, Russia*

1. Introduction

The transition to the Neolithic was a crucial period in the development of Eurasian societies, defining to a large extent their subsequent evolution. The introduction of agro-pastoral farming, which originated in the Near East about 12,000 years ago and then spread throughout Europe, is usually considered a key feature of this transition (Zvelebil, 1996). Yet the Neolithic was not a simple, single-faceted phenomenon. In his early definition of the Neolithic, Sir John Lubbock (Lubbock, 1865) specified its main characteristics to be the growing of crops, the taming of animals, the use of polished stone and bone tools, and pottery-making.

Ceramic pottery is one of the defining characteristics of the Neolithic. It is true that there are examples of early farming communities apparently not involved in pottery-making. For example, aceramic Neolithic cultures have been identified in the Levant, Upper Mesopotamia and Anatolia (9800–7500 BC), and also in the Peloponnese (7000–6500 BC) and Thessaly Plain (7300–6300 BC). (All BC dates supplied are radiocarbon dates calibrated using OxCal v3.10 (Bronk Ramsey, 2001) with calibration curve intcal04.14c.) Wheat, barley and legumes were cultivated at those sites; permanent houses with stone foundations were used, but there is no convincing evidence of pottery (Perles, 2001). In contrast, the Neolithic in North-Eastern boreal Europe is identified with a sedentary (or seasonally sedentary) settlement pattern, social hierarchy and sophisticated symbolic expression, the use of polished stone and bone tools, large-scale manufacture of ceramic ware, but not with agriculture (Oshibkina, 1996): the subsistence apparently remained based on foraging. This combination of attributes is characteristic of the 'boreal Neolithic'; of these, pottery is in practise the most easily identifiable.

In the present paper we attempt to develop a unified framework describing the spread of both the 'agro-pastoral' and 'boreal' Neolithic. Our quantitative model of the Neolithization is based on the large amount of relevant radiocarbon dates now available.

2. Selection of Radiocarbon Dates

The compilation of dates used in this study to model the spread of the Neolithic in Europe is available upon request from the authors; unlike all other similar studies known to us it includes dates from the East of Europe. We used data from Gkiasta et al. (2003), Shennan and Steele (2000) and Thissen et al. (2006) for Southern, Central and Western Europe (SCWE), and Dolukhanov et al. (2005) and Timofeev et al. (2004) for Eastern Europe (EE). Our selection and treatment of the dates, described in this section, is motivated by our attempt to understand the spread of agriculture and pottery making throughout Europe.

Many archaeological sites considered have long series of radiocarbon dates: often with 3–10 dates, and occasionally with 30–50. Associated with each radiocarbon measurement is a laboratory error, which after calibration was converted to a calibration error. The laboratory error characterises the accuracy of the measurement of the sample radioactivity rather than the true age of the archaeological site (Dolukhanov et al., 2005); it is thus often unrepresentatively small, suggesting an accuracy of 30 years on occasion. We therefore estimated a minimum error of the radiocarbon determination of archaeological age, and then used it when treating sites with multiple dates. A global minimum error of σ_{min} = 160 years is obtained from well explored, archaeologically homogeneous sites with a large number of tightly clustered dates. Such sites are: (1) Ilipinar, 65 dates, with the standard deviation σ = 168 years (and the mean date 6870 BC); (2) Achilleion, 41 dates, σ = 169 years (the mean 8682 BC); (3) Asikli Höyük, 47 dates, σ = 156 years (the mean 7206 BC). Similar estimates are σ_{min} = 100 years for LBK sites and σ_{min} = 130 years for the Serteya site in North-Western Russia (Dolukhanov et al., 2005); the typical errors vary between different regions and periods. We use the larger of the above values of σ_{min} (i.e., 160 years) when assessing the quality of the model described below.

For sites with multiple radiocarbon date determinations, the dates are treated and reduced to at most three dates that are representative of the arrival of multiple Neolithic episodes to that location. Examples of sites with multiple measurements

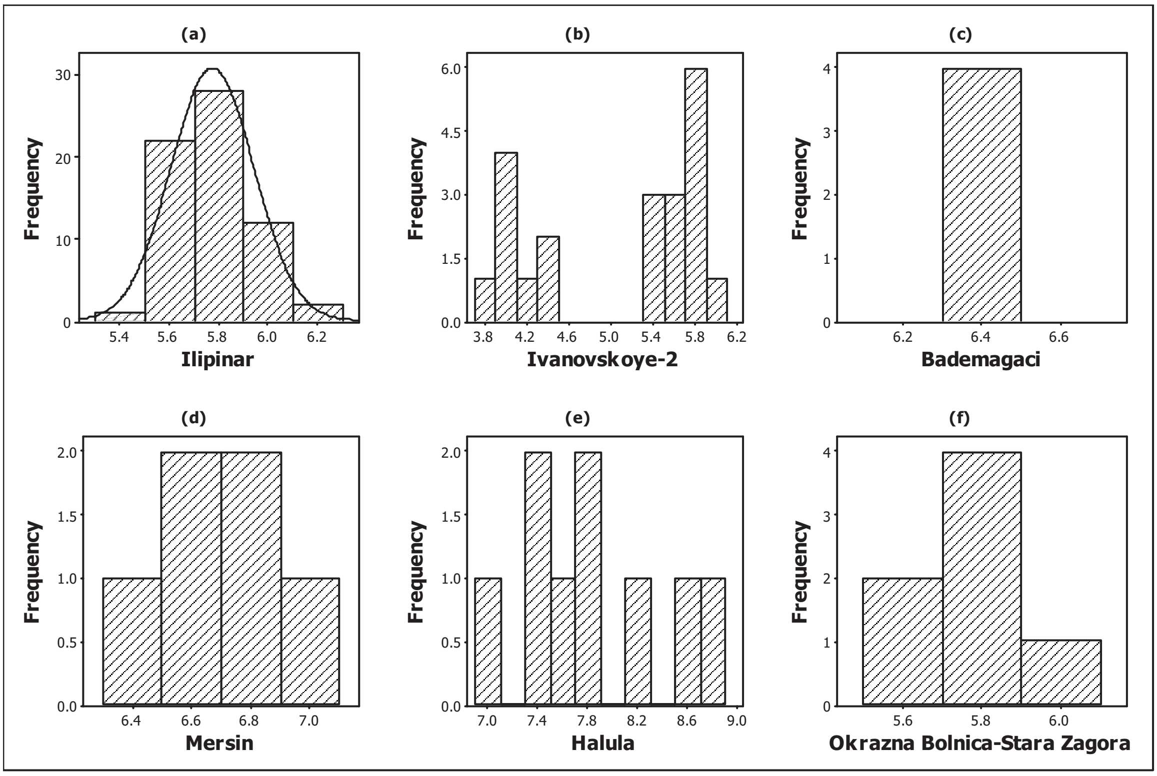

Figure 1. Histograms of radiocarbon ages from archaeological sites in the unit of 1,000 years with various temporal distributions. (**a**) The 65 dates from Ilipinar are approximately normally distributed, so the χ^2 criterion can be employed to calculate the age of this site as described by Dolukhanov et al (2005). (**b**) Ivanovskoye-2 has 21 dates showing a multimodal structure where each peak can be treated as above. (**c**) The 4 dates from Bademağaci combine into a single date when their errors are taken into account (**d**) The 6 dates from Mersin are almost uniformly distributed in time, so the oldest date can be used as representative of the arrival of the Neolithic. (**e**) The 9 dates from Halula are treated as in (d). (**f**) The 7 dates from Okrazna Bolnica – Stara Zagora are not numerous enough to justify the application of the χ^2 test, but they form a tight cluster, so the mean date can be used for this site.

are Ilipinar and Ivanovskoye-2, where 65 and 21 dates have been published, respectively. Figures 1a and b indicate that for these sites the series of dates form very different distributions; different strategies are used to process these different types of date series as described in the caption to Figure 1 (see Dolukhanov et al., 2005, for more details). If a geographical location provides only one radiocarbon measurement associated with early Neolithic activity, then this is taken to be the most likely date for the arrival of the Neolithic. The uncertainty of this radiocarbon date is taken to be the larger of the calibration error obtained at the 3σ level and the global minimum error discussed above. There are numerous such sites in our collection, including Casabianca, Dachstein and Inchtuthil.

If only a few (less than 8) date measurements are available for a site and those dates all agree within the calibration error, we use their mean value and characterise its uncertainty with an error equal to the maximum of the calibrated measurement errors σ_i, the standard deviation of the dates involved $\sigma(t_i)$, and the global minimum error introduced above:

$$\sigma = \max\{\sigma_i, \sigma(t_i), \sigma_{\min}\}, \qquad (1)$$

where $i=1, 2, \ldots n$, with n the total number of dates in the cluster. An example of such a site is Bademağaci, where we have 4 dates, all within 60 years of one another; Figure 1c shows the histogram of radiocarbon dates of this site. The typical error of these dates is approximately 30 years, thus Equation (1) yields $\sigma_{\min}$ as an uncertainty estimate. However, we apply slightly different procedures for clusters of dates that do not quite agree within the calibration error.

For a series of dates that cluster in time but do not agree within the calibration error, we use different approaches depending on the number of dates available and their errors. Should the cluster contain less than 8 dates, we take the mean of the dates (as in the previous case), as any more sophisticated statistical technique would be inappropriate for such a small sample; the error is taken as Equation (1). An example of such a site is Okranza Bolnica–Stara Zagora with 7 measurements, and Figure 1f shows that the dates are tightly clustered around the mean value.

If however, the cluster has more than 8 dates (e.g. Ilipinar, shown in Figure 1a), the χ^2 statistical test can be used to calculate the most likely date T of a coeval subsample as described in detail by Dolukhanov et al. (2005):

$$\boldsymbol{T} = \frac{\sum_{i=1}^{n} \boldsymbol{t}_i / \tilde{\boldsymbol{\sigma}}_i^2}{\sum_{i=1}^{n} 1 / \tilde{\boldsymbol{\sigma}}_i^2} \, .$$

where $\tilde{\boldsymbol{\sigma}}_i = \max(\sigma_i, \sigma_{\min})$. The coeval subsample is obtained by calculating the statistic $\boldsymbol{X}^2 = \sum_{i=1}^{n} \frac{(\boldsymbol{t}_i - \boldsymbol{T})^2}{\tilde{\boldsymbol{\sigma}}_i^2}$ and comparing it with χ^2. If $X^2 \leq \chi^2_{n-1}$, the sample is coeval and the date T is the best representative of the sample. If $X^2 > \chi^2_{n-1}$, the sample is not coeval, and the strongest outliers in the sample are discarded one by one until the criterion for a coeval sample is satisfied.

If a site has many radiocarbon determinations that do not cluster around a single date, a histogram of the dates is analyzed. If the data have a wide range and have no discernable peaks (i.e., are approximately uniformly distributed in time), this may suggest prolonged Neolithic activity at the site, and we choose, as do many other authors, the oldest date (or one of the oldest, if there are reasons to reject outliers) as representing the first appearance of the Neolithic. Examples of such sites are Mersin and Halula where there are 6 and 9 dates with a range of 550 and 1900 years, respectively, and no significant peaks (see Figures 1d and 1e); here the oldest dates are 6950 and 8800 years BC and the associated errors are 217 and 167 years.

Apart from sites with either no significant peak or only one peak, there are sites whose radiocarbon dates have a multimodal structure which may indicate multiple waves of advance passing through this location. Ivanovskoye-2 (with 21 dates) is a typical site in this category, and Figure 1b depicts two distinct peaks. In such cases multiple dates were attributed to the site, with the above methods applied to each peak. After this selection and processing, the total number of dates in our compilation is 478.

3. Modelling

The mechanisms of the spread of the Neolithic in Europe remain controversial. Gordon Childe (1925) advocated direct migration of the farming population from the Near East. This idea was developed in the form of the demic expansion (wave of advance) model (Ammerman and Cavalli-Sforza, 1973). The Neolithization was viewed as the spread of colonist farmers who overwhelmed the indigenous hunter-gatherers or converted them to the cultivation of domesticated cereals and the rearing of animal stock (Price, 2000). An alternative approach views the Neolithization as an adoption of agriculture (or other attributes) by indigenous hunter-gatherers through the diffusion of cultural novelties by means of intermarriages, assimilation and borrowing (Tilley, 1994, Thomas, 1996, Whittle, 1996). Recent genetic evidence favours cultural transmission (Haak et al., 2005).

Irrespective of the particular mechanism of the spread of the Neolithic (or of its various signatures), the underlying process can be considered some sort of 'random walk', of either humans or ideas. Therefore, mathematical modelling of the spread (at suitably large scales in space and time) can arguably be based on a 'universal' equation (known as reaction-diffusion equation) with parameters chosen appropriately (Cavalli-Sforza and Feldman, 1981). A salient feature of this equation is the development of a propagation front (where the population density, or any other relevant variable, is equal to a given constant value) which advances at a constant speed (Murray, 1993) (in the approximation of a homogeneous habitat). This type of spread of incipient agriculture has been confirmed by radiocarbon dates (Ammerman and Biagi, 2003, Ammerman and Cavalli-Sforza, 1971, Ammerman and Cavalli-Sforza, 1973, Ammerman and Cavalli-Sforza, 1984, Gkiasta et al., 2003, Pinhasi et al., 2005). In Figure 2a we plot the distance from a putative source in the Near East versus the ^{14}C dates for early Neolithic sites in SCWE; the linear correlation is consistent with a constant propagation speed. Due to the inhomogeneous nature of the landscape of Europe we would not expect to see a precise correlation between distance from source and time of first arrival; there are many geographical features that naturally cause barriers to travel (e.g. the Mediterranean sea). It was also suggested in a previous work (Davison et al., 2006) that there are variations in the propagation speed in the region of major rivers; this again detracts from the linear nature of the spread. In spite of this the correlation coefficient is found to be -0.80. This is surprisingly high, given the above caveats.

In contrast to earlier models, we include the 'boreal', East-European (EE) Neolithic sites, which we present in the same format in Fig. 2b. It is clear that the Eastern data are not all consistent with the idea of spread from a single source in the Near East. A correlation coefficient of -0.52 is sufficient evidence to conclude that the dates do not cluster around a line of best fit; thus any conclusion drawn from straight line fitting would be questionable at best. There is also a tail of older dates that vary little in space; this suggests an area of prolonged occupation by Neolithic peoples. This may be indicative of an area where a Neolithic tradition began but halted until it had saturated the area, before subsequently expanding across the landscape. Our modelling indicates that another wave of advance swept westward through Eastern Europe about 1500 years earlier than the conventional Near-Eastern one; we speculate that it may even have spread further to produce early ceramic sites in Western Europe (e.g. the La Hoguette and Roucadour groups).

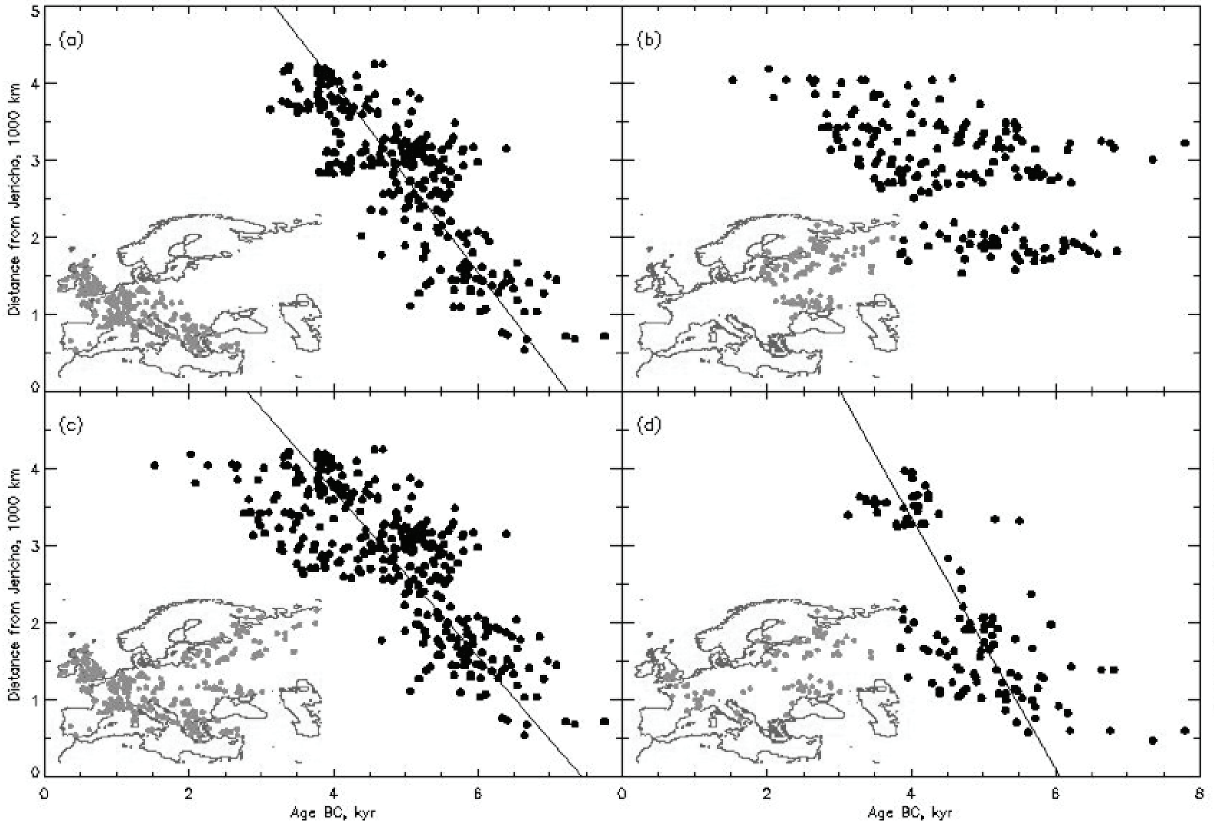

Figure 2. Radiocarbon dates of early Neolithic sites versus the great-circle distance from the assumed source. Inset maps show the location of the sites plotted, and the straight lines correspond to spread at a constant speed given below. **(a)** Sites from Southern, Central and Western Europe (SCWE) with respect to a Near Eastern source (Jericho). The linear correlation (cross-correlation coefficient $C = -0.80$) suggests a mean speed of advance of $U = 1.2 \pm 0.1$ km/year (2σ error). **(b)** Sites from Eastern Europe (EE) show very poor correlation with respect to the same Near-Eastern source ($C = -0.52$), so that straight-line fitting is not useful. **(c)** Sites attributed, using our two-source model, to the Near-Eastern source (note a significant number of EE sites) show a reasonable correlation ($C = -0.77$) and a mean speed $U = 1.1 \pm 0.1$ km/year. **(d)** Sites attributed to the Eastern source (from both EE and SCWE) show a correlation similar to that of Panel (**c**) ($C = -0.76$), and a mean speed $U = 1.7 \pm 0.3$ km/year.

Our population dynamics model, described in detail in Davison et al. (2006), was refined for our present simulations. The model is based on the random walk of individuals first considered in a similar context by Fisher (1937). At any point in space each individual will take a step in any given direction with the same probability; i.e. they are as likely to step left as right. This assumption of equal probabilities gives rise to an isotropic random walk (i.e. classical diffusion). If however the probability of moving in one direction is altered by a desire for a particular environment, then the equal probabilities assumption of the isotropic random walk is violated; this gives rise to an anisotropic random walk. We thus solve the reaction–diffusion equation supplemented with an advection of speed **V,** arising from this anisotropic component of the random walk of individuals that underlies the large-scale diffusion (Davison et al., 2006, Murray, 1993):

$$\frac{\partial N}{\partial t} + (\mathbf{V} \cdot \nabla) N = \gamma N \left(1 - \frac{N}{K}\right) + \nabla \cdot (\nu \nabla N), \qquad (2)$$

where N is the population density, γ is the intrinsic growth rate of the population, K is the carrying capacity, and ν is the diffusivity (mobility) of the population. We solve Equation (2) numerically in two dimensions on a spherical surface with a grid spacing of 1/12 degree (2–10 km, depending on latitude). All the variables in Equation (2) can be functions of position and time, as described below and by Davison et al. (2006).

We consider two non-interacting populations, each modelled with Equation (2), but with different values of the parameters; the difference is intended to represent differences between subsistence strategies (farmers versus hunter-gatherers) and/or between demic and cultural diffusion. We use non-interacting populations as it is thought that farmers and hunter-gatherers rarely moved through a region simultaneously. In addition to this, the two populations scarcely compete for resources due to their distinct subsistence strategies; their interactions would therefore have been weak, and a non-interacting model is acceptable as a first approximation.

We therefore numerically solve two versions of Equation (2), one for each of two non-interacting populations, with different origins of dispersal. The numerical scheme adopted has centered differences in space

$$f''(x_0) = \frac{f(x_0+h) - 2f(x_0) + f(x_0-h)}{h^2} - \frac{h^2}{12} f^{iv}(\xi), \qquad x_0 \le \xi \le x_0 + h,$$

and evolves with explicit Euler time stepping using forward differences in time. The step size is controlled using the Courant–Friedrichs–Lewy (CFL) condition; thus the population front is prevented from advancing more than one grid cell in one time step:

$$\Delta t \le \min\left\{ \frac{A_1}{2\nu} \frac{\Delta\phi^2 \Delta\theta^2}{\Delta\phi^2 + \Delta\theta^2}, \frac{A_2}{2V_\phi}\Delta\phi, \frac{A_3}{2V_\theta}\Delta\theta \right\} \quad 0 < A_i \le 1 \cdot$$

The boundaries of the computational domain are at 75ºN and 25ºN, and 60ºE and 15ºW, as shown in Figure 4; these were chosen to comfortably incorporate the pan-European area of interest. We use zero-flux conditions at the domain boundaries, i.e. dN/dn = 0, where n is the normal to the boundary; at most points this condition is academic, as the boundary is in the (unpopulated) sea. The environmental factors included in the model are the altitude, latitude, coastlines and the Danube-Rhine river system. The equation describing the farming population includes the advection velocity **V** along the major waterways (the Danube, the Rhine and the sea coastlines; $\mathbf{V} \neq \mathbf{0}$ within corridors 10 km wide on each side of a river or 10 km inshore near the sea), resulting from the anisotropic diffusion in those areas. The components of the advective velocity are given in Davison et al. (2006), but will be briefly discussed here. There are two considerations when prescribing **V**, the direction and the magnitude. The direction is taken to be parallel to the shoreline/river and away from the maximum of the population. The magnitude is prescribed to diminish with distance from shoreline/river, from a maximum value described below.

The focus of our model is the speed of the front propagation *U,* since this quantity can be most readily linked to the radiocarbon age used to date the 'first arrival' of the wave of advance. This feature of the solution depends only on the linear terms in Equation (2) and, in particular, is independent of the carrying capacity *K*. Moreover, to a first approximation *U* only depends on the product $\gamma\nu$:

$$U = 2\sqrt{\gamma\nu} \, . \qquad (3)$$

Taking the intrinsic growth rate of a farming population as $\gamma = 0.02$ year^{-1} (Birdsell, 1957), the mean speed of propagation of $U \approx 1$ km/year for the farming population front suggests a background (low-latitude) value of the diffusivity of $\nu = 12.5$ km^2/year (Ammerman and Cavalli-Sforza, 1971, Davison et al., 2006). For the wave spreading from Eastern Europe, $U \approx 1.6$ km/year is acceptable as a rough estimate obtained from the EE radiocarbon dates (Dolukhanov et al., 2005); this estimate is confirmed by our model (see Figure 2d). Analysis of the spread of Paleolithic hunter-gatherers yields $U \approx 0.8$ km/year; the corresponding demographic parameters would then be $\gamma = 0.02$–0.03 year^{-1} and $\nu = 50$–140 km^2/year (Fort et al., 2004). These authors use an expression for *U* different from Equation (3); it is plausible, therefore, that the intrinsic growth rate obtained by Fort et al. (2004) for hunter-gatherers is a significant overestimate. For $\nu = 100$ km^2/year and $U \approx 1.6$ km/year, the nominal value of γ obtained from Equation (3) is about 0.006 year^{-1}. A growth rate of $\gamma = 0.01$ year^{-1} has been suggested for indigenous North-American populations in historical times (Young and Bettinger, 1992). The range $\gamma = 0.003$–0.03 year^{-1} is considered in a model of Paleoindian dispersal (Steele et al., 1998). Our simulations adopt $\gamma = 0.007$ year^{-1} and $\nu = 91.4$ km^2/year for the hunter-gatherers.

For the wave that spreads from the Near East carrying farming, *K* and ν smoothly tend to zero within 100 m of an altitude of 1 km, above which land farming becomes impractical. For the wave spreading from the East, *K* and ν are similarly truncated at an altitude of 1.5 km, as foraging is possible at higher altitudes than farming. Figure 3a shows these dependences. The low-altitude (background) values of *K* adopted are 0.07 persons/km^2 for hunter-gatherers (Dolukhanov, 1979, Steele et al., 1998) and 3.5 persons/km^2 for farmers, a value 50 times larger than that for hunter-gatherers (Ammerman and Cavalli-Sforza, 1984). The values of *K* do not affect any results reported in this paper.

For both farmers and hunter-gatherers, both the intrinsic growth rate and the carrying capacity vanish in seas, which are incapable of supporting a human population. The diffusivity decays exponentially as $\nu \propto \exp(-d/l)$, where *d* is the shortest distance from the coast and $l = 40$ km, allowing the population to travel across narrow seas despite having no sustainable existence there (see Figure 3b). The value of *l* has been fine-tuned in this work to reproduce the delay, indicated by radiocarbon dates, in the spread of the Neolithic from the continent to Britain and Scandinavia. This provides an interesting inference regarding the sea-faring capabilities of the time, suggesting confident travel within about 40 km of the coast. At this stage we are using present day sea levels, although we acknowledge that this may be misleading due to changes in sea level over the past 6,000 years. It may be that the need to allow sea travel is simply compensating for the

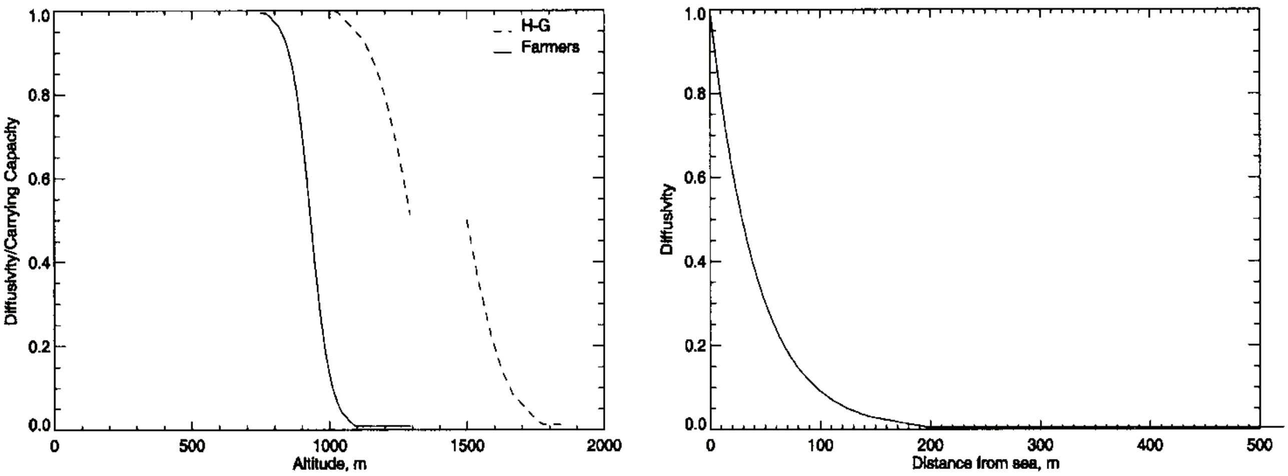

Figure 3. **(a)** Dependence of diffusivity and carrying capacity on altitude. **(b)** Dependence of diffusivity on distance from seashore.

altered shoreline. In ongoing work we include paleotopography in our model, and aim to investigate the spread across seas further, with particular focus on Scandinavia and the UK.

The inclusion of advection along the Danube–Rhine corridor and the sea coastlines is required to reproduce the rapid spread of the Linear Pottery and Impressed Ware cultures apparent from the radiocarbon and archaeological evidence (see Davison et al. (2006) for details). The spread of farming in the Danube–Rhine corridor was as rapid as 4 km/year (Ammerman and Cavalli-Sforza, 1971), and that in the Mediterranean coastal areas reached 20 km/year (Zilhão, 2001); we set our maximum advective velocity in these regions accordingly. There are no indications that similar acceleration occurred for the hunter-gatherers spreading from the East. We therefore adopt $\mathbf{V} = \mathbf{0}$ in the corresponding equation.

The starting positions and times for the two waves of advance — i.e., the initial conditions for Equation (2) — were selected as follows. For the population of farmers, we position the origin and adjust the starting time so as to minimize the root mean square difference between the SCWE ^{14}C dates and the arrival time of the modelled population at the corresponding locations. This places the centre at 35°N, 39°E, with the propagation starting at 6,700 BC. For the source in the East of Europe, we have tentatively selected a region centered at 71°N, 56°E in the Ural mountains (to the east of the Neolithic sites used here), so that the propagation front reaches the sites in a well developed form. We do *not* suggest that pottery-making originated independently in this region. More reasonably, this technology spread, through the bottleneck between the Ural Mountains and the Caspian Sea, from a location further to the east. The starting time for this wave of advance was fixed by trial and error at 8200 BC; this reasonably fits most of the dates in Eastern Europe attributable to this centre. For both populations, the initial distribution of N is a truncated Gaussian of a radius 300 km.

4. Previous Population Dynamics Models

There have been many earlier attempts to explain the pattern of the spread through Europe of the Neolithic (usually considered as synonymous with land farming in these studies). These have almost exclusively used radiocarbon dating evidence for Neolithic first arrivals.

Edmonson (1961) conducted a pioneering study of Neolithic diffusion rates. He suggested that an invention will travel radially from its origin, spreading in all directions with the same speed. He worked under the assumption of ergodicity; that the population is homogeneous and individuals behave identically. This is mathematically analogous to isotropic diffusion, with inventions diffusing with constant speed through the available space. Edmonson suggests that this extremely simplified model explains the real observations well; this was the birth of the idea of the Neolithic as a diffusive phenomenon.

His estimation of the apparent mean propagation speed of Neolithic traits, such as copper or pottery, was approximately 1.9 km/year (1.2 miles/year). (This estimate refers to a far larger geographical area than Europe.) It is clear from the tables he compiled that the scatter in speeds about this value is significant; values are as large as 4.3 km/yr in Kenya, and as low as 0.18 km/yr in China. Edmonson assumed that he was measuring cultural transmission.

The earliest representation of the spatio-temporal trends of the Neolithic transition in Europe were the maps presented by Clark (1965a). Clarke produced one of the pioneering analyses (also presented in Clark, 1965b) of radiocarbon dates (see Figure 4). The data were binned into three broad

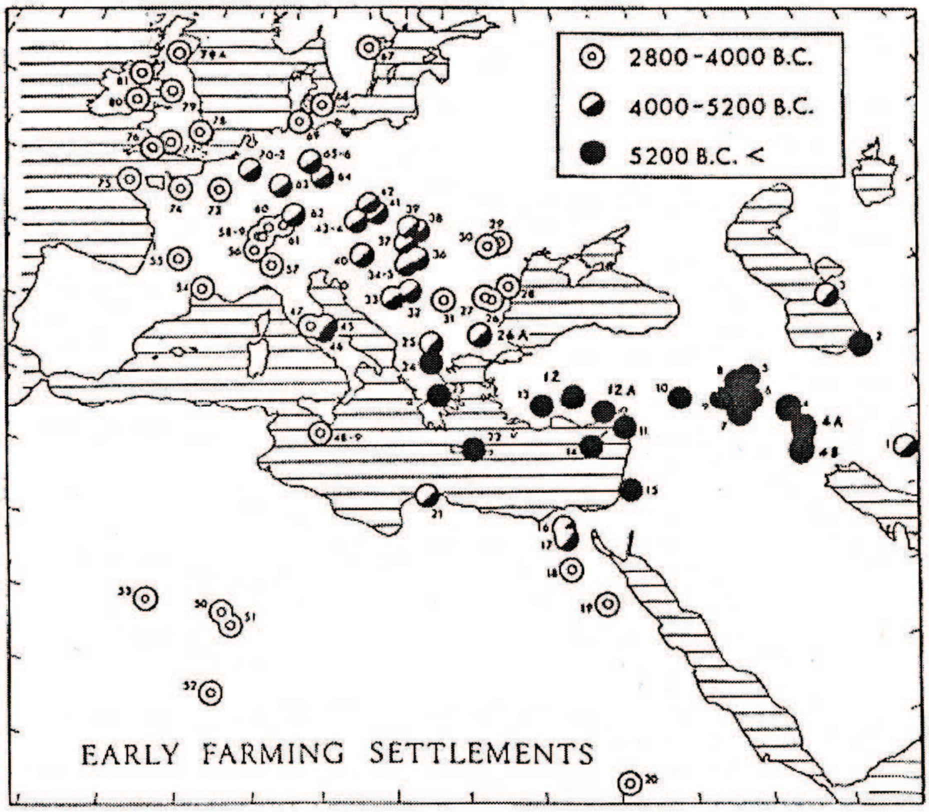

Figure 4. Early representation of radiocarbon dates for the Neolithic of Europe, presented by Clark (1965). Dates are binned into the three broad age ranges shown in the inset.

age ranges (2,800-4,000 BC; 4,000-5,200 BC; and earlier than 5,200 BC). The information gained from such a schematic representation can only be as detailed as the binning process allows however there are still some discernable trends.

Clark (1965a) verified what had been long advocated by archaeologists such as Gordon Childe (discussed above in section 3), that the Neolithic revolution penetrated Europe from the South-East, spreading through Greece and the south Balkans and then, with side branches northwards towards the lower Danube and into Bessarabia, and westwards across the Adriatic to middle Italy, pushing into the middle Danube and so into central Europe. Clark claimed (based on Figure 4) that the agricultural revolution was confined to an area of about 10 degrees of latitude between Greece and Iran until around 5,200 BC. This analysis is admittedly crude — with little content beyond the 'ideogram' of Figure 4 — but Clark concludes that such a crude message is better than no message at all. And indeed, the pattern found remains identifiable in the extensive radiocarbon record now available.

Ammerman and Cavalli-Sforza (1971) focused on measuring the rate of spread of early farming in Europe. They suggested that the terms 'early farming' and 'Neolithic' are synonymous, but we argue that there are examples of Neolithic sites hosting no evidence of farming, so that the terms should not be used interchangeably. They did not consider pottery as a Neolithic signature, and in contrast to Edmonson, their measurement is based on a single trait (cereal). The geographical domain of study was significantly narrower than that of previous works, focusing primarily on Western Europe, where the radiocarbon evidence for cereals was at the time most abundant. Ammerman and Cavalli-Sforza focused their attention on the radiocarbon evidence of early farming *first arrivals*. They provided a regression analysis of distance from a source and age in years BP. They located the source by placing a grid over Europe and calculating the correlation coefficient between distance from each grid point and age BP for all data; the grid point with largest correlation coefficient magnitude was accepted as the source. The linear regression techniques adopted gave a rate of spread of $U \approx 1$ km/year on average in Europe; this estimate has remained widely accepted since then. They also noted very significant regional variations in the rate of spread. For example, unfavourable ecological and geographical factors caused a retardation of spread to the Alps; similarly retarded spread occurs at latitudes above 54° N. The Danube and Rhine valleys, the propagation path of the LBK culture, had an increased propagation speed (perhaps as high as 4-6 km/year), as did the Mediterranean coast. Ammerman and Cavalli-Sforza (1971) gave the speed of front propagation in the Mediterranean as 1.5 km/year, and in the West Mediterranean as 2.1 km/year.

An updated estimate of the propagation speed in the Mediterranean coastal area was derived more recently by Zilhão (2001), and is significantly higher than that estimated by Ammerman and Cavalli-Sforza (1971) from more limited data. Zilhão considered various radiocarbon measurements, and concluded that the spread of the Cardial and related Neolithic cultures in Iberia, over the 2000 km from the gulf of Genoa to the estuary of the Mondego, took no more than 100-200 years; this gives an average speed of 10-20 km/year. The major contribution of this work was to reassess the problem of reservoir effects in the dating of bulk shell samples. By comparing the radiocarbon dates of archaeologically and stratigraphically contiguous samples of both shell and charcoal, an estimate of the reservoir effect on the shells can be obtained; together with the advent of AMS dating, this enabled the re-evaluation of the spread of the Neolithic in the Mediterranean coastal area.

Thus the speeds of propagation, U, of the wave front of invading Neolithic farmers in Europe can be summarised as follows:

$U \approx 1$ km/yr on average in Europe,

$U \approx 4$–6 km/yr for the Danube–Rhine valleys (LBK culture),

$U \approx 10$–20 km/yr in Mediterranean coast regions (Impressed ware culture).

Interpretations of these observations are usually based on the reaction-diffusion equation of population dynamics known as the Fisher–Kolmogorov–Petrovskii–Piskuniov equation; FKPP hereafter (Fisher, 1937, Kolmogorov et al., 1937). The constant propagation speed of the population front is a salient feature of solutions to this equation in one dimension (Murray, 1993).

There have been a number of applications of this equation to biological processes and population dynamics; in particular, efforts have been made to apply it to the Neolithic process. The specific applications of this approach to the spread of the Neolithic in Europe, however, have hardly advanced beyond simple one-dimensional models in a homogeneous environment.

The simplest and first model of this type was Ammerman and Cavalli-Sforza (1973). Following their 1971 paper on estimates of the rate of spread of the Neolithic (as discussed above), Ammerman and Cavalli-Sforza (1973) presented a 'wave-of-advance' model. This used the FKPP equation,

$$\frac{\partial N}{\partial t} = \gamma N\left(1 - \frac{N}{K}\right) + \nu \nabla^2 N, \qquad (4)$$

with logistic growth and homogeneous isotropic diffusion, as an approximation for the process. They considered various approximations of the parameter values, treating the Neolithic as a 'demic' diffusion process. This model neglected any heterogeneity of the environment; even coastlines were neglected at this level of approximation. A simulation was carried out in one dimension.

Despite its apparent simplicity, the 'wave-of-advance' model is remarkably successful in explaining the constant rate of spread of farming over the vast area from the Near East to Western Europe. Further developments of this model, and comments by Ammerman and Cavalli-Sforza themselves, make clear the need to include heterogeneity of the geographical domain. Regional variations in the spread of the Neolithic — most notably the rapid advances of the Linear Pottery (LBK) and Impressed Ware traditions, along the Danube–Rhine corridor and the Mediterranean coastline, respectively — are key phenomena already discussed above.

The results of Ammerman and Cavalli-Sforza have more recently been confirmed by Gkiasta et al. (2003), using a significantly more comprehensive radiocarbon database. The latter authors suggested that the regional variations in the spread may be due to variations in the importance of demic versus cultural transmission, with the former leading to a more abrupt transition. However, the radiocarbon data alone do not appear sufficient to clarify and quantify this distinction.

In reaction to the work of Ammerman and Cavalli-Sforza, Zilhão (2001) considered the likely applicability of such a model to the Neolithic Cardial culture in the Mediterranean coast area. The conclusion was that, in order to achieve the speeds observed in these areas via a 'wave of advance' model, the diffusivity would have to be 30 times greater than that observed ethnographically. On these grounds, Zilhão concluded that the spread in this region took place via maritime pioneer colonization, rather than the direct random (land) migration inherent to the 'wave of advance' model.

While much work has been carried out into the measurement of the Neolithic dispersal, work on modelling this phenomenon remains sparse. Fort and Méndez (1999a,b) discussed the front propagation speed resulting from various generalizations of the FKPP equation, but their results were restricted to one dimension and to homogeneous systems. The model introduced in the preceding section, and discussed further below, attempts to take into account the effect of heterogeneous, two-dimensional environments on the process.

Steele et al. (1998) took steps towards addressing the influence of the environment on a wave of advance, when they developed a model of Paleo-Indian dispersal into North America. This hunter-gatherer population was described by a two-dimensional reaction-diffusion equation (i.e. the FKPP equation), which was solved numerically on a grid. The advance of this model was the introduction of environmental

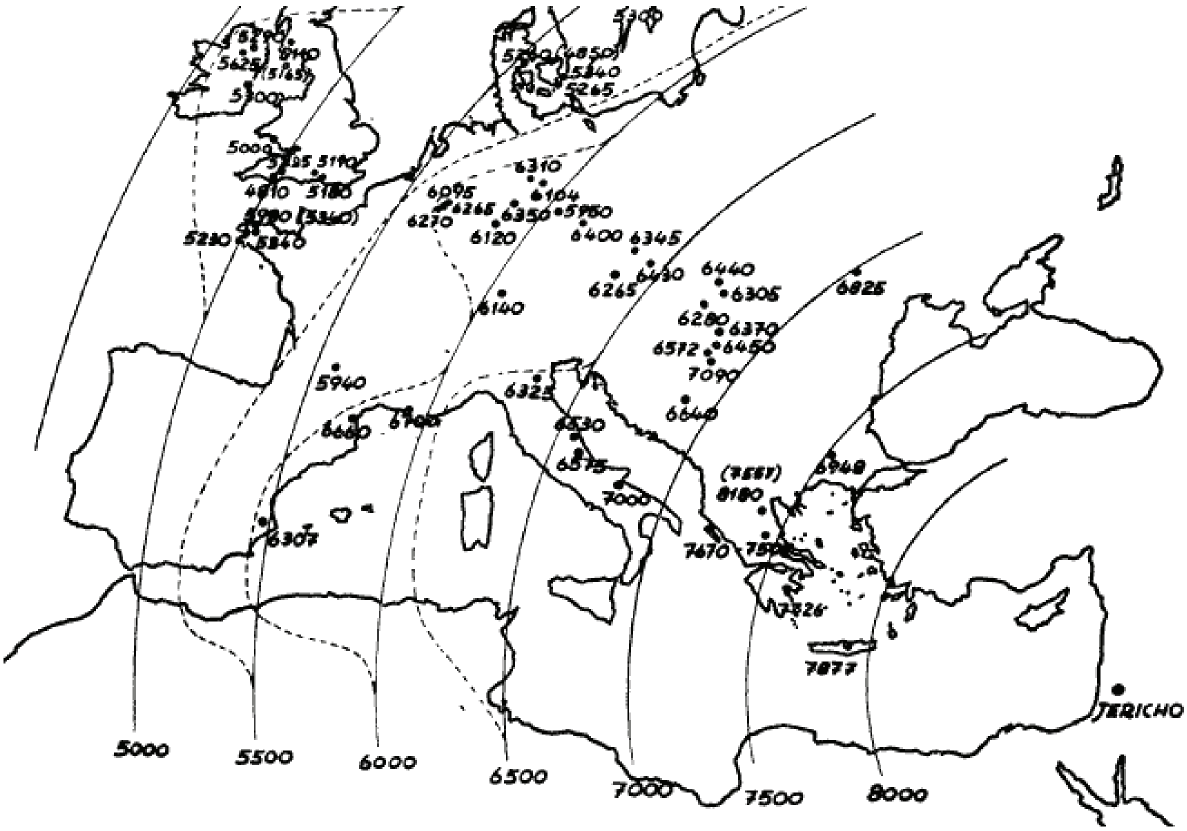

Figure 5. Map from Ammerman and Cavalli-Sforza (1971), showing the spread of early farming in Europe. Dates are in years BP. The arcs indicate the expected position of the wave of advance at 500 yr intervals. The dashed lines represent the authors attempt to take into account some regional variation in the rate of spread.

heterogeneities into the parameters; they allowed for spatial variation in the carrying capacity, and used their extensive paleo-environmental reconstructions as input data. The carrying capacity varied across the grid according to the median observed hunter-gatherer population densities in different habitats. The diffusion constant was held globally constant throughout the simulations. Various simulations were carried out for both constant and varying carrying capacity, and a number of final population densities presented; a patchy population distribution was achieved by varying the value of carrying capacity in space. These authors used comparison with the United States fluted point data as their measure of model success, and concluded that in the absence of environmental variation, these data cannot be accurately reproduced by a model of this type. By varying carrying capacity however, the model could accurately reproduce the greatest density of occupation in the eastern woodland habitats. They noted that the diffusivity (mobility) of people must also be a function of position and time, and suggested that the spread might have followed major river valleys (Anderson, 1990), but did not include these effects into their model.

In addition to the work described above, some preliminary studies have also been carried out into multi-population models of human dispersal, in the context of Neolithic populations. The space into which the Neolithic penetrated was at the time inhabited by Mesolithic hunter-gatherer groups. Many authors believe that, rather than a 'demic' process in which the hunters simply became extinct, the Neolithic revolution occurred as a result of a combination of human migration and technological (cultural) transmission. If this were the case, then the models described above would not be sufficient to capture this more complex process. A model which includes three populations was first proposed by Aoki et al. (1996), who examined the travelling wave solutions for the spread of farmers into a region occupied by hunter-gatherers in one dimension. The model has three interacting populations: farmers (F), hunters (H), and converts (C) from hunting to farming. There are thus three coupled reaction-diffusion equations

$$\frac{\partial F}{\partial t} = r_f F\left[1-(F+C)/K\right] + D\frac{\partial^2 F}{\partial x^2},$$

$$\frac{\partial C}{\partial t} = r_c C\left[1-(F+C)/K\right] + D\frac{\partial^2 C}{\partial x^2} + e(F+C)H,$$

$$\frac{\partial H}{\partial t} = r_h H\left[1-H/L\right] + D\frac{\partial^2 H}{\partial x^2} - e(F+C)H.$$

Here D is the (universal) diffusion coefficient, K and L are the carrying capacities of total farmers and hunters respectively, and the r parameters are the growth rates for the three populations. In this model there is also the parameter *e* which represents the 'conversion rate' of hunters to farmers. Aoki et al. (1996) discuss the different wave front combinations that can be formed by different combinations of parameters.

More recently, Ackland et al. (2007) have significantly extended the multi-population approach of Aoki et al. (1996), and combined this with ideas first put forward by Cohen (1992). Here, in addition to logistic growth and demic diffusion, two further interactions are introduced. Hunters may convert to farming upon contact with original farmers (Aoki et al., 1996) or converted farmers, and there is direct competition for resources between the two farming populations (original farmers and converts). Modified logistic and diffusive terms (first proposed by Cohen, 1992) are employed. A number of scenarios are simulated in which competing populations are appropriate, one being the Neolithic revolution in Europe (here, as in many other cases, this is considered synonymous with the introduction of arable farming). The model results in an internal boundary, at which the dominant invading population becomes the converts rather than the original farmers, occurring close to the observed boundary of the LBK culture. However, the LBK boundary does not extend as far east as the boundary in their model, and also extends further west along the Rhine-Danube valley. This disparity is attributed to the probability that the LBK culture spread faster along these rivers than elsewhere, a feature they did not try to model. This is consistent with the radiocarbon record examined by Ammerman and Cavalli-Sforza among others, as discussed above.

In any model of interacting populations, however, there is the inherent difficulty of estimating the 'conversion rate' between populations. There exists little archaeological evidence for the initial spread of farming, with regard to the quantification of interactions with the *in situ* hunter-gatherers. In the current work, we adopt an approach which neglects any population interaction. This is based on the assumption that there is no competition for resources between the two populations; i.e., we assume a hunter-gatherer population can live side by side with a farming population (at the typically low Neolithic population densities) and not deplete the same resources.

5. Comparison of the model with radiocarbon dates

The quality of the model was assessed by considering the time lag $\Delta T = T - T_{\mathrm{m}}$ between the modelled arrival time(s) of the wave(s) of advance to a site, T_{m}, and the actual ^{14}C date(s) of this site, T, obtained as described in Sect. 2. The sites were attributed to that centre (Near East or Urals) which provided the smallest magnitude of ΔT. This procedure admittedly favours the model, and the attributions have to be carefully compared with the archaeological and typological characteristics of each site. Such evidence is incomplete or insufficient in a great number of cases; we leave the laborious task of incorporating independent evidence in a systematic and detailed manner for future work. Our formulaic method of attribution has inevitably failed in some cases, but our preliminary checks have confirmed that the results are still broadly consistent with the evidence available.

First, we considered a model with a single source in the Near East. The resulting time lags are presented in Figure 6a–c. In Figure 6a the sites shown are those at which the one-source model date and the radiocarbon date agree within 500 years (55% of the pan-European dates); Figure 6d gives a similar figure for the two source model (now 70% of the pan-European dates). The points in the EE area are significantly more abundant in Figure 6d than in 6a, while the difference in the SCWE area is less striking; this suggests that while the SCWE sites are fitted reasonably well with the one source model, with $|\Delta T| < 500$ years for 68% of data points, the fit is unacceptably poor for EE, where only 38% of the radiocarbon dates can be fit to within 500 years. The standard deviation of the pan-European time lags here is $s = 800$ years. Outliers are numerous (illustrated by the abundance of points in Figure 6c) when all of the European sites are included, and they make the distribution skewed, and offset from $\Delta T = 0$. The outliers are mainly located in the east; for the SCWE sites, the distribution is more tightly clustered ($s = 540$ years), has negligible mean value, and is quite symmetric. In contrast, the time lags for sites in Eastern Europe (EE), with respect to the centre in the Near East, have a rather flat distribution ($s =$ 1040 years), which is strongly skewed and has a significant mean value (310 years). The failure of the single-source model to accommodate the ^{14}C dates from Eastern Europe justifies our use of the more complicated model with two sources of propagation. (Attempts were also made to locate a single source in various other locations, such as the Urals, but this did not improve the agreement.)

Adding another source in the East makes the model much more successful; the values of the time lag, shown in Figure 6d–f, are systematically smaller (i.e. there are significantly fewer points in Figure 6f (5%) compared to Figure 6c (17%)). The resulting ΔT distribution for all the sites is quite narrow ($s = 520$ years) and almost perfectly symmetric, with a negligible mean value (40 years). The distributions remain similarly acceptable when calculated separately for each source (with s = 490 and 570 years, respectively). The improvement is especially striking in EE, where the sites are split almost equally between the two sources.

We tentatively consider a model acceptable if the standard deviation s, of the time lag ΔT , is not larger than 3 standard dating errors σ; i.e., about 500 years, given our estimate of σ close to 160 years over the pan-European domain. This criterion cannot be satisfied with any single-source model, but is satisfied comfortably with two sources. While we

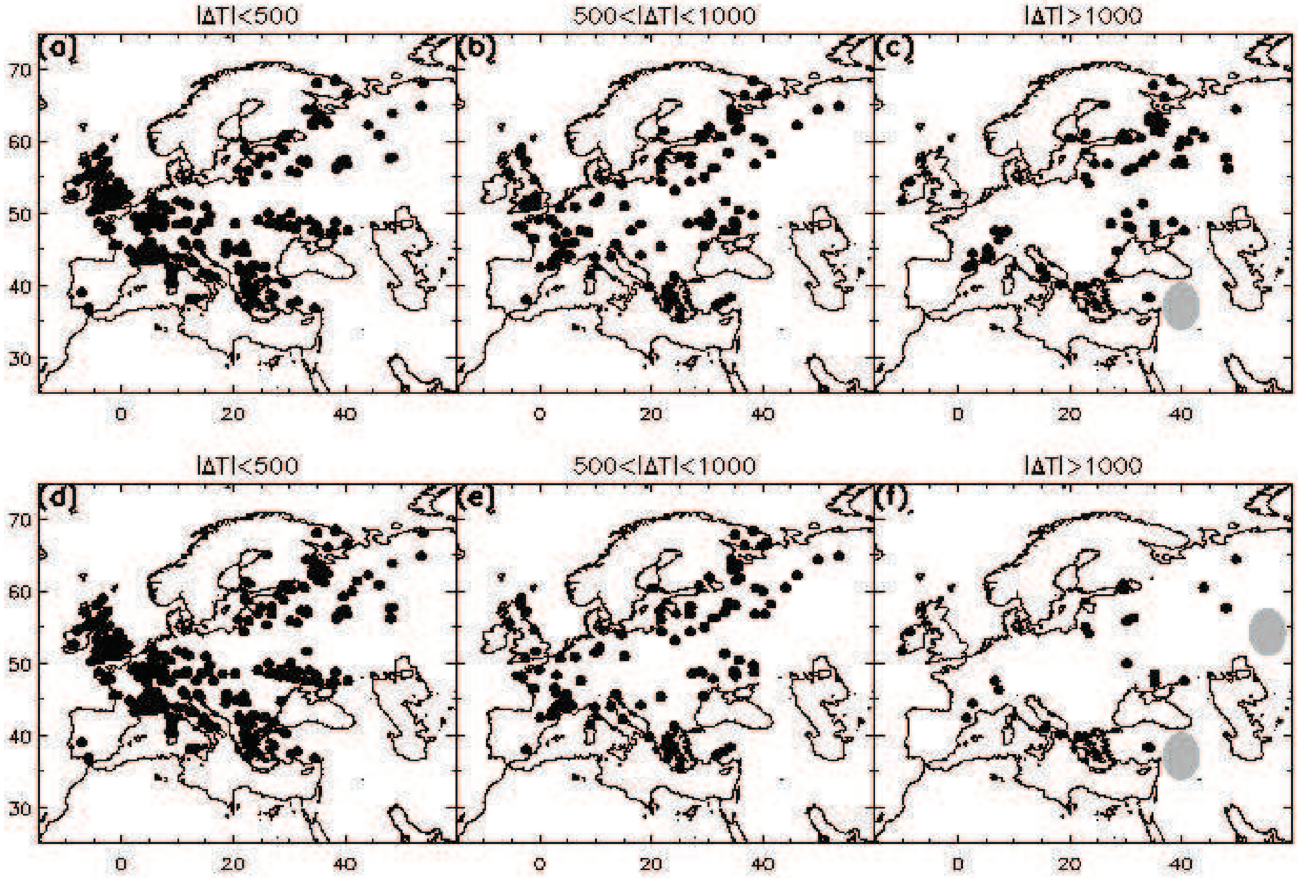

Figure 6. Time lags, $\Delta T = T - T_m$, between the actual and modelled arrival times for the early Neolithic sites: panels **(a)–(c)** refer to a model with a single source in the Near East, and panels **(d)–(f)** to our best model with two sources (with the second on the Eastern edge of Europe). The positions of the sources are shown in grey in panels (c) and (f). Sites with $|\Delta T| < 500$ are shown in (a) and (d), those with 500 yr < $|\Delta T|$ < 1000 yr in panels (b) and (e), and those with $|\Delta T|$ > 1000 yr in panels (c) and (f). There are 265, 132, 81 sites in panels (a)–(c) and 336, 116, 26 sites in (d)–(f), respectively. Many data points correspond to several nearby sites, diminishing the apparent difference between the two models. The advantage of the two-source model is nevertheless clear and significant.

would never expect a large-scale model of the sort proposed here to accurately describe the complex process of the Neolithization in fine detail (and so the resulting values of ΔT cannot be uniformly small), the degree of improvement in terms of the standard deviation of ΔT clearly favours the two-source model. The reduction in s is statistically significant, and cannot be explained by the increase in the complexity of the model alone. The confidence intervals of the sample standard deviations s for one-source and two-source models do not overlap ($740< \sigma_{\text{One Source}} <840$ $480< \sigma_{\text{Two Source}}<550$); moreover, the F-test confirms this at a 99% significance level.

It is instructive to represent the data in the same format as in Figure 2a, b, but now with each date attributed to one of the sources, as suggested by our model. This has been done in Figure 2c, d, where the close correlation of Figure 2a is restored for the pan-European data. The dates are consistent with constant rates of spread from one of the two sources. Using straight-line fitting, we obtain the average speed of front propagation of 1.1 ± 0.1 km/year for the wave originating in the Near East (Figure 2c), and 1.7 ± 0.3 km/year for the source in the East (Figure 2d); 2σ values are given as uncertainties here and below. The spread from the Near East is slowed in Eastern Europe to 0.7 ± 0.1 km/year; excluding the dates from the East (as in Figure 2a) gives a higher speed of 1.2 ± 0.1 km/year. The estimates for the data in both western and eastern Europe are compatible with earlier results (Dolukhanov et al., 2005, Gkiasta et al., 2003, Pinhasi et al., 2005). Care must be taken when using such estimates, however, since the spread occurs in a strongly heterogeneous space, and so cannot be fully characterised by a single constant speed. The rate of spread varies on both pan-European scale and on smaller scales, e.g., near major waterways (Davison et al., 2006).

Our allocation of sites to sources is discussed above, and must be critically evaluated as typological archaeological evidence becomes available. Provisionally, however, we consider a few sites here, and analyse how they fit into the two source model. Taking Ivanovskoye-2 as an example, the data form two peaks (Figure 1b). The times at which each of the waves arrive at this location are 4349BC (for the Near-Eastern wave) and 5400BC (for the Eastern Wave); it can be seen that these each correspond to one peak. As a second example, we accept two dates for the Mayak site; one from the younger cluster (2601 ± 192 BC), and one from the older date (4590 ± 47 BC) which is an outlier to the younger peak. When the allocation of sites to sources is then performed, one of the sites is consistent with the near-eastern wave (arriving at 2506 BC), and the other with the eastern wave (arriving at 4718 BC). Thus in these two representative test cases, it is shown that where there are two discernible peaks, they generally correspond one to each of our proposed waves of advance. This is indicative of the Neolithic process being at the least dual faceted.

Conclusions

Our model has significant implications for the understanding of the Neolithization of Europe. It substantiates our suggestion that the spread of the Neolithic involved at least two waves propagating from distinct centres, starting at about 8200 BC in Eastern Europe and 6700 BC in the Near East. The earlier wave, spreading from the east via the 'steppe corridor', resulted in the spread of pottery-making and the establishment of the 'eastern version' of the Neolithic in Europe. A later wave, originating in the Fertile Crescent of the Near East, is the well-studied process that brought farming to Europe.

It is conceivable that the westernmost extension of the earlier (eastern) wave of advance produced the pre-agricultural ceramic sites of La Hoguette type in north-eastern France and western Germany, and of Roucadour-type (also known as Epicardial) in western Mediterranean and Atlantic France (Berg and Hauzer, 2001, Jeunesse, 1987). The available dates for the earlier Roucadour sites (7500–6500 BC) (Roussault-Laroque, 1990) are not inconsistent with this idea, but a definitive conclusion needs additional work.

The nature of the eastern source needs to be further explored. The early-pottery sites of the Yelshanian Culture (Mamonov, 2000) have been identified in a vast steppe area stretching between the Lower Volga and the Ural Rivers. The oldest dates from that area are about 8000 BC (although the peak of the culture occurred 1000 years later) (Dolukhanov et al., 2005). Even earlier dates have been obtained for pottery-bearing sites in Southern Siberia and the Russian Far East (Kuzmin and Orlova, 2000, Timofeev et al., 2004). This empirical relation between our hypothetical eastern source and the earlier pottery-bearing sites further east may indicate some causal relationship.

According to our model, the early Neolithic sites in Eastern Europe belong to both waves, in roughly equal numbers. Unlike elsewhere in Europe, the wave attributable to the Near East does not seem to have introduced farming in the East. The reason for this is not clear, but may involve the local environment: low fertility of soils and prolonged winters combined with the richness of aquatic and terrestrial wildlife resources (Dolukhanov, 1996).

Regardless of the precise nature of the eastern source, the current work suggests the existence of a wave which spread into Europe from the east carrying the tradition of early Neolithic pottery-making. If confirmed by further evidence (in particular, archaeological, typological, and genetic evidence), this suggestion will require some serious re-evaluation of the origins of the Neolithic in Europe.

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Mathematical models of the Neolithic transition: a review for non-mathematicians

Joaquim Fort

Departament de Física, Universitat de Girona, Campus de Montilivi, 17071 Girona, Catalonia, Spain (joaquim.fort@udg.edu)

1. Introduction

This paper surveys the main existing mathematical models of the Neolithic transition. They are presented in their historical context, in a self-contained way, and using as little mathematics as possible. Still, we reproduce all necessary formulae to reach the results reviewed.

Section 2 presents the classical model by Ammerman and Cavalli-Sforza. Some later refinements of their model are surveyed in sections 3 to 6. We also compare the speed predicted by each model to that implied by the archaeological data. Section 7 contains a new derivation of a recent model. Regional variability is discussed in sections 8 and 9 (using archaeological data and mathematical models, respectively). Finally, section 10 is devoted to concluding remarks.

2. The model by Ammerman and Cavalli-Sforza

While working at Fisher's laboratory in Cambridge from 1949 until 1951, Cavalli-Sforza (1990) learnt about Fisher's model. It was initially conceived to describe the spread of advantageous genes (Fisher, 1937), and later applied to biological invasions (Skellman, 1951). Cavalli-Sforza noted that, if the Neolithic transition was not a process of cultural adoption but mainly due to the dispersal of populations, then: (i) Fisher's equation could hold, and (ii) the values of its parameters could be estimated from anthropological data. This was the first mathematical model of the Neolithic transition. Indeed, according to Fisher's model the population front speed (in kilometers per year) is predicted as (Fisher, 1937; Skellman, 1951)

$$c_{\text{predicted}} = 2\sqrt{aD}\,, \qquad (1)$$

where a is called the initial growth rate of the population number (per year) and D is the population diffusion coefficient (in km^2 per year).

The faster a population reproduces, the higher its value of a will be, and according to Equation (1) the invasion front will spread faster. Similarly, the further away individuals disperse from their parents, the higher the value of D will be and, again, Equation (1) predicts a faster invasion.

Ammerman and Cavalli-Sforza (1971) gathered the archaeological data available and used them to estimate an observed speed of

$$c_{\text{observed}} = 1.0 \pm 0.2 \text{ km/year.} \qquad (2)$$

They also estimated the diffusion coefficient as Ammerman and Cavalli-Sforza (1984)

$$D \approx \frac{<\Delta^2>}{T}, \qquad (3)$$

where $<\Delta^2>$ is the mean of the squared distance Δ^2 moved by individuals in a generation time, T. Finally, Ammerman and Cavalli-Sforza (1984) also found anthropological observations in the literature for human reproduction, mobility and the generation time T. Those anthropological observations yield the characteristic values

$$a = 0.032 \text{ year}^{-1}, \qquad (4)$$

$$<\Delta^2> = 1544 \text{ km}^2, \qquad (5)$$

$$T = 25 \text{ year.} \qquad (6)$$

Using these values in Equations (3) and (1) yields

$$c_{\text{predicted}} = 2.8 \text{ km/year.} \qquad (7)$$

The prediction (7) is much faster than the speed (2) observed from the archaeological record.

The characteristic mobility value (5) was obtained from *individual* mobility data per generation for pre-industrial agriculturalists (Stauder, 1971). Some *mating* data (distances between birthplaces between husbands and wives) yield much lower values of $<\Delta^2>$, and thus of the predicted speed (1) (Ammerman and Cavalli-Sforza, 1984). However, mating data seem inappropriate because derivations of Fisher's model (Okubo and Levin, 2001; Fort and Méndez, 1999) show that $<\Delta^2>$ corresponds to distances Δ moved *per individual* during the generation time T (i.e., distances moved by individuals from their birthplace until the place where they have children).

This theoretical model, proposed by Ammerman and Cavalli-Sforza (1984), was the first mathematical computation of the predicted speed of the Neolithic transition.

3. Fisher's model in two-dimensional space

Equation (3) gives an order-of-magnitude estimation of the diffusion coefficient D. However, its precise value depends on the number of dimensions, as follows:

(i) For a one-dimensional space (e.g., a population of birds dispersing along a coast) (Okubo and Levin, 2001),

$$D = \frac{<\Delta^2>}{2T}; \qquad (8)$$

(ii) For a two-dimensional space (e.g., a population of humans invading Europe) (Fort and Méndez, 1999),

$$D = \frac{<\Delta^2>}{4T}; \qquad (9)$$

(iii) For a three-dimensional space (e.g. a fish population in an ocean),

$$D = \frac{<\Delta^2>}{6T}. \qquad (10)$$

As it might be expected intuitively, D and therefore the invasion speed (1) are lower the higher the number of available dimensions into which the population can disperse.

Using the observed values (5)-(6) in the two-dimensional formula (9) yields

$$D = 386\frac{\text{km}^2}{\text{gen}} = 15.44\frac{\text{km}^2}{\text{yr}}, \qquad (11)$$

which used into Equation (1) (with the same values of a and T as above) leads to

$$c_{\text{predicted}} = 1.4\ \text{km/year}. \qquad (12)$$

This is a more accurate estimation than (7). However, it is still outside the observed range from the archaeological observations quoted in Equation (2), namely 0.8-1.2 km/year (Ammerman and Cavalli-Sforza, 1971).

4. Time-delayed model

A more refined approach (Fort and Méndez, 1999) noted that Fisher's speed (1) does not take into account the fact that newborn children spend some time T with their parents until they become adults and can migrate. If this effect is taken into account, the predicted speed is

$$c_{\text{predicted}\ T} = 2\frac{\sqrt{aD}}{1+\dfrac{aT}{2}}, \qquad (13)$$

instead of Fisher's speed (1). Note that if the effect of the dispersive delay is neglected ($T = 0$), Equation (13) reduces to Fisher's speed (1), as it should.

Using the same parameter values as above, the more refined prediction (13) yields a speed of

$$c_{\text{predicted}\ T} = 1.0\ \text{km/year}, \qquad (14)$$

which is consistent with the observed range (0.8-1.2 km/year).

5. Mathematical models versus archaeological observations

Figure 1 shows the distances to Jericho (the presumed center of the Neolithic population dispersal) versus the oldest date of archaeological sites, according to the data used by Ammerman and Cavalli-Sforza (1971, 1984). The full line is their fit to the data. The distance-versus-dates and dates-versus-distances regressions (not shown) yield the observed speed quoted in Equation (2), namely 1.0±0.2 km/year (95% confidence interval) (Fort and Méndez, 1999). Each of the three other lines in Figure 1 gives the best fit using the speed predicted by each of the three models above, namely (7), (12) and (14). The values of χ^2 are the errors of the models relative to the data (i.e., the sum of the squared distances). Clearly the prediction of Equation (14) gives a lower error than those from the non-delayed models (7) and (12).

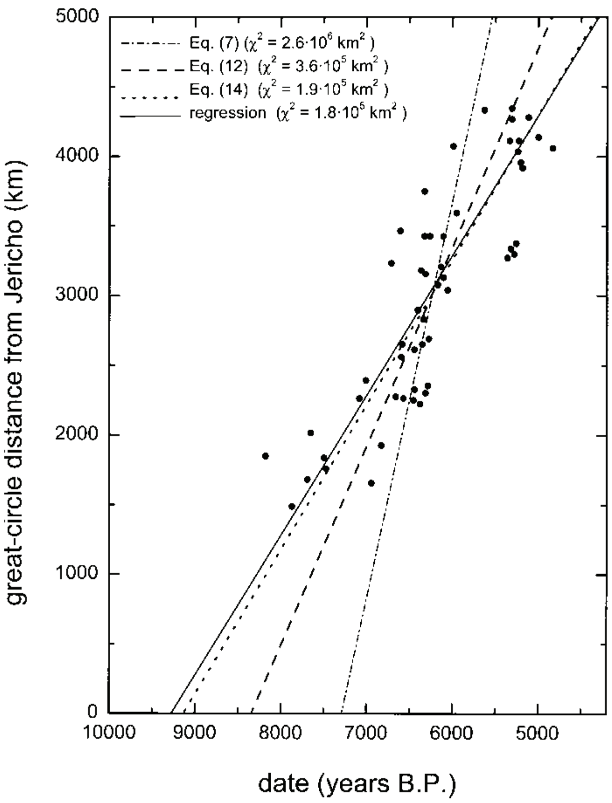

Figure 1. Comparison between observations (from archaeology) and predictions (from mathematical models), after (Fort and Méndez, 1999). The data points (one per archaeological site) and their principal-axis regression are from Ammerman and Cavalli-Sforza (1971, 1984). The time-delayed model, Equation (14), gives a better agreement with the data (i.e., a slower rate of spread) than the non-delayed models corresponding to Equations (7) and (12).

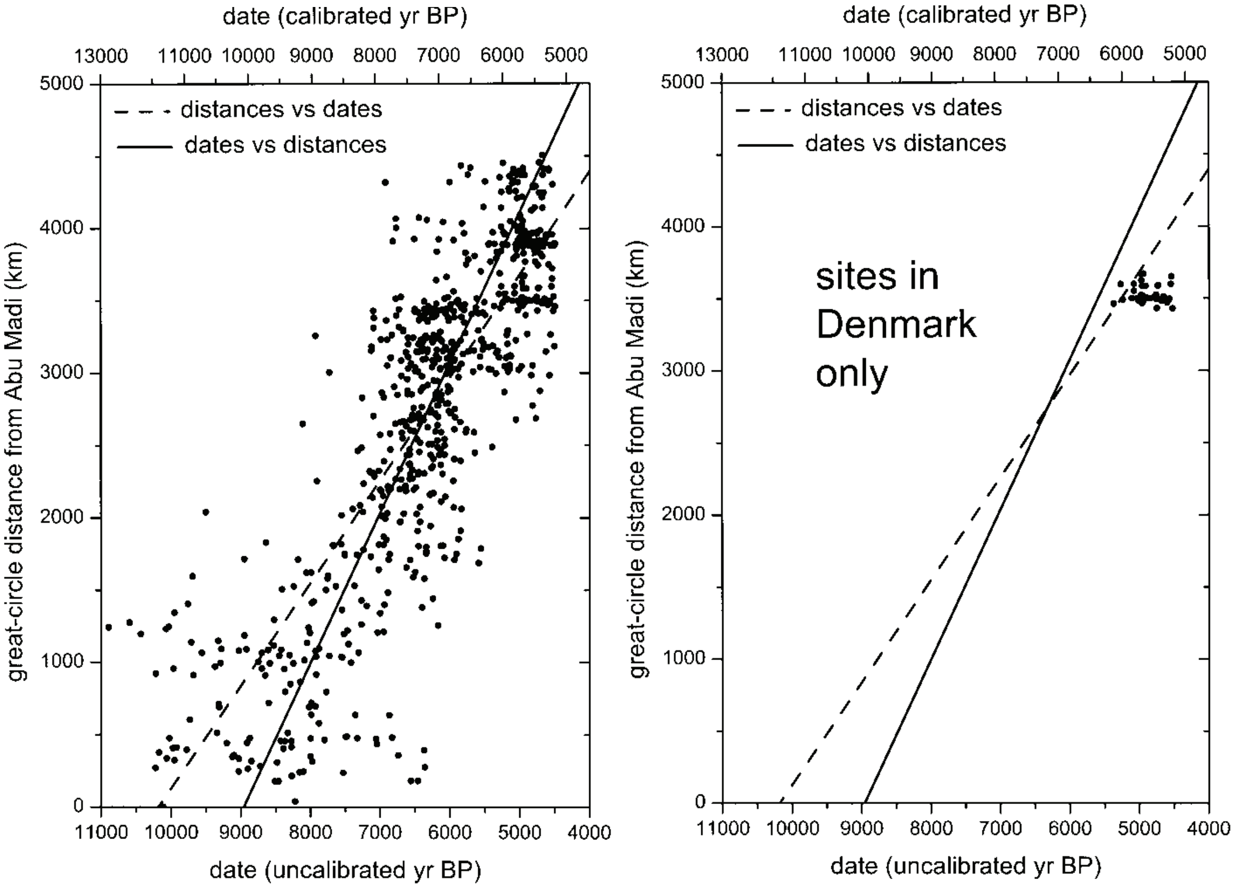

Figure 2. **(a)** Computation of the speed range using 735 sites, after Pinhasi, Fort and Ammerman (2005). As in Figure 1, great-circle distances have been used. The speed implied by the distance-versus-time regression (dashed line) is its slope, namely 0.71 ± 0.04 km/year. The speed implied by the time-versus-distance regression (full line) is the inverse of the corresponding slope, namely 1.04 ± 0.05 km/year (95% confidence intervals). Therefore, we estimate the overall speed range as 0.7–1.1 km/year. **(b)** The straight lines are regression fits to 735 sites (the same lines as in Fig. 2.a). However, only sites in Denmark from Fig. 2.a are replotted here (38 data points). A consistent delay shows up in this region, because most sites are to the right (more recent dates) of the regression lines. Further mathematical models are necessary to describe this observation.

A sensitivity analysis using the observed error ranges for the values of the parameters (4)-(6) was also performed, reinforcing the conclusion that the non-delayed models (sections 3 and 4) give speeds too fast compared to the archaeological record (Fort and Méndez, 1999).

As mentioned above, the distance-versus-dates and dates-versus-distances regressions of the 53 sites in Figure 1 lead to an observed speed range of 1.0±0.2 km/year. However, that dataset is now over thirty-five years old (Ammerman and Cavalli-Sforza, 1971). Therefore, it is very important to know if archaeological data available today yield a similar speed range or not. Gkiasta et al. (2003) performed such an analysis with 510 sites and obtained a speed of 1.3 km/year. However, they did not compute an error range for this speed. And they assumed that Jericho was the origin of the dispersal; a different presumed origin will yield a different speed. As stressed by Ammerman and Cavalli-Sforza, the most probable origin should be that which yields a higher correlation coefficient. Such an analysis has been recently performed for 735 sites (Pinhasi, Fort & Ammerman 2005), and the speed range (using again great-circle distances) is 0.7-1.1 km/year. Again, this range was computed from combining the distance-versus time and the time-versus-distance regressions (Figure 2a). This speed range (0.7-1.1 km/year) can be viewed as a reassuring result, because it is compatible with that obtained by Ammerman and Cavalli-Sforza 35 years earlier (0.8-1.2 km/year). There is no inconsistency and, therefore, this seems to be a sound line of research.

6. Cohabitation models

Let $p(x,y,t)$ stand for the population density (i.e., the number of individuals per unit area centered at the spatial point (x,y) at time t). Fisher's speed (1), as well as its time-delayed generalization (13), can be derived by assuming that, for low values of the population density $p(x,y,t)$,

$$p(x,y,t+T) = R_0\ p(x,y,t) + \sum \Pi(x',y' \to x,y)\ p(x',y',t) \quad (15)$$

where the net reproductive rate R_0 depends on the initial growth rate *a* (appearing in Equation (1)) as $R_0 = e^{aT}$ (Fort, Pérez-Losada and Isern, 2007). In the last term, $\Pi(x',y' \to x,y)$ is the net probability than an individual moves from (x',y') to (x,y). The sum Σ indicates that we take into account all possible origins (x',y').

Recently it has been argued that a more realistic model should be the following (Fort, Pérez-Losada and Isern, 2007)

$$p(x,y,t+T) = R_0 \sum \Pi(x',y' \to x,y)\ p(x',y',t). \quad (16)$$

Similar models are widely used in ecology (Weinberger, 1978; Clark, 1998; Fort, 2007). The difference is that model (15) considers that children appear at the same location as the parents (first term in Equation 15), and parents migrate away from their children (last term). This is not realistic for human populations. In contrast, Equation (16) considers that children grow up with their parents at their final location. Thus Equation (16) is a cohabitation model, whereas (15) is not. The same conceptual limitation applies to Fisher's model (1) and its time-delayed generalization (13), because they are both special cases of the model (15). The differences between the cohabitation model (16) and the model (13) are as large as 30% (Fort, Pérez-Losada and Isern, 2007). However, the speed range predicted by (16) is still consistent with the observed range, namely 0.7-1.1 km/year (from Figure 2a).

7. Dispersive-variability models

In this section we present a new derivation of the cohabitation model, reviewed in the previous subsection. This derivation is motivated by work by other authors showing the importance of taking the age-structure of populations into account in mathematical models (Pinhasi, Fort and Ammerman, 2005), as well as by some recent dispersive-variability models (Harris, 2003; Méndez, Ortega-Cejas and Campos, 2005).

Any human population can be regarded as composed of three sub-populations, with different behaviors: juveniles (e.g., individuals $<\tau$ years old, where τ is the age at first reproduction), reproducing adults (e.g., aged $\geq \tau$ years old and reproducing), and non-reproducing adults (because of age, sterility, or other reasons). Let $p_J(x,y,t)$, $p_A(x,y,t)$ and $p_{AN}(x,y,t)$ stand for the corresponding numbers of individuals per unit area centered at position (x,y) at time *t*.

Obviously, the number of juveniles appearing per generation should be related to the number of reproducing adults in the preceding generation $p_A(x,y,t)$, not to the total number of individuals, i.e.

$$p(x,y,t) = p_A(x,y,t) + p_J(x,y,t) + p_{AN}(x,y,t).$$

How can be write down such a relationship mathematically? If we consider (as a useful approximation) a simple, time-averaged model in which all individuals begin to reproduce at once, we can simply write

$$p_J(x',y',t+T_1) = f\ p_A(x',y',t). \quad (17)$$

where *f* is the population fecundity, and T_1 is the mean age difference between the first and the last child.

In agreement with anthropological observations (Stauder, 1971), let juveniles migrate away from their parents after some mean time T_2. Then,

$$p_A(x,y,t+T_1+T_2) = s\sum \Pi(x',y' \to x,y)\ p_J(x',y',t+T_1), \quad (18)$$

where *s* is the fraction of juveniles who will become reproducing adults, and $\Pi(x',y' \to x,y)$ is again the jump probability from (x',y') to (x,y).

Of course, more complicated models can be considered. But this simple model is more detailed than those in the previous sections, because here we take into account that the reproductive and dispersive behavior may depend on age (albeit in the simplest possible way). How does the front speed change when considering this more detailed description? Interestingly, it does not change at all! Indeed, using Equation (17) in the right-hand side of Equation (18), and defining $T = T_1 + T_2$, we come to

$$p_A(x,y,t+T) = R_0 \sum \Pi(x',y' \to x,y)\ p_A(x',y',t), \quad (19)$$

where $R_0 = s\ f$. So we obtain again the cohabitation model, given by Equation (16). The only difference is that here the reproducing adult subpopulation $p_A(x,y,t)$ appears, instead of the total population $p(x,y,t)$. But the important point is that the speed of invasion front solutions is the same as for the cohabitation model in the preceding section. This gives further support to the cohabitation model. It also shows that it is always possible to build more complicated mathematical models, but in some cases this does not lead to any new prediction that can be compared to the archeological data. So it does not seem worthwhile complicating the model from the previous section further (in this direction). Instead, a good guide is given by a quote by Albert Einstein: *"Mathematical models should be kept as simple as possible — but not simpler"*.

8. Regional variability: archaeological observations

According to the mathematical models reviewed above, the speed of the Neolithic front is a constant. This predicts that all data points in Figure 1 should fall on a straight line. Clearly this is not the case. Some possible reasons are the following:

(i) Errors in the radiocarbon dates and/or the computed distances. The latter can be due to the existence of several independent spatial origins of agriculture (e.g., an origin for wheat, another one for barley, etc.), to the unavailability of some regions for human settlement (seas and high mountains), etc.

(ii) Regional variability in the spread rate. This should show up as most data points (for the region considered) falling either to the right or to the left of the regression (full line in Figure 1). If the spread slows down in a region, sites will be younger than average, and fall on the right of the regression (more recent dates). Conversely, if the spread accelerates in a region, its sites will be older than average and fall to the left of the regression. For example, Ammerman and Cavalli-Sforza (1971) mentioned a definite slowing down of the spread in Scandinavia. Does their observation hold up for the archaeological data available today? To answer this question, in Figure 2b we repeat the same regressions as in Figure 2a, but plot only the 38 sites from Denmark (from the 735 sites in Figure 2a). Clearly, most data points in Figure 2b lie to the right of the regression lines. Therefore, the new data confirm that the spread was indeed slower in Denmark. No mathematical model has so far explained this observation, let alone the value of its delay time in years.

In the next section, we will discuss how regional variability could be included in mathematical models. But before doing so, let us mention that besides the slowing down of the spread in Northern Europe, there are additional archaeological observations of regional variation that deserve attention; e.g. the delay into the Alpine area (Ammerman and Cavalli-Sforza, 1984; Gkiasta et al., 2003), the accelerated spread of the Bandkeramik in central Europe (Ammerman and Cavalli-Sforza, 1971), and the extremely fast spread along the Western Mediterranean (Ammerman and Cavalli-Sforza, 1971; Zilhão, 2001). Interestingly, the latter is similar in speed to the Neolithic expansion in Oceania (Fort, 2003).

9. Regional variability: mathematical models

Regional variability can be due to many possible reasons, such as:

(i) Geographic or climatic barriers. They are a possible explanation for what appears as a 1,000-year halt in the Neolithic spread into Southern Scandinavia, due to a slow shift from hunter-gatherer into farming economics, possibly because of local difficulties in the practice of agriculture (Price, 2003). Such a halt does not appear of purely cultural origin, but ultimately due to geographic factors.

(ii) Cultural effects. Regions of fast acculturation by hunter-gatherers could in principle show a faster spread (and reduce the coexistence time between hunter-gatherers and farmers, which can be estimated from archaeological data). Mathematically, only recently several-population models have described cultural diffusion effects (Ortega-Cejas, Fort and Méndez, 2006; Ackland et al., 2007; Fort et al., 2008). This is a wide topic that deserves further work.

(iii) Non-homogeneous values of demographic parameters. From a purely mathematical perspective, this may correspond either to human dispersal parameters (diffusion coefficient *D,* dispersal probability distribution $\Pi(x',y' \rightarrow x,y)$, time interval between subsequent migrations *T*) or reproductive ones (values of *a* and R_0). However, we are not aware of any anthropological data backing such suggestions.

(iv) Anisotropic dispersal effects. When the invading population front enters a region unsuitable for agriculture, humans may have a higher tendency to migrate backwards than forwards. There is some anthropological support for this suggestion, because migration data for the human colonization of Northern America in the XIX century are indeed anisotropic. Mathematical models including such effects have been recently proposed (Davison et al., 2006; Fort and Pujol, 2007).

10. Conclusions

We have surveyed the main mathematical models of the Neolithic transition, as well as their comparison to archaeological observations.

Some additional models, e.g. models with several values of the generation time (Fort, Jana and Humet, 2004), have not been reviewed in this paper (mainly because they yield similar results for the predicted spread rate to the models surveyed).

As reviewed in section 8, archaeological data show that regional variations in the spread rate are important. This is an interesting point that deserves further efforts using mathematical models, such as those summarized in section 9.

Acknowledgments

This work was partially funded by the European Comission (grant No. NEST-28192-FEPRE), the MEC-FEDER (grant No. FIS-2006-12296-C02-02) and the Generalitat de Catalunya (grant No. SGR-2005-00087).

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Population spread along self-organized paths

François G. Feugier,* Graeme R. Sarson,* Anvar Shukurov* and Pavel Dolukhanov†

*School of Mathematics and Statistics and †School of Historical Studies, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK

1. Introduction

The spatiotemporal aspects of the transition from foraging to food production, the defining feature of the Neolithic, are often viewed as a systematic propagation, across Eurasia, of a well-pronounced front (or "wave of advance"), either of the invading farming population (Ammerman and Cavalli-Sforza, 1973) or of the advancing farming technology (Whittle, 1996; Price et al., 2001), or of a mixture of both. Mathematical models of this process, and their comparisons with radiocarbon dates and other evidence, treat the front as a continuous, smooth borderline that advances at more or less the same speed across its whole extent, of order 2000 km. Although regional variations in the speed of the advance are well known, they are often attributed to natural factors such as major waterways and coastlines, mountain barriers, etc. (Pinhasi et al., 2005; Davison et al., 2006; Ackland et al., 2007). This approach provides models of the spread of the Neolithic that favourably agree with the large-scale features of the radiocarbon ages of the early Neolithic sites across Europe (Gkiasta et al., 2003; Pinhasi et al., 2005; Davison et al., 2007).

However, these models apply at relatively large scales exceeding a few hundred kilometres and neglect many specific features of the spread of a human population, as opposed to the spread of flames, fires and bacteria. A characteristic feature of human travel (as well as that of many animals) is journey optimization, where the spread does not occur uniformly across the propagation front, but rather accelerates along certain locations and directions where most of the population migrate. Such behaviour creates paths that form a system of communication and travel networks. More importantly, such networks can survive long after the period of initial spread to provide communication systems for the settled population. As discussed by Davison et al. (2006), waterways and coastlines are natural elements of such networks. In this paper we consider another mechanism of the development of discrete propagation paths based on the self-organisation of the human migration. This mechanism can be efficient even in a homogeneous terrain in the absence of waterways and other natural preferable propagation routes. The self-organised spread results in a meso-scale pattern of propagation paths whose width, in the context of the Neolithic, can be argued to be about 50 km (see Section 2.5). Such a network of paths, better suited for human migration, can significantly alter the overall speed of the spread of the population.

Self-organisation is a feature of many nonlinear systems that appears in a wide range of natural phenomena. An example of self-organisation directly relevant to this work is the formation of trails by migrating animals or humans. Since animals can move by their own will, they try to optimise the length and comfort of their travel. On land, a two-dimensional environment, no third dimension is available into which to make a detour (as is possible in water or air), thus providing less choice and hence increasing the importance of balancing the comfort and length of a journey.

Beyond just using existing habitat features, many animals including humans are capable of modifying the environment, e.g., creating and using trails to optimize their travel (Helbing et al., 1997a,b). A widely known example is that ants develop trails, often tens of metres long, between the nest and the foraging places. It is plausible that the resulting modification of the landscape can affect the spread of the population into a previously unexplored area by providing a network of persistent travel paths (trails or roads).

Helbing et al. (1997a,b) use a gradient-climbing approach based on chemo-attraction for their model of path formation. They introduce a potential function designed to quantify the "comfort of walking" on a given terrain. The direction of individual walkers is calculated with the sum of the normalized gradient of that potential and the attractiveness based on distance to a fixed target. Pedestrians move at constant speed, and the magnitude of the potential at a given location increases proportionally to their density at that location; this feature introduces a positive feedback loop and nonlinearity into the system. These simulations show the emergence of well-defined trails on which pedestrians prefer to walk. As pedestrians choose, at any given moment, an intermediate (optimized) direction between the target and the gradient of the potential, trails evolve into a minimal-way system which is the best compromise between distance and comfort (Helbing et al. 1997a,b). However, as the current direction of movement is calculated as the sum of the normalized gradient and the direction to the target, pedestrians walk constantly off the current trails, unless the trail is perfectly aligned with the target. Also, in that sum the attraction to the target is not normalized, i.e. weighted by the distance to the target; this can result in an undefined moving direction if the normalized gradient balances the attraction to the target.

Another model is introduced by Page et al. (2006) who propose an algorithm to find, on a complicated terrain, an optimal path for a traveller who needs to move along valleys to a fixed destination. Their algorithm is based on global information on the terrain, wherein the ridges are defined as positions of negative normal curvature of maximum magnitude, calculated by use of the Weingarten matrix, and whose positions are known in advance. Then a global potential is constructed, represented by the sum of a repulsive potential, having maximum magnitude at the ridges, and an attractive potential based on the distance to a target point. By taking the gradient of the global potential, their algorithm can establish a path that avoids ridges and leads to the target point. This approach requires previous knowledge of the whole terrain and it would be difficult to adapt it to a self-consistent, time-dependent potential as in our model of population spread to an unexplored area. Furthermore, identification of ridges (or valleys) with positions of extremal normal curvature is a technique of 3D image segmentation that seems appropriate for path planning only in cases similar to the one in Figure 1a, where the altitude profile across the domain has no plateaus, so that the top of a mountain (or bottom of a valley) corresponds to a point of maximum curvature. In more general cases, ridges (or valleys) may not correspond to places where the surface is most strongly curved, as in Figure 1b, and therefore the optimal path has to be defined in a different way. If, however, there are additional constraints (such as the need to avoid external detection in military applications), travelling along places of maximum curvature, as shown by the circles in the valley in Figure 1b, may still be the best strategy.

Our aim here is to introduce a model of optimal path development for a population spreading into an unexplored habitat, where factors beyond geographical features such as altitude, slope steepness, water barriers and waterways are important. We include an element of self-organization which makes the spread non-uniform even in a homogeneous habitat. We expect that this can significantly affect the overall speed of the spreading population fronts as well as the way the population occupies territories. As a first step in this direction, here we suggest a simple heuristic model describing the development of trails in a homogeneous habitat.

2. The model and basic equations

2.1. Navigation towards and on the nearest trail

In order to quantify the tendency of migrating people to follow a path already used by other individuals, and eventually to develop a persistent path network, we introduce the dimensionless variable ϕ, a function of position $\boldsymbol{x}$ and time t, that quantifies the quality of a given location with respect to travel. The more people use a given path, the larger is the value of ϕ and the more attractive this path becomes. This can be compared to the effect of people walking in a high-grass savannah: as more people walk through the savannah, grass is laid down and progression becomes easier. If, however, the trail is not used for a certain time, it can gradually disappear.

We note an analogy of the profile of the trail quality $\phi(\boldsymbol{x}, t)$ at fixed t to a landscape, where it is easier to walk along ridges (relatively large values of ϕ) rather than along the valleys, where the altitude (the magnitude of ϕ) is relatively low. In this analogy, ridges would be the trails, and valleys would be areas between trails where it is harder to walk. It is clear that the absolute altitude (the magnitude of ϕ) is a poor indicator of the quality of travel since there can be convenient ridges at low overall altitude and inconvenient valleys at high altitudes, i.e. positions of the *local* extrema of ϕ. (Our choice to identify ridges rather than valleys as places suitable for travel is arbitrary and can be reversed without affecting the nature of the model.) In addition, the terrain, i.e. the spatial form of the trail quality, changes with time depending on the behaviour of the spreading population. The desired algorithm must be able to suggest, at any location and at any time, the direction to the nearest ridge and, simultaneously, to optimise the overall direction of travel with respect to a certain target direction. We assume that the information about the terrain (the spatial distribution of ϕ) is local, i.e., the travelling individuals only know the profile of ϕ in their immediate vicinity. And yet, with this limited information, they should be able to reach the nearest ridge with a reasonably small effort and within a reasonably short time.

To detect the ridges of the profile of $\phi(\boldsymbol{x}, t)$ from local information, we use the maximum and minimum curvatures at a given location, and their associated directions (Haralick et al., 1983). At a typical position, the shortest path towards a ridge of $\phi(\boldsymbol{x}, t)$ is that along the direction of the largest curvature of the surface $\big(x, y, \phi(x, y)\big)$ whereas the direction along the smallest curvature is oriented along the ridge, as illustrated in Figure 2.

To obtain the curvatures of the profile we first need to calculate the Hessian matrix H of ϕ,

$$H = \begin{pmatrix} \frac{\partial^2 \phi}{\partial x^2} & \frac{\partial^2 \phi}{\partial x\, \partial y} \\ \frac{\partial^2 \phi}{\partial x\, \partial y} & \frac{\partial^2 \phi}{\partial y^2} \end{pmatrix}, \qquad (1)$$

and find its eigenvalues by calculating the roots of its characteristic polynomial

$$\lambda^2 - \lambda\, \mathrm{Tr}(H) + \mathrm{Det}(H) = 0, \qquad (2)$$

where $\mathrm{Det}(H)$ is the determinant of H and $\mathrm{Tr}(H)$ is its trace; the two (real) eigenvalues thus obtained are ordered such that $\lambda_1 \leq \lambda_2$. The corresponding eigenvectors are

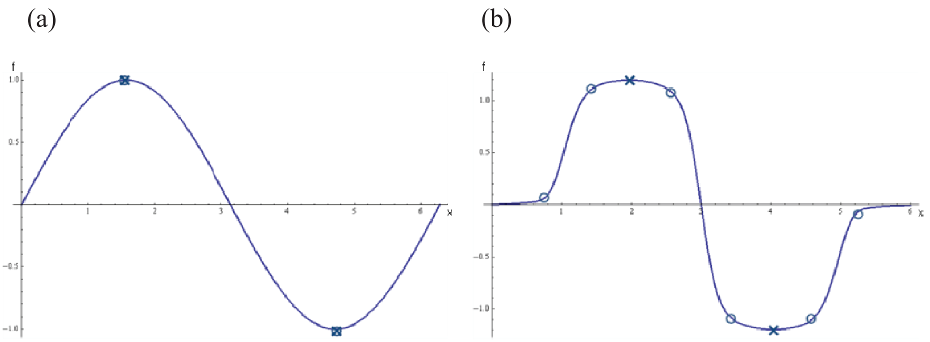
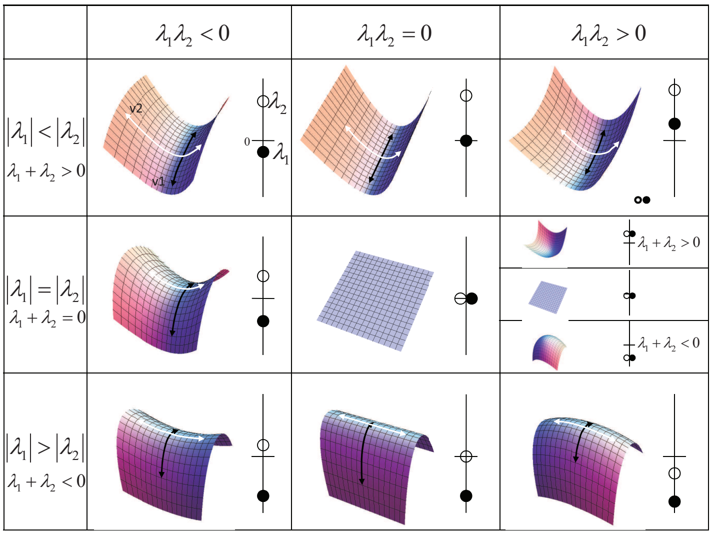


Figure 1. Examples of transversal sections of two different profiles of a ridge and a valley showing the positions of local curvature and altitude extrema. The variable *f* can represent altitude or the value of the trail "potential" (or quality). Circles represent places where local curvature has maximum magnitude, whereas crosses stand for places of maximum (minimum) height, i.e. ridges (valleys). **(a)** If the transversal section is a simple sine curve, ridges and valleys correspond to points of maximum curvature. **(b)** In a more general case, ridges and valleys do not correspond to points of maximum curvature.

Figure 2. Relation between minimum and maximum curvatures of a smooth surface in 3D $(x, y, \phi(x, y))$ space, with their respective orientations, depending on the profile of ϕ. λ_1 and λ_2 are the eigenvalues of the Hessian matrix defined in Equation (2), with $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ the corresponding eigenvectors. Black circles show the value of the minimum curvature λ_1 on the real vertical axis (with horizontal tick at zero); and black double arrows show the direction of the minimum–curvature line to which $\boldsymbol{v}_1$ is tangent. White circles and double arrows similarly show the value of the maximum curvature λ_2 and the maximum–curvature line to which $\boldsymbol{v}_2$ is tangent. What corresponds to a ridge occurs where



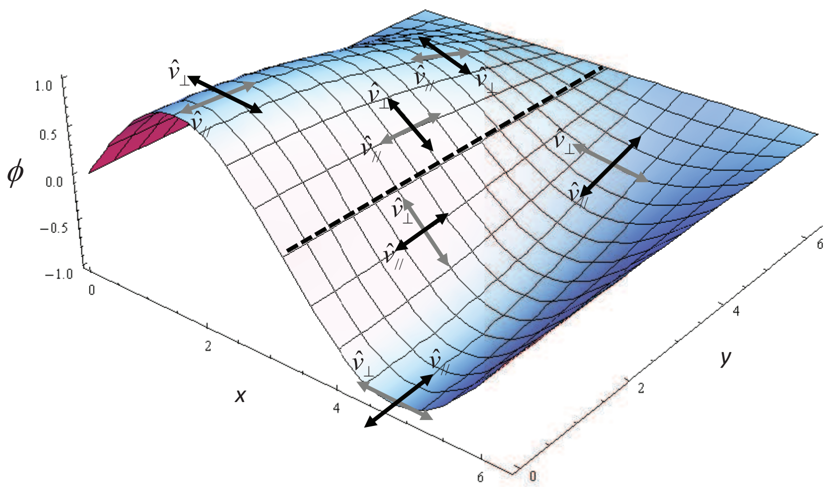


Figure 3. Swap of the two eigenvectors between a ridge and a valley on a typical $(x, y, \phi(x, y))$ profile. Black double arrows: direction of $\boldsymbol{v}_1$; grey double arrows: direction of $\boldsymbol{v}_2$; black dashed line: location with no curvature, and therefore null eigenvectors. We see that, when going from the bottom of the valley $(\lambda_1 + \lambda_2 > 0)$ to the top of the ridge $(\lambda_1 + \lambda_2 < 0)$, the directions of $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ are swapped when crossing the dashed line. $\hat{\boldsymbol{v}}_{\parallel}$ and $\hat{\boldsymbol{v}}_{\perp}$, defined relative to the ridge, are accordingly taken as either $\boldsymbol{v}_1$ or $\boldsymbol{v}_2$, depending on the sign of $\lambda_1 + \lambda_2$.

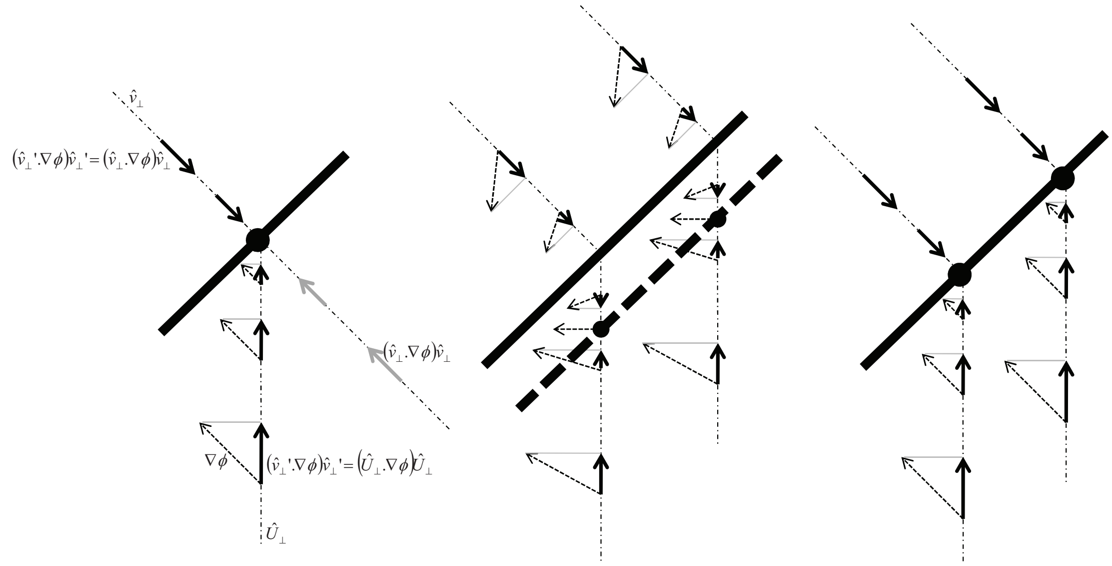


Figure 4. Effect of Equation (8) on population movement, in a situation where $\boldsymbol{U}$ is directed to the right. Thick lines corresponds to the trail/ridge; solid black arrows represent $\hat{\boldsymbol{v}}_\perp'(\hat{\boldsymbol{v}}_\perp'\cdot\boldsymbol{\nabla\phi})$ i.e. the direction of motion determined by Equation (8); gray arrows show $\hat{\boldsymbol{v}}_\perp(\hat{\boldsymbol{v}}_\perp\cdot\boldsymbol{\nabla\phi})$ when $(\hat{\boldsymbol{U}}\cdot\hat{\boldsymbol{v}}_\perp)(\hat{\boldsymbol{v}}_\perp\cdot\boldsymbol{\nabla\phi}) < 0$; dashed arrows correspond to $\boldsymbol{\nabla\phi}$; dot-dashed lines show the direction of $\hat{\boldsymbol{U}}_\perp$ and $\hat{\boldsymbol{v}}_\perp$; thick dashed lines corresponds to the line where $(\hat{\boldsymbol{U}}_\perp\cdot\boldsymbol{\nabla\phi}) = \boldsymbol{0}$ when it differs from the ridge itself; black circles indicate points of convergence of people walking along $\hat{\boldsymbol{v}}_\perp'(\hat{\boldsymbol{v}}_\perp'\cdot\boldsymbol{\nabla\phi})$. (a) When $\hat{\boldsymbol{v}}_\perp(\hat{\boldsymbol{v}}_\perp\cdot\boldsymbol{\nabla\phi})$ is opposed to $\hat{\boldsymbol{U}}$, people following that direction would increase their distance to the target (gray arrows). To avoid this, Equation (8) makes walkers move in the direction of $\hat{\boldsymbol{U}}_\perp$. (b) The ridge is not flat but rises towards the left, as shown by the orientation of the gradient. In that situation, following $\hat{\boldsymbol{v}}_\perp'(\hat{\boldsymbol{v}}_\perp'\cdot\boldsymbol{\nabla\phi})$ does not lead to the ridge but beside it (black circles), where individuals would follow the thick dashed line. (c) The ridge becomes flat due to the trail dynamics, and people walk perfectly on it even if it is not parallel to $\boldsymbol{U}$.

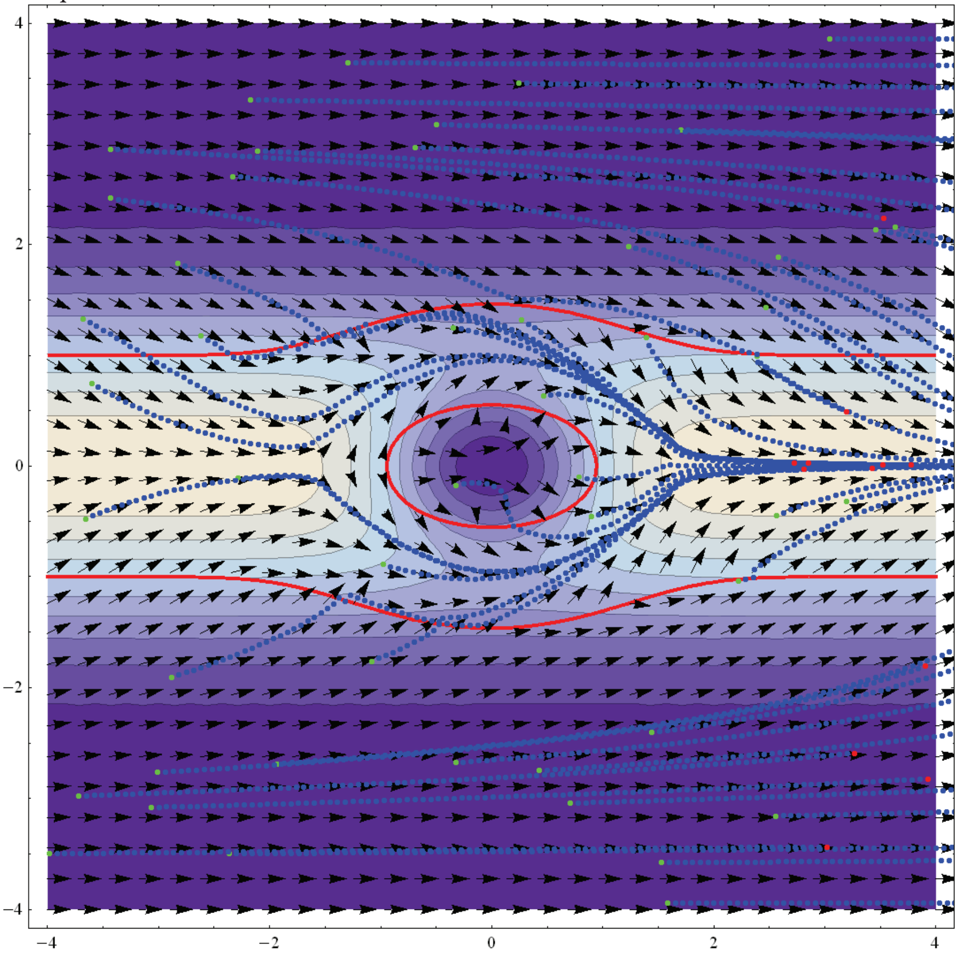


Figure 5. Trajectories produced by equation (9) from 50 random starting points on a typical profile of $\boldsymbol{\phi}$. Bright colours of the profile represent high values whereas dark colours are for low values of $\boldsymbol{\phi}$. Arrows show the direction of $\hat{\boldsymbol{v}}_{\boldsymbol{0}}$. The direction of the target is to the right, $\hat{\boldsymbol{U}} = \binom{1}{0}$. Red thick lines show $\boldsymbol{\lambda_1} + \boldsymbol{\lambda_2} = \boldsymbol{0}$ (inside the central circle and in the top and bottom parts of the figure $\boldsymbol{\lambda_1} + \boldsymbol{\lambda_2} > 0$). We clearly see that trajectories can go down as well as up the gradient of $\boldsymbol{\phi}$, but that they are never in the opposite direction to $\hat{\boldsymbol{U}}$.

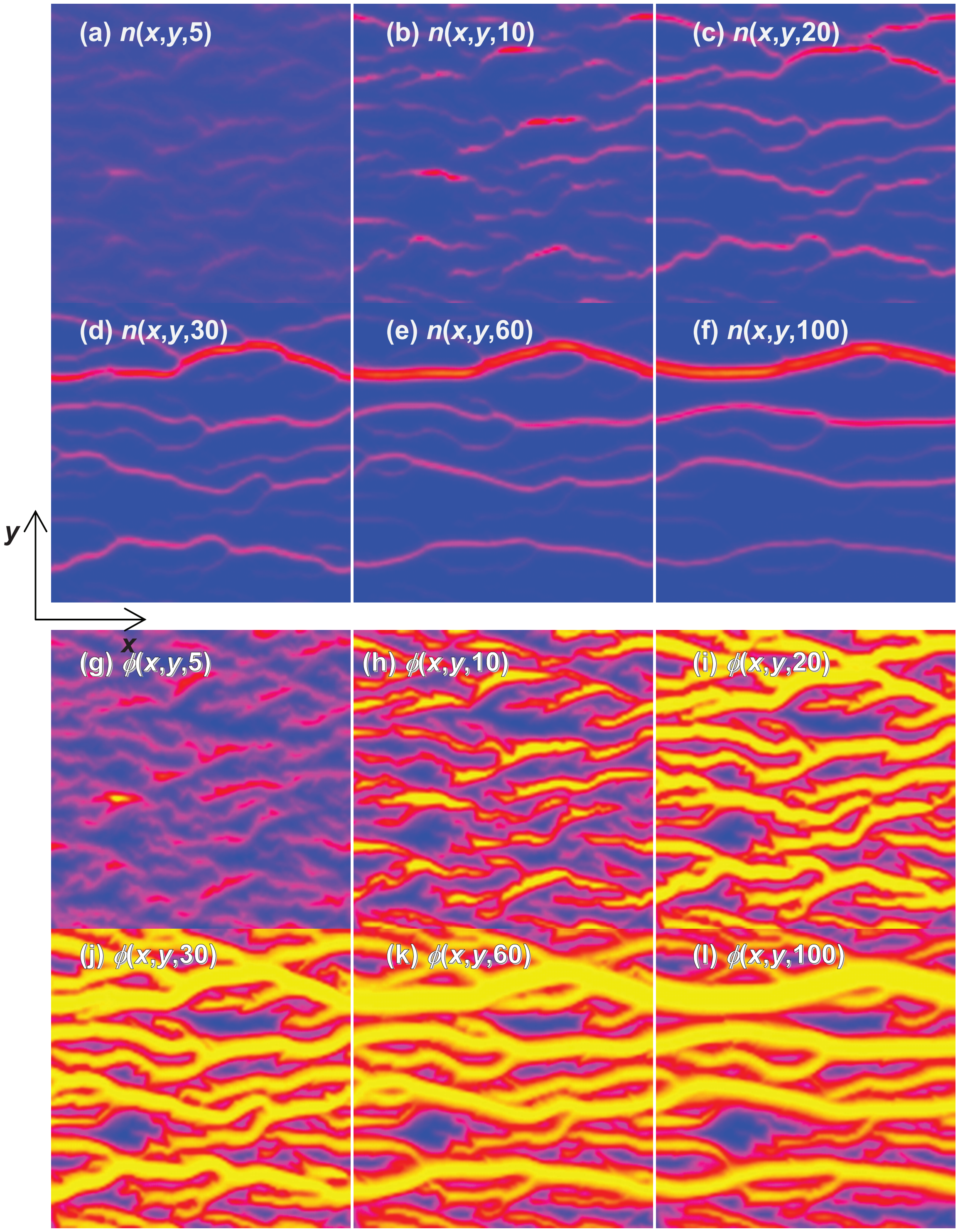


Figure 6. Snapshots of the population density $\boldsymbol{n(x,y,t)}$ [panels (**a**)–(**f**)] and the trail quality $\boldsymbol{\phi(x,y,t)}$ [panels (**g**)–(**l**)] in the unit square $\mathbf{0} \leq (\boldsymbol{x},\boldsymbol{y}) \leq \mathbf{1}$ at different times, t = 5, 10, 20, 30, 60 and 100 years, respectively, where the x and y-axis are horizontal and vertical, respectively. (**a**), (**g**)**:** After the simulation starts, the initial uniform value of $\boldsymbol{n} = \mathbf{3.5}/\boldsymbol{km}^{\mathbf{2}}$ has lost its initial homogeneity due to the noise in the initial values of $\boldsymbol{\phi}$. For t = 5, the maximum and minimum values of n already differ by 44% (1.3 and 0.5 km^{-2}, respectively). (**b**), (**h**)**:** As time progresses, clusters of population emerge due to fluctuations in $\boldsymbol{\phi}$. People at the front of a cluster (with regard to the direction $\widehat{\boldsymbol{U}}$ of motion) find lower values of $\boldsymbol{\phi}$ than at the end of the cluster, because flux of people leads to an increase in $\boldsymbol{\phi}$. Hence, people at the end of a cluster catch up with people in front, making the cluster more pronounced. (**c**), (**i**)**:** Clusters merge to form continuous but irregular trails. (**d**)–(**f**), (**j**)–(**l**)**:** As $\boldsymbol{\phi}$ becomes uniform along each trails, having reached its maximum value $\boldsymbol{\phi} = \mathbf{1}$, the population moves at a constant speed along trails, reducing the degree of clustering. Smaller trails slowly disappear while bigger trails become more regular and attract more people. Eventually, the population density is noticeably higher on the trails (with a maximum density equal to 45/km^2) than outside the trails (with a minimum density close to 0). Parameter values are $\mathbf{Re} = \mathbf{100}, \boldsymbol{B} = \mathbf{0.05}, \boldsymbol{V} = \mathbf{0.1}$ **and** $\boldsymbol{E} = \mathbf{1}$. Colour code: blue (black) corresponds to low values, red (gray) to average values, and yellow (white) to high values.

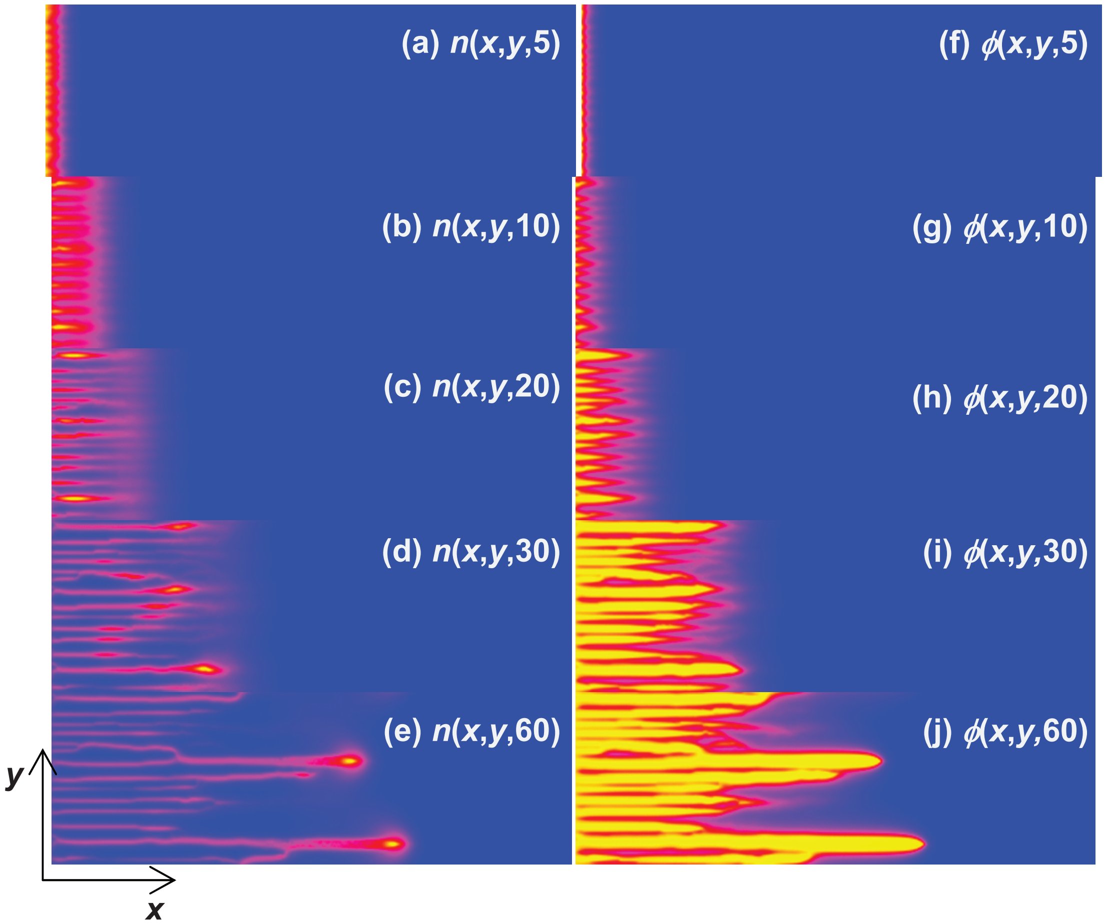


Figure 7. Trail formation and decay of the propagation front, **(a)**-**(e)**: population density n (for a better visibility of the result the logarithm of n is used) and **(f)**-**(j)**: trail quality $\boldsymbol{\phi}$. Parameter values and initial conditions for $\boldsymbol{\phi}$ are the same as in Figure 6, but the shape of the domain is different and the boundary conditions are periodic only at $\boldsymbol{y} = \mathbf{0}, \mathbf{1}$. Initially, $\boldsymbol{n} = \mathbf{0}$ for $\boldsymbol{x} > 0$. The population density at the boundary at $\boldsymbol{x} = \mathbf{0}$ is maintained at a constant level $\boldsymbol{n} = \mathbf{1}$ throughout the simulation, so the population enters the domain from the left and moves at a constant background speed to the right. The colour scale is logarithmic: blue (black) corresponds to low values; red (gray), to moderate ones, and yellow (white) indicates maximum values. **(a)**: The initially straight propagation front quickly becomes undulated, leading to rapid development of trails which are visible in panel **(f)**. **(b)**, **(g)**: Trails emerge and grow longer as the front progresses. **(c)**, **(h)**: As the trails form, some of them merge, as visible at the top and bottom of panel (c), so trails with larger values of $\boldsymbol{\phi}$ carry more people. People entering from the left find good trails (high values of $\boldsymbol{\phi}$) already developed, whereas people near the front encounter lower values of $\boldsymbol{\phi}$. As a result people behind the front start to catch up with people at the front, so peaks of high population density propagate from the left towards the tips of the trails. **(d)**, **(i)**: Trails with larger values of n move faster and destroy the coherence of the propagation front. **(e)**, **(j)**: The front has decayed into just two trails that propagate almost independently.

$$\boldsymbol{v}_1 = \begin{pmatrix} \frac{\partial^2\phi}{\partial x \partial y} \\ \lambda_1 - \frac{\partial^2\phi}{\partial x^2} \end{pmatrix}, \qquad \boldsymbol{v}_2 = \begin{pmatrix} \frac{\partial^2\phi}{\partial x \partial y} \\ \lambda_2 - \frac{\partial^2\phi}{\partial y^2} \end{pmatrix}. \tag{3a,b}$$

Here we do not use the Weingarten matrix, which gives extremal normal curvatures, as ridges on a landscape are defined by points of highest local altitude. Since altitude is defined in terms of the fixed vertical direction, knowledge of the normal curvature of the surface $\left(x, y, \phi(x, y)\right)$ is not required.

As illustrated in Figure 3, the unit direction $\widehat{\boldsymbol{v}}_\perp$ towards the ridge is given by the eigenvector belonging to the eigenvalue

$$\lambda_\perp = \begin{cases} \lambda_1 \text{ if } \lambda_1 + \lambda_2 \leq 0, \\ \lambda_2 \text{ otherwise}, \end{cases} \tag{4}$$

and, thus, is given by

$$\widehat{\boldsymbol{v}}_\perp = \begin{cases} \frac{\boldsymbol{v}_1}{|\boldsymbol{v}_1|} \text{ if } \lambda_1 + \lambda_2 \leq 0, \\ \frac{\boldsymbol{v}_2}{|\boldsymbol{v}_2|} \text{ otherwise}. \end{cases} \tag{5}$$

Likewise, the minimum curvature is

$$\lambda_\parallel = \begin{cases} \lambda_2 \text{ if } \lambda_1 + \lambda_2 \leq 0, \\ \lambda_1 \text{ otherwise}, \end{cases} \tag{6}$$

and its unit vector direction is

$$\hat{\boldsymbol{v}}_{\parallel} = \begin{cases} \frac{\boldsymbol{v}_2}{|\boldsymbol{v}_2|} \text{ if } \lambda_1 + \lambda_2 \le 0, \\ \frac{\boldsymbol{v}_1}{|\boldsymbol{v}_1|} \text{ otherwise.} \end{cases} \quad (7)$$

In this manner we always have $\boldsymbol{v}_{\perp}$ which is parallel to the eigenvector corresponding to the maximum curvature $\lambda_{\perp}$, i.e. the direction perpendicular to a ridge or a valley; and $\boldsymbol{v}_{\parallel}$ which is always parallel to the direction of the eigenvector of the minimum curvature $\lambda_{\parallel}$, i.e. the direction parallel to a ridge or a valley. Note that $\boldsymbol{v}_{\perp}$ is perpendicular to $\boldsymbol{v}_{\parallel}$ due to the symmetry of the Hessian matrix.

The ridges and valleys in the profile of ϕ can be detected as follows. If $\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi = 0$ at some location, this corresponds to a ridge (trail) oriented along $\hat{\boldsymbol{v}}_{\parallel}$ if $\lambda_1 + \lambda_2 < 0$, and to a similarly oriented valley if $\lambda_1 + \lambda_2 > 0$ (Haralick et al., 1983). The degenerate case of $\lambda_1 + \lambda_2 = 0$ corresponds to a rare symmetric saddle or to a plane.

Now that we can identify a trail, we need people to get on it and travel along it as long as this brings them closer to the target, i.e. the orientation of the trail and the direction to the target form an acute angle. Let us formulate conditions for that.

We define the unit vector $\hat{\boldsymbol{U}}$ as the direction of the target. For simplicity, in the present work $\hat{\boldsymbol{U}}$ is independent of time and is a uniform vector field. But one can include evolving and position-dependent $\hat{\boldsymbol{U}}$; e.g. allowing $\hat{\boldsymbol{U}}$ to depend on the distance to the target, the gradient of resources, or making $\hat{\boldsymbol{U}}$ dependent on information about the domain available to the migrating individuals (e.g., obtained from advancing explorer groups). Such ramifications are the subject of ongoing work.

To get on a trail, common sense would lead people to move perpendicularly to the trail itself. Since $\hat{\boldsymbol{v}}_{\perp}$ is always directed along the maximum curvature in the profile of ϕ, it provides a direction perpendicular to ridges (trails), but $\hat{\boldsymbol{v}}_{\perp}$ itself (as defined by Equation 5) may point either towards the ridge (if $\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi > 0$) or away from it (if $\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi < 0$). We therefore use a velocity component directed along $\hat{\boldsymbol{v}}_{\perp}(\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi)$ to bring people to the nearest trail and keep them on it. Where $\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi$ differs from zero, individuals are off the trail and moving along $\hat{\boldsymbol{v}}_{\perp}(\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi)$ leads them towards it; where $\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi = 0$ they are on the trail and they stop moving across it because now $\hat{\boldsymbol{v}}_{\perp}(\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi) = \boldsymbol{0}$. But in some cases this could lead individuals to walk backwards (with respect to the target direction) to reach a trail, if the best trail is behind them, i.e. if $(\hat{\boldsymbol{U}} \cdot \hat{\boldsymbol{v}}_{\perp})(\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi) < 0$. To avoid this, we define

$$\hat{\boldsymbol{v}}_{\perp}{}' = \begin{cases} \hat{\boldsymbol{U}}_{\perp} \text{ if } (\hat{\boldsymbol{U}} \cdot \hat{\boldsymbol{v}}_{\perp})(\hat{\boldsymbol{v}}_{\perp} \cdot \nabla\phi) < 0, \\ \hat{\boldsymbol{v}}_{\perp} \text{ otherwise,} \end{cases} \quad (8)$$

where $\hat{\boldsymbol{U}}_{\perp} = \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} \hat{\boldsymbol{U}}$, and make individuals follow the direction $\hat{\boldsymbol{v}}_{\perp}{}'(\hat{\boldsymbol{v}}_{\perp}{}' \cdot \nabla\phi)$. This means that, in the worst case, individuals will reach the nearest trail by moving perpendicularly to the target direction, without approaching the target (see Figure 4a). The condition in (8) is arbitrary and could be replaced by many alternatives, but it has the advantage of adding no new parameters to the model. When a ridge in the profile of ϕ is not flat, but has a decreasing slope when moving in direction of the target, people may not walk right on the ridge but slightly beside it, on the line where $(\hat{\boldsymbol{U}}_{\perp} \cdot \nabla\phi) = 0$, as shown in Figure 4b. This behaviour is the consequence of Equation (8). However, due to the trail dynamics presented in Section 2.2 below, the ridge will quickly become flat and people will walk straight on it even if it is not exactly aligned with $\hat{\boldsymbol{U}}$ (Figure 4c). If the trail is exactly at right angles to $\hat{\boldsymbol{U}}$, people will follow it (as they will not be going backwards relative to $\hat{\boldsymbol{U}}$), but only for a short time, as in realistic situations the trail will not remain perfectly perpendicular to $\hat{\boldsymbol{U}}$.

Once we are on the trail, we need to follow it to get closer to the target. The direction $\hat{\boldsymbol{v}}_{\parallel}$ is always parallel to the trail axis but not necessarily directed towards the target (i.e. $\hat{\boldsymbol{v}}_{\parallel} \cdot \hat{\boldsymbol{U}}$ can be negative). Therefore, we use $\hat{\boldsymbol{v}}_{\parallel}(\hat{\boldsymbol{v}}_{\parallel} \cdot \hat{\boldsymbol{U}})$ as the direction to walk along a trail while approaching the target.

The net direction of travel is a compromise between the direction towards the trail, $\hat{\boldsymbol{v}}_{\perp}$, and that along the trail $\hat{\boldsymbol{v}}_{\parallel}$ towards the target. We can write an expression for the unit vector $\hat{\boldsymbol{v}}_{\boldsymbol{0}}$ pointing in the direction which will be followed by individuals at each point $\boldsymbol{x} = (x, y)$ at any time *t*:

$$\hat{\boldsymbol{v}}_0(x, y, t) = \frac{\alpha(\hat{\boldsymbol{v}}_{\perp}{}' \cdot \nabla\phi)\hat{\boldsymbol{v}}_{\perp}{}' + (\hat{\boldsymbol{v}}_{\parallel} \cdot \hat{\boldsymbol{U}})\hat{\boldsymbol{v}}_{\parallel}}{|\alpha(\hat{\boldsymbol{v}}_{\perp}{}' \cdot \nabla\phi)\hat{\boldsymbol{v}}_{\perp}{}' + (\hat{\boldsymbol{v}}_{\parallel} \cdot \hat{\boldsymbol{U}})\hat{\boldsymbol{v}}_{\parallel}|}, \quad (9)$$

where α is a stiffness factor (with the dimensions of a length) setting the relative importance of movement in the direction of $\hat{\boldsymbol{v}}_{\perp}{}'$ compared to the direction of $\hat{\boldsymbol{v}}_{\parallel}$.

Figure 5 shows trajectories produced by Equation (9). In this model, a trail is the locus of points where ϕ is largest, if moving along the minimum curvature direction (i.e. a line connecting the local maxima of the ϕ profiles in that direction). Similarly, the ridge of a mountain system is the locus of the points of maximum altitude in each cross-section perpendicular to the ridge (Figure 1). In other words, the directional derivative of ϕ across the ridge vanishes at the ridge (Figure 4a). The same is true for the valleys, but with the minimum altitude and a direction perpendicular to the valley, respectively.

2.2. Trail dynamics

Since it is easier to walk on places with large values of ϕ, it is sensible to assume that the speed of motion is proportional to ϕ. We further assume that the speed of travel is equal to $v_{\max}$ on the trails (where $\phi = 1$) and $v_{\min}$ on pristine land (were $\phi = 0$), with $v_{\min} < v_{\max}$, leading to the following expression for the velocity of travel at an arbitrary position:

$$v = v_{\min}(1 - \phi) + v_{\max}\phi \quad \text{and} \quad \boldsymbol{v} = v\hat{\boldsymbol{v}}_{\boldsymbol{0}}. \quad (10)$$

The maximum and minimum speeds are here assumed to be constants. However, $v_{\min}$ can be set to depend on position to reflect the nature of the terrain, whereas $v_{\max}$ can be reasonably assumed to be genuine constant controlled by biological and technological constraints.

Now we consider the dynamics of the trail quality and suggest the following equation:

$$\frac{\partial\phi}{\partial t} = (1-\phi)\frac{nv}{KL} - \frac{1}{\tau}\phi, \qquad (11)$$

where ϕ is the dimensionless variable quantifying the trail quality (with $\phi = 0$ where the trail is absent and $\phi = 1$ for the maximally developed trail), K is the carrying capacity of the population, L is a parameter which can be identified with the characteristic width of a trail, $L = W$, and τ is the characteristic time of the decay of trails due to the natural recovery of plants, homeostasis, etc. (In a slightly different context, this last term might reasonably be replaced by the diffusion operator containing $\nabla^2\phi$.) The first term on the right-hand side describes the formation of a trail at a rate proportional to the population flux on it, nv (we note that both the population density n and the speed of travel v are functions of position and time): the more people use the trail, the better it becomes. We assume that ϕ is bounded from above by unity (hence the factor $1-\phi$) for the following reason. If the trail is already perfect, the population will move at the maximum speed $v_{\max}$. Although the flux nv can still increase further if n increases, this would not improve the trail any more since the speed of travel cannot exceed $v_{\max}$. In other words, the quality of the trail cannot grow indefinitely but is rather limited from above.

We note that Equation (11) does not have the trivial solution $\phi = 0$ as long as $nv \neq 0$; thus, any movement of the population results in the emergence of trails. Note also that ϕ initially grows linearly in time (rather than exponentially) since $\partial\phi/\partial t \approx nv/(KW)$ for $|\phi| \ll 1$.

The choice of the dimensionless variable ϕ to characterise the quality of a trail can depend on the specific problem at hand; among plausible options, we mention the height and density of vegetation, the steepness of the path, wear, and the yearly traffic.

2.3. Population dynamics

For the population density n we assume the standard continuity equation,

$$\frac{\partial n}{\partial t} = -\nabla\cdot(n\boldsymbol{v}) + D\nabla^2 n, \qquad (12),$$

where D is the diffusivity here assumed to be a constant for the sake of simplicity. The first term on the right-hand side is responsible for both advection at velocity $\boldsymbol{v}$, described by $-\boldsymbol{v}\cdot\nabla n$, and reduction (increase) in the population density in regions of divergent (convergent) motion, $-n\nabla\cdot\boldsymbol{v}$. One can easily add the logistic term $\gamma n(1-n/K)$ to the right-hand side in order to take into account population growth (here γ is the intrinsic growth rate of the population), and also allow for the variability of the diffusivity.

2.4. Dimensionless variables and the model control parameters

We introduce dimensionless variables, denoted with tilde, using the following units:

$$n = \tilde{n}\frac{F_0}{W}, \quad t = \tilde{t}\frac{W}{v_{\max}}, \quad \boldsymbol{x} = \tilde{\boldsymbol{x}}W, \quad \boldsymbol{v} = \tilde{\boldsymbol{v}}v_{\max},$$

where $F_0 = KL$, and we choose $L = W$, where W is the characteristic trail width introduced above. After dropping the tildes, Equations (9)–(12) reduce to the following dimensionless form:

$$\frac{\partial n}{\partial t} = -\nabla.(n\boldsymbol{v}) + \frac{1}{\mathrm{Re}}\nabla^2 n, \qquad (13)$$

$$\frac{\partial\phi}{\partial t} = (1-\phi)nv - B\phi, \qquad (14)$$

$$\boldsymbol{v} = \hat{\boldsymbol{v}}_{\boldsymbol{0}}[V(1-\phi)+\phi], \qquad (15)$$

$$\hat{\boldsymbol{v}}_{\boldsymbol{0}} = \frac{E(\hat{v}_{\perp}{}'\cdot\nabla\phi)\hat{v}_{\perp}{}' + (\hat{v}_{\parallel}\cdot\boldsymbol{U})\hat{v}_{\parallel}}{|E(\hat{v}_{\perp}{}'\cdot\nabla\phi)\hat{v}_{\perp}{}' + (\hat{v}_{\parallel}\cdot\boldsymbol{U})\hat{v}_{\parallel}|}, \qquad (16)$$

where dimensionless parameters are defined as

$$\mathrm{Re} = \frac{v_{\max}W}{D}, \quad B = \frac{W}{\tau v_{\max}}, \quad V = \frac{v_{\min}}{v_{\max}}, \quad E = \frac{\alpha}{W}. \qquad (17)$$

The model is controlled by the four parameters of Equation (17). The Reynolds number Re quantifies the efficiency of travel relative to diffusion: the larger is Re, the weaker are the diffusive effects in the population spread. The rate at which trails decay if not used is characterised by B: this is the ratio of the typical trail width W to the distance travelled along the trail in the trail decay time τ; the faster is the decay, the larger is B (with other parameters fixed). The efficiency of travel on the trails is measured by the third parameter, V: this is the ratio of the travel speeds on pristine land and the maximum speed on trails. Finally, E characterises the advantage provided by travelling on the trails: for a traveller at a distance from a trail, it is equal to the distance travelled towards the nearest trail per unit distance travelled along it.

2.5. Spread of the Neolithic

Specific values of the model parameters, of course, depend on the application. Here we present those relevant to modelling the spread of the Neolithic, a global transition to food production that occurred gradually in Eurasia from about 12,000 BC to 3,000 BC (e.g., Harris et al., 1996). The typical diffusivity of the farming population can be estimated as (e.g., Davison et al., 2006)

$$D \approx 13\ \mathrm{km}^2/\mathrm{year},$$

from the mean speed of the wave of advance of agriculture into Europe from the Levant, about 1 km/year (e.g., Gkiasta et al., 2003). The latter speed is presumably a compromise between the speed of spread along the waterways, perhaps reaching 10 km/year along the Mediterranean coast (Zilhão, 2001), and a lower speed of progress into unexplored land. This gives an idea of the range of travel speeds relevant to the spread of the Neolithic. Thus, the maximum travel speed can be taken as

$$v_{\max} = (10\text{–}20)\ \mathrm{km/year},$$

whereas the minimum speed can be tentatively chosen as
$v_{\min} = (0.5\text{–}1)$ km/year.

It is more difficult to estimate the relevant trail width. A quantity of the dimension of length naturally arising in modelling the spread of growing populations is the width of the population front, $W \approx 2(D/\gamma)^{1/2}$, where γ is the intrinsic growth rate of the population. We identify the typical trail width with this length scale. With $\gamma \approx 0.02\ \text{year}^{-1}$ (see Davison et al., 2006, and references therein) and the above value of D, we thus obtain $W \approx 50$ km.

In the context of the transcontinental spread of the Neolithic, trails are the major communication corridors of a width $W \approx 50$ km, which can be expected to be rather persistent. Thus, we tentatively adopt the trail decay time to be of the order of 2–3 generation times,
$\tau \approx 50$ years.
And finally, we arbitrarily choose the stiffness parameter α to be equal to the trail width,
$\alpha \approx 50$ km.

With this choice of dimensional parameters, we obtain from Equation (18) the following estimates for the control parameters relevant to the spread of a farming population:

$$Re = 50\text{–}100, \quad B = 0.1\text{–}0.05, \quad V = 0.1\text{–}0.025, \quad E = 1.$$

The corresponding time unit is $W/v_{\max} \approx 2.5\text{–}5$ years, distances are measured in the units of $W \approx 50$ km, velocities are normalised to $v_{\max} = 10\text{–}20$ km/year, and the population density n is measured in the units of the carrying capacity K. Here the first (second) entry in a range corresponds to the smaller (larger) value of $v_{\max}$ and, where relevant, the larger (smaller) value of $v_{\min}$ from the ranges suggested above. A value of K relevant to a Neolithic farming population is 3.5 km^{-2}, but the specific value of K does not affect our results: note that K does not appear in any dimensionless control parameters in Equation (17).

The above choice of parameters is admittedly somewhat arbitrary, especially regarding the values of τ and α. There is very little or no direct independent (archaeological) evidence for these parameters. However, we hope to be able, in our future work, to constrain the model parameters indirectly by comparing the predictions of the model with the quantitative evidence available for the spread of the Neolithic in various parts of Eurasia.

3. Results

The system governed by Equations (13)–(16) has a positive feedback loop which results in a spontaneous development of structures in both n and ϕ. Indeed, a small localised increase in the trail quality ϕ leads, via Equation (15), to an additional population velocity $\boldsymbol{v}$ directed towards that location as prescribed by Equation (16). Understandably, this results in an increase in the population density at that location via Equation (13). Any local increase in the population flux nv then leads to a further improvement of the trail quality, i.e., in further growth of ϕ from Equation (14); this completes the feedback loop. The mechanism will work in this manner, starting from any initial perturbations in population density.

3.1 Trails in a uniformly populated region

To explore and refine the model, we solved Equations (13)–(16) numerically in the unit square S, $0 \le (x, y) \le 1$ on a 100×100 grid. Periodic boundary conditions are used along both directions. This implies that the total population is conserved, $\iint_S n\, dxdy = \text{const}$, from Equation (13) because any loss (gain) of n through any side of the square is instantaneously compensated by equal gain (loss) through the opposite side, since the boundary conditions are periodic. The population density n is initially uniform. The initial condition for ϕ is a statistically uniform random noise of small amplitude, $0 \le \phi \le 10^{-5}$. The whole population is involved in the uniform background motion in the x-direction, $\widehat{\boldsymbol{U}} = \binom{1}{0}$.

Results of the simulations are shown in Figure 6. In these simulations, the formation of trails is launched through initial random fluctuations in the trail quality ϕ which quickly produce fluctuations in $\boldsymbol{v}$ and n. Since ϕ grows faster in regions with larger values of nv, a few regions develop stronger trails and, consequently, larger values of nv; this can be seen in panel (h), where well-pronounced trails start to develop. As follows from Equation (15), stronger trails (i.e., those with larger ϕ) are more attractive (in the sense that they induce larger velocity), so that the trail pattern develops further and isolated trails merge to form longer ones, as shown in panel (i). Trail bifurcations are less stable than junctions, but can still last during the 100 years of the simulation. The result is a slowly evolving system of trails; eventually, all the trails within the domain merge into a single major travel route; this tendency can already be seen in panels (f) and (l) of Figure 6.

To assess the importance of various elements of our model, we also considered a system where only the speed of travel, but not its direction, is affected by the value of ϕ. For this purpose we set $\widehat{\boldsymbol{v}}_{\boldsymbol{0}} = \widehat{\boldsymbol{U}} = \binom{1}{0}$ instead of Equation (16). This causes a uniform increase of ϕ to its equilibrium value $\phi^* = \frac{nv}{nv+B}$ over the whole domain, with the corresponding increase in the travel speed, whereas the distribution of n remains uniform, i.e. trails do not form. We do not show these results here.

3.2. Population spreading along trails

The above simulation illustrates how trails develop in a uniformly distributed, moving population. In application to the Neolithic, it is arguably more interesting to consider a population spreading into an unpopulated territory. Thus, we now consider trail formation on a migration front. In Figure 7, population enters from the left and moves towards the right. We use the same values of dimensionless parameters as in Section 3.1, but the length of the domain (along the x-axis) is 195 km and the width is 65 km (3×1 in dimensionless units). The boundary conditions are now periodic only in y. At $x = 0$, we now have $n = 1$ and, $n = 0$ at $x = 3$. Initially, the region is empty, i.e., $n = 0$ at $t = 0$, but, as above, the population is involved in a uniform imposed motion in the x-direction, with , $\widehat{\boldsymbol{U}} = \binom{1}{0}$.

Soon after the start of the simulation, the population front entering from the left loses its straight shape and develops numerous undulations. The advancing tips become the heads of developing trails. Some trails merge to form fewer but stronger and broader ones. Trails with larger values of ϕ propagate faster than weaker trails (following Equation 15), as can be seen in panels (e) and (j).

The gathering of population along the y-axis into linear trails occurs due to the trail attraction (via the velocity component $\widehat{\boldsymbol{v}}_{\perp}$). However, the population is also nonuniformly distributed along the trails, with maximum density near the trail tip. This happens because the speed of motion *along* the trail is larger where ϕ is larger, so that this speed is smaller near the tip of a trail than further down the trail. This produces a pile-up near the trail tip clearly visible in panels (c)–(e). The width of the resulting boundary layer at the trail tip is controlled by the diffusion of the population. This feature of the model appears to be rather unrealistic, and further refinements are required.

The global consequence of the formation of trails is that the coherence of the propagation front is lost at intermediate scales comparable or larger than the trail width. Of course suitable averaging of the population density over y would restore a coherent front at scales of order 10 times the apparent trail width in panels (e) and (j).

4. Discussion and conclusions

The purpose of this work is to propose a realistic mechanism for a spontaneous formation of trail systems. Our approach differs from that behind several other models where individuals follow an intermediate direction between the target and the gradient of a trail potential. This behaviour forces the population to travel always off the trail axis, except where the trail is oriented exactly towards the target.

In our model, we more realistically assume that people stay right on the trail as long as it brings them closer to the target, even if not immediately towards the target. However, if a trail diverts away from the target, individuals leave it to take a shortcut. We introduce the dimensionless variable ϕ standing for the quality of trails. Directions towards and along the nearest trail are obtained from the eigenvalues and eigenvectors of the Hessian matrix of ϕ. The maximum-curvature eigenvector is used to prescribe the direction to attract people towards trails. The minimum-curvature eigenvector is used to guide people along trails towards the target direction. Our model successfully reproduces the formation of a stable network of trails which are neither straight nor perfectly oriented towards the target direction, but rather meander slightly, as is intuitively expected.

Another result of our modelling is that the population migration front devolves into a complicated pattern of rapidly propagating streams which channel most of the population along discrete paths.

It might be expected that accelerated spread along the trails will result in a faster overall spread of the population, as compared with the advance of a continuous front at a modest speed. However, it is now clear that this feature is sensitive to the ratio of the maximum propagation speed on the trails to that on pristine land. In our present model, where $v_{\max}/v_{\min}$ is about two, the population migrates altogether slower with trails than without them. This is due to two factors. Firstly, individuals are attracted by the trails, so that they do not always move directly towards the target, but rather take detours to get on the trails and to follow them even though they are moving in the general direction of the target. This increases the overall distance travelled, hence the slower resulting progress towards the target. Secondly, ϕ has a peculiar distribution at the tip of a trail. Population density n is very large at the front of a progressing trail because people on the trail catch up with people at the front. As a result, the value of the flux nv is also large even if v is not maximum. Due to this large flux, ϕ increases quickly from 0 to 1 forming a boundary layer at the tip of the trail. This results in $\boldsymbol{v}_{\perp}$ becoming parallel to $\widehat{\boldsymbol{U}}$, and $\boldsymbol{v}_{\parallel}$ perpendicular to $\widehat{\boldsymbol{U}}$, which is a poor arrangement for the rapid progress of the trail. Individuals at the front of a trail do not move forward through the abrupt transition of ϕ. Rectifying this problem will be subject of our future work.

An interesting aspect of the model is that the trails are created solely by self-organization. The behaviour embedded in $\widehat{\boldsymbol{v}}_0$ does not explicitly create the trails. Rather, $\widehat{\boldsymbol{v}}_0$ arguably describes a natural local behaviour of travelling people, which can be expressed in terms of the following rule: "move along the most comfortable direction (i.e., along the higher path quality ϕ available) as long as this brings you closer to the target". This strategy results in the formation of a trail system.

Our simulations described at the end of Section 3.1 demonstrate that no trails develop when individuals move without paying attention to the quality of their path (the value of ϕ) and do not hesitate leaving regions with larger ϕ. This agrees with common sense, and suggests that trails do not emerge by chance. Where there is a trail, people in our model walk neither in a random direction nor directly towards the target, but they pay attention to both where they walk *and* where they go. These two tendencies together create trails, whereas either one only do not.

Pure chemotaxis, such as following the gradient of a potential, together with another term attracting motion towards a target, can lead to stable clusters in the distribution of the population. Indeed, if at some point the gradient of the potential balances the target attraction, individuals become stuck and never leave that position. A process to create a trail system must be very robust against such local equilibria. If this were not the case, ants would be stuck at the nearest local maxima of pheromones and never continue search for other maxima. We believe that robust trail formation must depend on something more than just gradient climbing.

It is plausible that the formation of trails can significantly modify the overall spread of a population as it biases travel even in a homogenous environment. Our present model is deliberately simple to illustrate the basic effects of the trail formation, and it does not necessarily capture such features as an accelerated spread of the population as a whole. However, we believe that the formation of trails can have significant effect on the spread of the Neolithic, among other migration processes. It was demonstrated by Davison et al. (2006) that accelerated spread within a very narrow vicinity of the Danube–Rhine river system affects the arrival time of the Neolithic across Western Europe in general. Cultural diffusion would be affected by trail formation in a similar manner, as long as its mechanism involves exchange of ideas between individuals who need to travel to establish contact. Self-organised migration and diffusion patterns can significantly affect our understanding of the spread of the Neolithic in Europe.

Acknowledgements

FGF thanks Rodion Stepanov for his kind help and comments. This work is supported by the EU FP6 Grant NEST No. 028192 FEPRE. GRS and AS gratefully acknowledge the hospitality of the Kavli Institute for Theoretical Physics (University of California at Santa Barbara, USA) and financial support from the National Science Foundation under Grant No. NSF PHY05-51164.

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Archaeology and Languages in Northern Eurasia: New Evidence and Hypotheses

Pavel M Dolukhanov

Newcastle University

Both anthropological and archaeological data substantiated by radiometric evidence strongly suggest that anatomically modern humans (AMH) emerged in Africa 130-190 thousand years ago and whence spread across Eurasia via the Near East. (Clark 2003, McDugall et al. 2005; Rightmire, Deacon 2001). Large-scale expansion of early AMH out of Africa is equally signalled by molecular genetic evidence (Richards et al. 2000). From the very beginning the sites of early AMH show the occurrence of 'symbolic' atrtefacts. The finds at Blombos Cave in South Africa's Cape Province in the level dated to c. 80 ka, include perforated *Nassarius kraussianus* shells and, more significantly, fragments of red ochre with incised geometric design (Henshilwood et al. 2003 a,b). Perforated marine shells with residues of red pigment have been discovered in Grotte des Pigeons in Morocco in a layer dated to 82 ka (Bouzouggar et al. 2007). Further examples of perforated shells have been reported from early AMH sites in Algeria (Oued Jebbana) and Israel (Skhul). All these finds strongly suggest that the emergence of AMH featured a 'cognitive' revolution which included both symbolic behaviour and human-like speech.

The further spread of AMH into Eurasia occurred during the 'Middle Weichselian glacial maximum' (60-50 ka), and the subsequent Middle Weichselian 'mega-interstadial' (50-25 ky). During these periods the entire northern Eurasia including its polar regions and the southern Siberia were effectively settled by the groups of AMH.

In the harsh conditions of the Last Glacial Maximum (25-18 ky), the population of Europe markedly decreased being basically restricted to two refugia, one in the west (focused on 'Franco-Cantabria), and one on the east, the the 'periglacial' area of Eastern Europe and Siberia. A suggestioin was made (Dolukhanov 2000, 2002, Dolukhanov *et al*. 2002) that the groups of modern humans in the former area (referred to as a 'Mediterranean') spoke the Basque and Caucasian-related languages. As about the latter ('periglacial') area, its inhabitants spoke a mutually comprehensible continuum of languages on which basis later developed the Uralic, Altaic and Palaeo-Siberian languages.

The recolonisation of Europe in the Late Glacial period, which resulted in the emergence of Mesolithic cultural entities proceeded from the two above-mentioned refugia. Hence, one may suggest that ther Mesolithic groups iun early Post-Glacial Europe spoke the dialects of the same languages. They formed a *substratum*, on which at a later stage the Indo-European *superstratum* was imposed.

Kalevi Wiik (1997a, 1997b, 2002) notes linguistic evidence of the 'Uralic' substratum in Indo-European (IE), and specifically, in Germanic languages. This includes in the first place IE loanwords acknowledgeable in Finno-Ugric (FU) languages, which date to the period of the initial contacts of their bearers. Still more important are the phonetic evidences of 'FU substratum' in the early Germanic evidence, which in Wiik's view resulted from the phonetic mostakes regurlarly commited by FU speakers while acquiring the IE *lingua franca*. These evidences include:

1. Word stress placed on the first syllable of the word.
2. Quality of stress was dependent on intensity rather than on fundamental frequency,
3. The length of the second syllable when they spoke the new Indo-European language was longer after a short initial syllable than after a long initial syllable. (Even today Finns and Estonians often make the second syllable of *living* longer as in the word *lifting*.)

4a. The strongly pronounced ("aspirated") plosives b^{β}, $d^{ð}$, g^{γ} and p^{f}, $t^{þ}$, k^{x} were pronounced only as "aspiration".

4b. The voiced ("soft") plosives were pronounced without voicing, i.e. ("hard") as *p,t,k*.

5. In some cases the voiceless consonants *p,t,k* pronounced with voicing, i.e. as *b,d,g*.
6. Two different places of articulation (the 'front' and 'back' ones) of consonants (such as *k* and *g*) were not distinguished[1].
7. The consonants were palatalised if followed by *i* or *j*.
8. The syllabic consonants could not be pronounced and an extra vowel (with the quality of *u*) was inserted in front of the consonant (*atl* > *atul*).

[1] Grimm's Law (*die erste/ germanische Lautverschiebung)* refers traditionally to three types of changes in the plosives:
a) voiceless (aspirated/unaspirated) plosives became the corresponding voiceless fricatives:
p/ ph > f *t/ th > þ* *k/ kh > x*
b) voiced aspirated plosives became the corresponding voiced fricatives:
bh > β *dh > ð* *gh > γ*
c) voiced unaspirated plosives became the corresponding voiceless plosives:
b > p *d > t* *g > k*

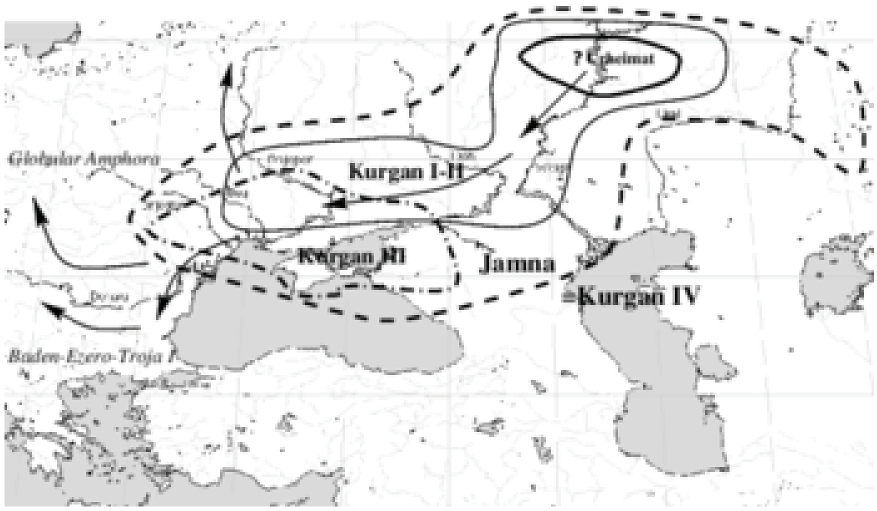

Fig. 1. Initial spread of Indo-European languages according to Marija Gimbutas (1971) and Jim Mallory (1989)

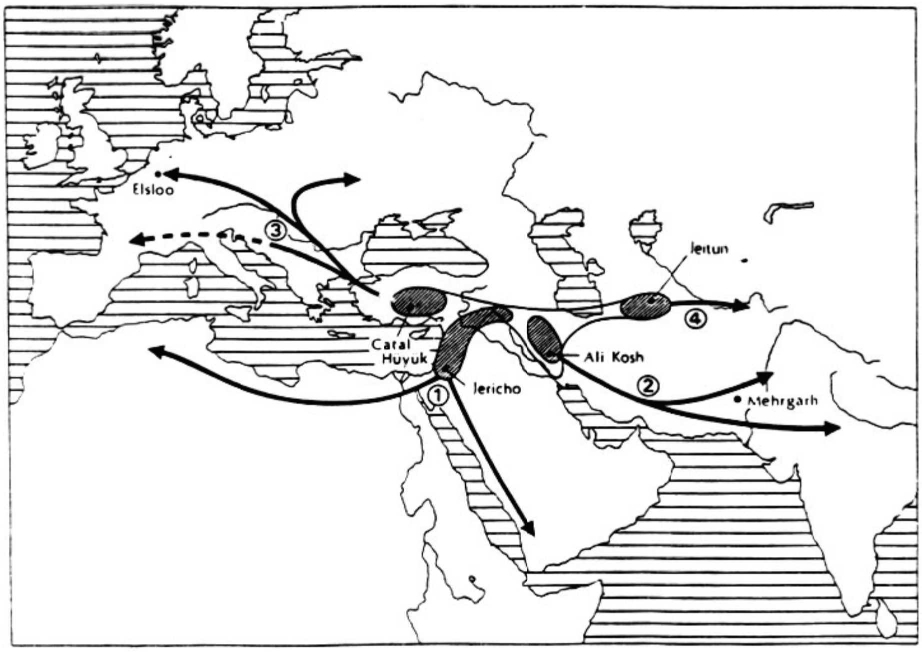

Fig. 2 Initial spread of Indo-European languages according to Colin Renfrew (1987)

9. The vowel *o* was difficult to pronounce, and no distinction was made between *o* and *a*.
10. It was difficult to distinguish between short *o* and *a* and both were pronounced as *a*.
11. Likewise, no distinction was made between the long vowels *ā* and *ō*, and both were pronounced as *ō*.

The emergence and spread of Indo-European languages remains the key issue in the problem of European linguistic reconstructions. The majority of archaeologists and linguists still share the view advanced by Marija Gimbutas (1971) and Jim Mallory (1989), according to which the early Indo-European speakers were the horse-riders of the East European steppes (Ukraine and southern Russia) who invaded Central Europe between 4500 and 2500 BC (Fig. 1). A particular attention is being attached to the Andronovo Bronze Age culture in Western Siberia and Central Asia, c. 2700-1000 BC, which bearers are considered as direct ancestors of 'Into-Iranian' speakers (Fig.). The main deficiency of the Gimbutas-Mallory hypothesis consists in the lack of strong archaeological evidence of large-scale IE dispersal covering a huge area of Europe and Western Asia, and a comparatively limited time-dimension, obviously not sufficiently deep for a massive language shift.

An alternative view has been suggested by Colin Renfrew (1987) who argued that Indo-European languages were spread by early farmers who gradually expanded over much of Europe and western Asia from the initial agricultural area of the Fertile Crescent in the Near East (Fig. 2)

Colin Renfrew's theory is essentially in agreement with the views advanced by two prominent linguists, T.V.Gamkrelidze and V.V. Ivanov (1984, 1995) who localized the hypothetical IE homeland in an arera of the southern Caucasus and northern Mesopotamia dating it to the 5th-4th millennia BC. These writers based their conclusions on the apparent lexico-semantic similarities related to agricultural and landscape terminologies, the and the newly arranged scheme of the evolution of Indo-European consonants.

Yet another theory put forward by I.M. D'iakonov (1985) places the IE homeland in the northern Balkan Peninsula. All these theories imply in various degrees that repeated migrations were the main mechanism of the dispersal of IE speech.

The present writer (Dolukhanov 1994) basically drawing on Colin Renfrew and Gamkrelidze-Ivanov theories, suggested the early IE to be *lingua francae* used by early agricultural communities in the process of Neolithic dispersal. In accordance with Wiik's views, it has been suggested that for a certain period the early IE languages coexisted and interacted with the Europe's substrate languages.

New evidence quoted in this volume shows that pottery making appeared at a very early age in a vast belt crossing Eurasia along the southern edge of the boreal forests and in the forest-steppe. Until recently, Jomon Culture in Japan, which 'incipient' stages date to around 11,000 BC had been considered as the oldest pottery bearing culture in the world (Aitkens & Higuchi, 1982). Newly available evidence demonstrates an even earlier dates for early pottery sites in the Russian Far East (Derevyanko and Medvedev 1997; Kuzmin and Orlova 1999). Thde papers in this volume shows the gradual spread of pottery-making on East European Plain between 8000 and 6000 BC.

In a cautious way, one may suggest that this be at least partially triggered by intensive intragroup contacts that encompassed the entire universe of the forest-steppe and forests of northern Eurasia. Viewed as a whole, this process may be linked to the westbound diffusion of the Altaic-related speech, which, at this stage actively contacted the Uralic languages.

Still more important arguments consisted in the discovery of the distinct 'La Hoguette' pottery at several LBK sites in its north-western area. It is represented by the pots of clay tempered with crushed shells and bone, with conic round-bottomed vessels, and decorated with garlands of comb-like impressions (Lüning, Kloos and Albert 1989, Van Berg and Hauzeur 2001). At the site of Place Saint Lambert in Belgium, the La Hoguette pottery has been found in a Late Mesolithic context yet with predominantly domesticated animal remains (Van Berg and Hauzeur 2001, p. 70). The general look of this pottery, as well as its 'Mesolithic' context, are remarkably similar to those of the 'early Neolithic' sites in the south of East European Plain. If this is the case, it implies the occurrence of a vast 'proto-agricultural' substratum, which encompassed the greater part of northern Eurasia, including its western 'peninsula'. One may equally suggest that the human groups which populated this area spoke mutually comprehensible 'substratum' languages which included the elements of the Uralic, Basque-Caucasian and Altaic speech.

The spread of early farming cultures in Europe implies a different scenario. The model of Neolithisation as a result of direct migrations is omnipresent in the works of Childe. According to Childe (1958, 110), the early Neolithic sites in Europe have been left by 'farmers spreading from the southern cradle of cereals'. This view was corroborated by Ammerman and Cavalli-Sforza (1973) who used the model of 'advance of advantageous gene' to assert that early agriculture was brought to Europe by the descendants of Middle Eastern farmers that completely overrun the indigenous Mesolithic population. An alternative hypothesis viewed the Neolithization as the result of the adoption of farming by the local hunter-gatherers (Whittle 1996, Moor 1994).

The sites of Linear Pottery Culture (LBK) cover a vast area of central Europe, stretching from the south-western Ukraine and Moldova in the east, and reaching the Paris Basin in the west. Since Childe (1958) the sites of LBK or 'Danubian I' culture have been considered as belonging to the first authentic groups of farmers in that area. The LBK subsistence was based on sustained, albeit diverse agricultural economy. The LBK farmers cultivated emmer and einkorn wheat, barley, millet, lentil, peas, flax, and poppy. Their livestock included cattle, sheep, goat, and pig. Wild animals were generally not numerous, but they reach 60% of the total animal remains in some areas in the south and east (Lüning 2000). Van Berg and Hauzeur (2001) note a remarkable homogeneity of LBK sites, both in the organisation of space and manifestations of the material and spiritual culture.

This latter view has been substantiated by the finds of the Late Mesolithic Danubian points found at LBK sites (Gronenborn 1990; Street *et al.* 2002). Gronenborn (1999) and Price (*et al.* 2001) suggest that the spread of the LBK involved small groups of immigrant farmers who contacted 'local forager-herder- horticulturalists'.

Price *et al.* (2001) and Bentley *et al.* (2002) argue that the 'initial' LBK appeared in Hungary at around 5700 BC and spread further west. Using 'traditional' radiocarbon dates, Gronenborn (1999: 156) suggests that the earliest LBK sites appeared in Transdanubia at around 5700–5660 BC, and reached Franconia at about 5500 BC. Dolukhanov *et al.* (2002) basing on the statistical analysis of radiocarbon measurements, conclude that the spread of LBK settlements occurred at a very rapid rate, at 5154 ± 62 BC. During a statistically short period of time, a wave of newcomers stemming from the western Asia and south-eastern Europe encompassed the entire area of Europe's loessic plains. The newcomers, numerically inferior, entered in intensive contacts with the local foragers, this included the establishment of trade networks and intermarriages. Based on the analysis of the Schwetzingen cemetery Price *et al*. (2001, 601) conclude that 'the majority of the migrants… were younger women'. This resulted in a rapid adoption of the entire 'cultural package' which consisted of both the material symbols and ideas. In accordance with the theory developed by Colin Renfrew (1987), one may assume that this was accompanied by an equally rapid language shift: an adoption of an Indo-European speech by the human groups who previously had spoken the 'substratum' languages.

This process was essentially repeated 4500 – 4000 BC when the agricultural civilisations, Cucuteni-Tripolye and Gumelnitsa, spread into the Ukraine. Like in the case of the case of the LBK, this was a rapid adoption of the 'cultural package' brought in by a new population, which actively interacted with the local one. Anthropological materials (Kruts 1972) prove that the 'Mediterranean-type moderately dolichocephalic' individuals form the majority of the individuals identified at Tripolye sites. At the same sites, one notes a 'Proto-European broad-faced' variety apparently inherited from the older population. Allegedly, this resulted in an equally rapid shift to the Indo-European in the areas directly involved in the adoption of agriculture.

The agricultural groups were actively involved in an interaction with their neighbours, who retained the subsistence based on hunter-gathering. This was the case of 'Dniepr-Donets culture, which sites conclude numerous Tripolye-imported items. The anthropological materials identified at Dniepr-Donets cemeteries, include two varieties (Potekhina 1999, 133). The first one finds a direct analogy in the first group (the long-headed and broad-faced) identified at the Dniepr Mesolithic cemeteries (Vasylievka 1 and 3). The second variety of Dniepr-Donets skeletons is mesocranic, with broad, high and flattened faces. It has analogies in Russian Karelia and southern Scandinavia (the cemeteries of Skateholm in southern Sweden and Vedbaek in Denmark. Khartanovich (1998) notes that these features are acknowledgeable in the Upper Palaerolithic populations of northern Eurasia, and remained common among the Neolithic groups of boreal North-Eastern Europe. Presently, these anthropological features occur among the Finish-speaking groups of the Europe's North: the Karelians, Komi-Zyrians, Izhora and Lapps. There is little doubt that this anthropological variety may be definitely identified with the Uralic speakers. Yet in the case of the Dniepr-Donets culture, the Uralic speakers were apparently in contact with the Indo-Europeans.

In the east, the contacts of the Tripolye farmers were targeted at the sites of Sredny Stog culture. The remarkable feature of Sredny Stog culture is the high proportion of the bones of domesticated horse amongst its faunal remains, at Dereivka and other sites (Telegin 1973, 1986). As has been recently suggested (Vasil'ev 1981; Vasil'ev & Sinyuk 1985), the Sredny Stog was part of a huge 'Mariupol cultural entity', which older sites lay in the Urals. One of the oldest sites, Khvalynsk cemetery, has been radiocarbon dated to 5200-4500 BC. Basing on that one may suggest that this 'cultural entity' which included the horse-riding and a strong horse-related symbolism, was result of a westbound migration, originating in the Urals or southern Siberia.

The evidence of the contacts between Tripolye and Sredny Stog cultures is manifold. The Sredny Stog sites include imported Tripolye wares belonging to its middle and later stages. One has evidence of a direct interaction. Nezvizko 3, a Late Triplye site, included a burial made in accordance with the Sredny Stog rite, and accompanied by the Tripolye inventory.

The language affiliation of the Sredny Stog/Mariupol cultural entity is subject to speculations. On the one hand, its eastern source seems to imply the Altaic language. On the other hand, its pastoral character and the horse-related symbolism strongly speak in favour of the Indo-European links. As a possible solution one may suggest that the initial Altaic language was gradually evinced by the Indo-European speech. Anthropological evidence does not contradict this suggestion (Potekhina 1999). The anthropological materials coming from the Mariupol area include at least two varieties. The first one is 'Proto-European' , with its routes in the Mesolithic substratum. The second one has a strong 'Mediterranean' component, being obviously indicative of an infiltration from the west.

Basing on the aforesaid one may formulate the following conclusions:

1. The greater part of Northern Eurasia was populated by anatomically modern humans through several successive migrations coming from Central and Eastern Europe. In anthropological sense the migrating groups included a robust variety of the 'Proto-Europeans'. These groups spoke the languages related to the Uralic, Altaic, and Palaeo-Siberian families.
2. Starting with the Mesolithic epoch, a population of the Mediterranean type infiltrates into East European Plain; this population spoke the Basque-Caucasian-related languages. The both groups were interacting on the territory of present-day Ukraine.
3. At 10,000-8,000 BC an active interaction of human groups in a vast area of the Eurasian forest-steppe led to strong cultural impulses spreading from the east and eventually encompassing the greater part of northern

Eurasia. Its final result consisted in a vast continuum of the 'substratum' Uralic, Altaic and Basque-Caucasian related languages.
4. The spread of the Indo-European languages in Europe is viewed as a result of a socio-cultural integration following the transition to agriculture. In its course the 'substratum' languages were supplanted by the Indo-European speech.
5. The marital alliances and the formation of the 'Creole' and pidgins were the main instrument of the language shift.

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Human Genetics and Neolithic Dispersals

O.P. Balanovsky[1]

[1] *Research Centre for Medical Genetics, Russian Academy of Medical Sciences, Moscow, Russia*

Numerous branches of knowledge are currently affected by certain Eurocentrism, this being especially the case of the studies focused on human population genetics. These studies were (and remain) developed predominantly in European laboratories and are less popular on other continents. Population geneticists need human populations as subject matter of their research, and in most cases we study those which are in proximity of our homes. That is why Europe is the continent which is by far better studied genetically, and the European genetic landscape is much deeper understood and discussed than any other part of the world. For the same reason the controversies between different schools of thought regarding various aspects of the European gene pool became much more apparent.

The two concepts

The variation of "classical" genetic markers (which became referred to like that when the DNA came to the fore to replace them) was best summarized in the book by Luigi Luca Cavalli-Sforza and his colleagues published in 1994. Unsurprisingly, the largest chapter of this book is the "European" one, which describes how the European genetic landscape had been formed during the Neolithic expansion from the Near East. It was one of the most minutely-elaborated concepts in population genetics at that time; nonetheless it was almost entirely rejected in the subsequent decade.
The European genetic landscape, as restored based on the analysis of classical markers, shows three principle features:

- a general homogeneity (the Europeans are genetically very similar to each other, compared to populations of other continents);
- the presence of only a few outliers (isolated peripheral populations such as Icelanders, Saami, or Sardinians); their peculiarities are the secondary, having arissen after these populations were demographically split off and underwent the genetic drift from the main European corpus;
- Clear geographic patterns of gradual genetic changes.

To identify these geographic patterns Cavalli-Sforza and his colleagues (Menozzi et al., 1978, Cavalli-Sforza et al., 1994) and independently Russian geneticists (Rychkov & Balanovskaya, 1992) developed the method of 'synthetic maps'. These maps are created by a complex mathematical algorithm but in a simpler way they consist of displaying the geographic distribution of an "ideal" genetic marker, which correlates with geographical patterns of the majority of real markers presenting the data (Menozzi et al., 1978; Rychkov & Balanovskaya, 1992; Balanovskaya & Nurbaev, 1997a). This synthetic map visually demonstrated gradual changes with a remarkable geographical pattern: from Anatolia via the Balkans over the rest of Europe i.e. from the Southeast to the Northwest (Fig 1). This picture was interpreted as a result of the gradual spread of farming (and farmers) across Europe which was known since Gordon Childe (1928) to follow the same trajectory.

This concept was additionally substantiated in two ways. First, the "isogenes" (lines connecting the same gene pools on the genetic map) have shown a remarkable agreement with isochrones (lines showing the early arrival of agriculture based on archaeological and radiometric evidence). Second, the concept and the mathematical model of the so-called demic diffusion was developed (Ammerman & Cavalli-Sforza, 1984). It implies a slow (generation by generation) migration of farmers which assimilated indigenous populations, and thereby gradually dissolved the initial "farming" gene pool. As a consequence, the geographic trajectory of migration becomes a geographic line of gradual genetic changes: from a "mainly farming" gene pool in Anatolia to a "mainly indigenous" one in the Europe's north-west and north-east (as the most distant from Anatolia).

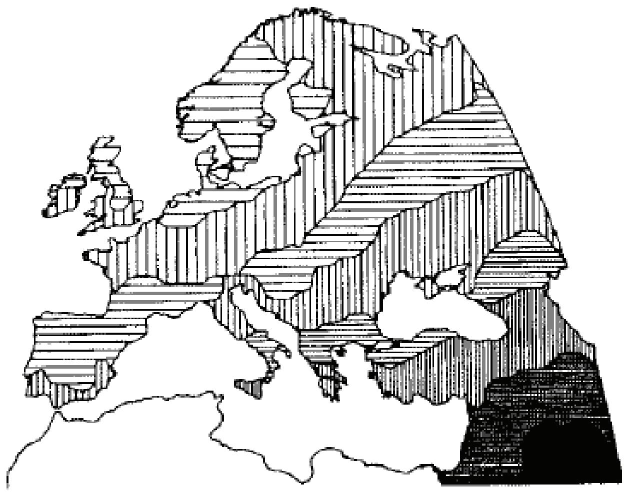

Figure 1. Synthetic map, summarizing genetic variation in Europe (from Cavalli-Sforza et al., 1994).

This elegant, reasonable and sufficiently substantiated concept of the origin and composition of the European gene pool dominated population genetics in the 1980s and 1990s. Generally, four elements of this concept could be potentially criticised: i) the data-set (classical markers); ii) the methodology (synthetic maps); iii) the logical foundation (attributing southeast-northwest pattern to Neolithisation) or iv) controversial results obtained with a use of independent data, methods and logics. Critics used all four elements but with a varaible success.

The popular idea that *classical markers* are "worse" than new DNA markers has never been positively proven and should be considered rather as a scientific fashion. Yet some critics tend to reject the classical markers arguing that they are affected by natural selection, and therefore their variation would be the result of both historical and biological factors. However, many DNA markers can be equally affected by biological factors and therefore geographic distribution of a genetic marker reflects the history which to some degree was blurred by biological selection affecting this marker. And, second, the biological factors differently affect various markers and therefore disappear when averaging, in the case when numerous markers are considered (Yamazaki & Maryama, 1973; Lewontin & Krakauer, 1975; Balanovskaya & Nurbaev, 1997b).

The method of synthetic maps was attacked by Robert Sokal, who used an alternative method (autocorrelation analysis) for revealing geographical patterns in the genetic data (Sokal, Oden, 1978). Using computer simulation he demonstrated that synthetic maps compiled from interpolated maps produce gradual pattern even from randomly permutated data, hence the obtained patterns are artificial (Sokal et al., 1999). However, our recent simulations (Balanovsky et al., 2008) failed to recognise any difference between synthetic maps from interpolated surfaces (criticized by Sokal and colleagues), on the one hand, and from non-interpolated raw data (considered as control by Sokal and colleagues), on the other. It is equally remarkable that Sokal and colleagues did not express doubt that the gradual genetic pattern from Anatolia is the main feature of the European gene pool, yet they did question the methods applied for to identify this pattern.

Curiously enough, the applied logic conclusion (attributing the observed genetic pattern to the Neolithic expansion as the both followed the same trajectory) had never been criticized to the best of our knowledge, though population geneticists were well aware that a correlation never proves the cause-effect relationship. The interpretation in terms of the Neolithic expansion seemed so obvious, transparent, and natural, that this logical mistake became only apparent when controversial results started emerging from independent data.

The evidence, demonstrating the Palaeolithic time for the origin of the European gene pool was based on mitochondrial DNA (mtDNA). The principal difference between mtDNA and Y chromosomal markers on the one hand, and the classical and autosomal DNA markers on the other, resides in the presence or absence of recombination. Autosomal markers recombine and therefore each marker is inherited independently from all other markers. MtDNA and the main portion of the Y chromosome do not recombine. That is why every occurring mutation gets transmitted from generation to generation alongside other mutations, which did occur earlier. In other words, the mutation (a mistake in the genetic text) became forever part of this text and is transmitted together with all the mistakes that had appeared in this text earlier. When comparing different texts (so-called haplotypes) it is possible to trace mutations back in time and reconstruct a "genealogy" of these texts. i.e. to draw their 'family tree'. This tree is commonly rooted in the most recent common ancestor (a "mitochondrial Eve") and each branch of the tree differs by its particular set of mutations. Next, each twig of a certain branch carries all mutations characteristic to this branch, together with a set of additional "twig-specific" mutations. These branches and twigs are called haplogroups (subhaplogroups) each of them unites a group of closely related haplotypes (which can be compared with a leaves of this tree). Assuming an average rate of mutations one can calculate the age of each haplogroup by multiplying the number of accumulated mutations by the mutation rate.

This methodology, applied to the European mitochondrial pool (Richards et al., 1996), demonstrated that most branches (haplogroups) found in Europe were much older that the Neolithic and most of them fell into the age range of the Upper Palaeolithic. Based on this evidence it was concluded, that European gene pool was formed by the initial peopling of the continent by anatomically modern humans (AMH) during the Upper Palaeolithic, and that it is still present in the most of present-day Europeans. As for the Neolithic expansion, it had, therefore, a limited impact on the European gene pool. Hence, this new concept imposed the "cultural diffusion" model of Neolithisation in contrast to demic diffusion" model advanced by Ammerman and Cavalli-Sforza (1984).

The following decade witnessed a heated debate between two camps of geneticists, namely the 'cultural diffusionists' and the 'demists'. Despite the ongoing debate, the methodological limits and benefits of both models are apparent. The source database for demic diffusion model was much richer (hundreds of markers studied in dozens of populations) while Richards and colleagues were restricted to one marker (mtDNA) studied in a limited set of populations. Arguably, as Barbujani and colleagues (1998) pointed out, the Palaeolithic origins of haplogroups found in Europeans do not necessarily imply that these haplogroups were present in Europe since the Palaeolithic. As haplogroups age is calculated based on its diversity, they could have accumulated

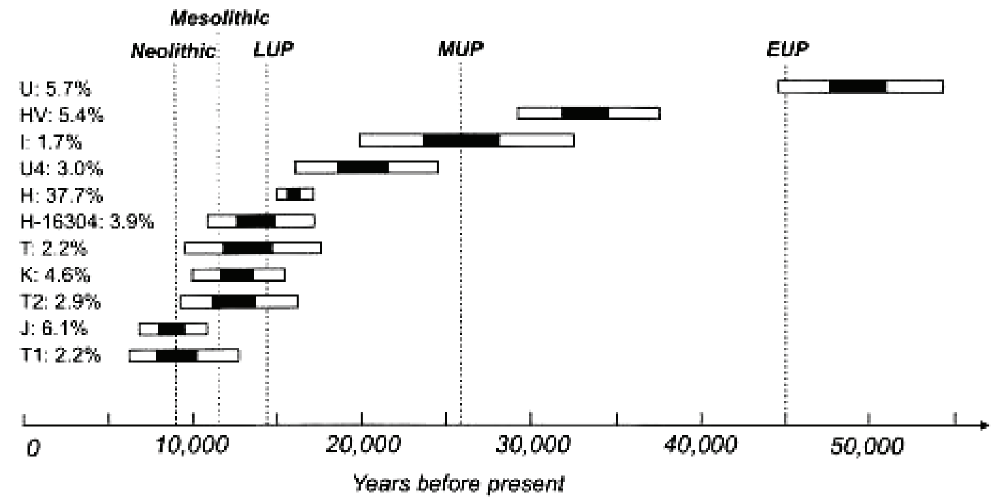

Figure 2. Ages of mitochondrial haplogroups in Europe (From Richards et al., 2000).
EUP - Early Upper Palaeolithic; MUP – Middle Upper Palaeolithic; LUP – Late Upper Palaeolithic.

diversity in other parts of the world arriving into Europe being already diverse. This problem of the pre-existing diversity met elegant solution in the following paper by Richards and colleagues (2000), which became the most recognized study of European population genetics. In that paper the founder mtDNA lineages were identified which were deemed as the starting points for the entire European diversity accumulated *in situ*. Although different criteria for "founding" resulted in slightly different time assessments, all calculations demonstrated the Upper Palaeolithic age for most European clusters of lineages (haplogroups), while haplogroups whose appearance in Europe can be attributed to the Neolithic period make up only a quarter of the total European gene pool (fig. 2).

The opponents of this concept did not miss the opportunity to point out that the deepest time assessment for an *in situ* European haplogroup was paradoxically older than the age of AMH appearance in Europe (Barbujani, Bertorelle, 2001). It should be noted that the time estimates are based largely on the calibration points used (mutation rate). But nevertheless the ability to present a time estimate was the strongest among of Richards et al. arguments whereas the contrary concept was based exclusively on the similarity between the genetic pattern and that of the Neolithic spread. This enabled one to pinpoint the main logical weak point in the "Neolithic" concept, namely, that the AMH initial settlement of Europe followed the same geographical trajectory which was later used by expanding Neolithic farmers. When Barbujani and Bertorelle (2001) summed up this discussion they admitted, that the gradual "out of Anatolia" geographic pattern, as established by classical and (later) other markers was correct. Yet this pattern could have originated from both, the Palaeolithic and Neolithic migrations, as the both were believed to follow the same Anatolian route (fig. 3). The lesson learnt was that geographic patterns of genetic variation do not allow distinguish between these scenarios, and one needs non-recombining systems which are essential for time estimations.

Nearly simultaneously with the seminal publication summarising the mtDNA data (Richards et al., 2000), two papers on the second non-recombining system appeared, summing up the paternal perspective, i.e. Y chromosomal variations in Europe (Semino et al., 2000; Rosser et al., 2000). The both papers were based on extensive datasets. Although written in a different manner they established similar features.

Rosser and colleagues followed a phenomenological approach, describing patterns of Y chromosomal variation. They found very clear geographical clines in the distribution of all haplogroups and statistically calculated that the genetic similarity of populations was affected by their geographic proximity rather than linguistic similarity. In contrast, to that Semino and colleagues following an interpretative approach concluded that the observed geographical patterns could have been caused by the factors of similar geographic distribution in the Palaeolithic epoch. One may easily note, that in doing so they committed the same logical mistake as they interpreted geographical pattern "by association" with the known event of the same spatial pattern. And indeed, having reanalysed Semino's dataset, Chikhi et al (2002) came to the opposite conclusion and interpreted the clines as having been formed during the Neolithic. At that time, age estimates for Y chromosomal haplogroups were much less informative and reliable than those for mtDNA. The reason for this is that it is hard to distinguish on the Y chromosome the pre-existing diversity (which founder population had brought from its homeland) and one accumulated *in situ*. (Founder analysis, which was the convenient instrument for mtDNA, proved to be too complex to be applied to the Y chromosome.)

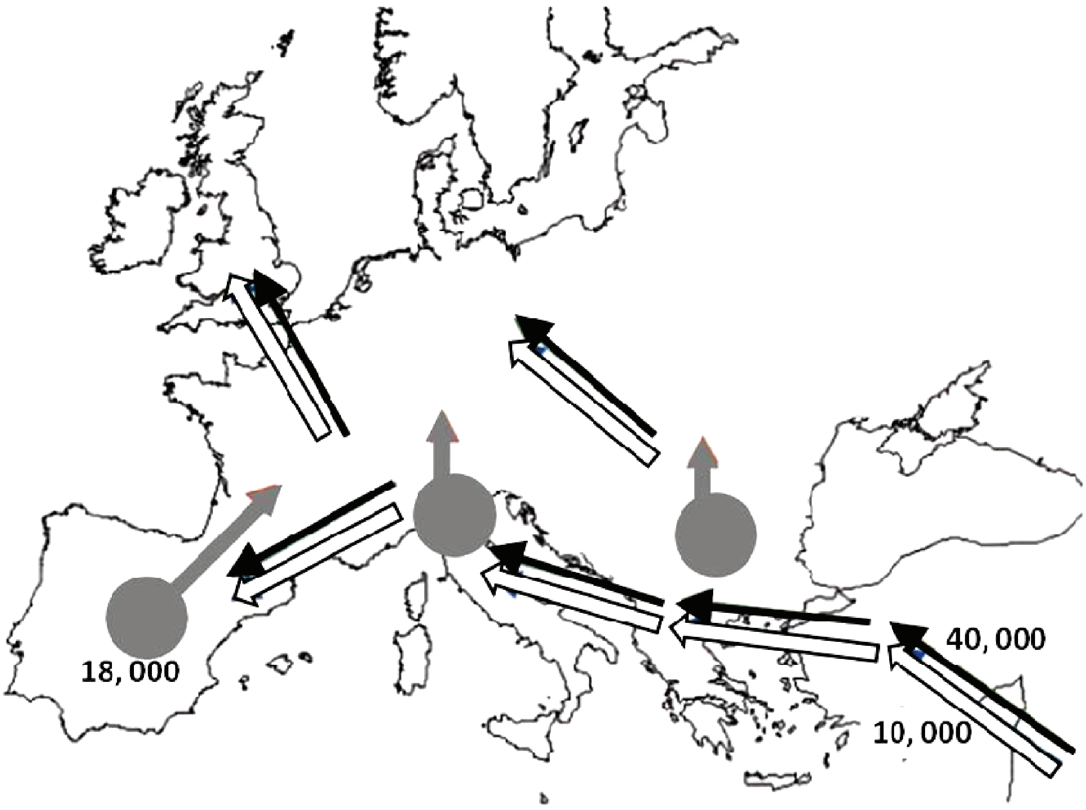

Figure 3. A scheme of the main demographic processes documented in the archeological record of Europe (from Barbujani, Bertorelle, 2001). Numbers are approximate dates, in years before the present. Black arrows, Paleolithic colonization; grey arrows, Late Palaeolithic recolonization from glacial refugia (grey circles); white arrows, Neolithic demic diffusion.

Since the 1990s, the studies on mitochondrial DNA and Y chromosome diversity became dominant in population genetics, which resulted in a specific "two-system" way of thinking. According to it, the greater part of migratory events was allegedly reflected in the both systems. Over the following years numerous studies were published on Y chromosomal and mtDNA variation in virtually all European countries. Most of them provided missing pieces for the European genetic puzzle but did refrain from making oversimplified and/or general conclusions. Those which did could be roughly classified into two groups: those describing the overall genetic landscape (based on the data of the totality of haplogroups) and deducing a particular genetic event from the distribution of particular haplogroup (the haplogroup-driving approach).

Mitochondrial landscape of Europe

From the perspective of mitochondrial DNA, the European gene pool consists of 7-10 most frequent haplogroups. All but one of them came from the Near East: in the majority of cases during the Early Upper Palaeolithic (EUP) in conjunction with the initial AMH dispersal and a smaller part during the Neolithic epoch (in the course of Neolithisation, Richards et al., 2000). The genetic landscape has been reshaped in the Mesolithic/Late Palaeolithic times, during the repopulation of Europe from the southern European refugia. The only European haplogroup that presumably had emerged in Europe (haplogroup V) became spread across the entire continent during Mesolithic/Late Palaeolithic re-colonisation (Torroni et al., 2001). The western European origin of this haplogroup (the Franco-Cantabrian refugium) is presumed, based on its high frequency in this area as well as the occurrence of its phylogenetic predecessor (pre-V lineages). However, a recent accumulation of genetic data on previously poorly studied Eastern Europe, enabled the present author (Balanovsky, 2008) to suppose the occurrence of an additional East European centre of origin of this haplogroup. This finding is based on even higher frequency and yet again, on the presence of pre-V lineages in East European steppe area. Impossibility to distinguish between the western and eastern European homelands emphasised the important feature of the European mitochondrial landscape – its extreme homogeneity.

Indeed, when additional data from different European populations became available the genetic similarity in haplogroup frequencies (and identity in haplogroup spectra) has been immediately recognised (Simoni et al., 2000). As a result, mtDNA studies has appeared dealing with Europe as a whole, comparing it with the Near East or other areas, while attempts to trace genetic processes *within* Europe

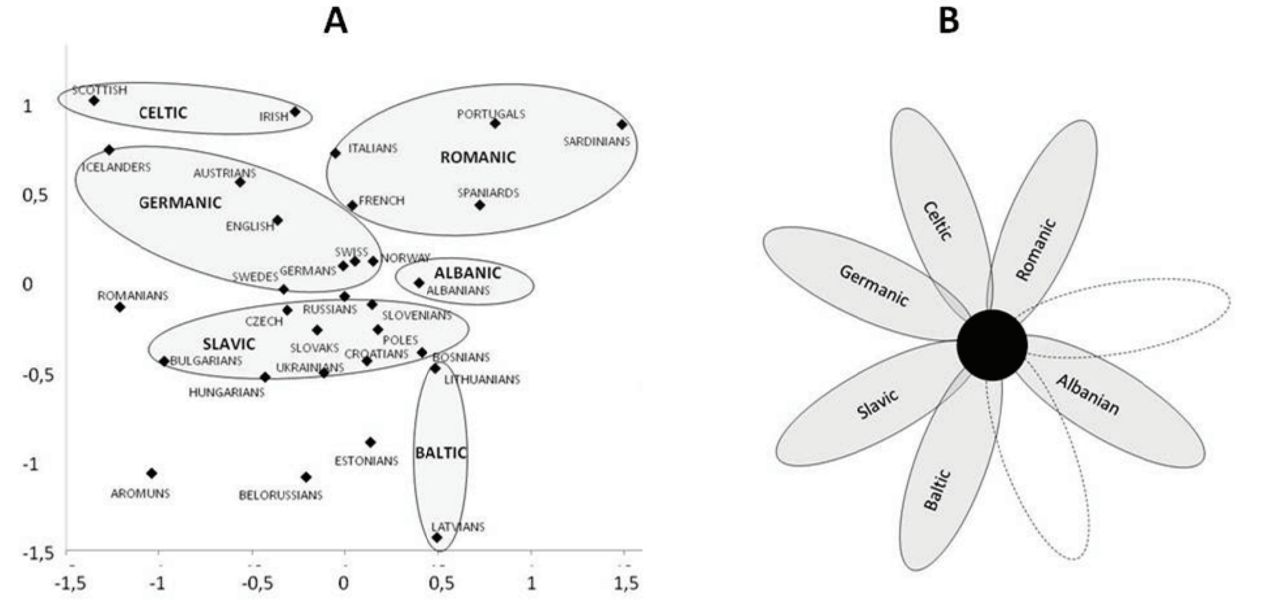

Figure 4. Genetic relationships of European populations from mitochondrial DNA perspective.
A. The multidimensional scaling plot (geometric distances between points display the genetic distances between corresponding populations). Ellipses mark populations belonging to the same linguistic group.
B. The idealized approximation of the plot (A) by flower-like structure. Black core - proto-Indo-European population; dotted ellipses – hypothetical extinct linguistic groups.

encountered problems (Helgason et al., 2000). This development was rather discouraging for archaeologists and linguists who were typically interested in a genetic support of existing hypothesis in their respective disciplines, although on a much smaller scale. Fortunately, the paper entitled "In search of geographic patterns in European mitochondrial DNA" (Richards et al., 2002) made the point that with the emergence of a larger dataset (with more than 3,000 individual mtDNAs) a spatial structuring became more apparent (e.g. the south-north difference was acknowledged among macro-regions of Europe: Mediterranean area, Central Europe, Scandinavia, and, surprisingly, the Basque Country).

Presently one can affirm that size of the dataset is the key factor. Having at our disposal the database six times larger than previously possessed, comprising 20,000 European mtDNAs (Balanovska, Zaporozhchenko, Pshenichnov, Balanovsky; MURKA Mitochondrial Database and Integrated Software, unpublished) we were able to recognise a much clearer patterning (fig. 4). European populations altogether occupying all parts of this plot provide a geometrical illustration of the genetic variation in Europe. The most remarkable feature is that the pattern distinctly resembles linguistic groups: populations cluster together according to their linguistic group of the Indo-European family. Three largest clusters are formed by Romanic, Slavic and Germanic speakers, while Baltic and Celtic speakers form smaller clusters and Albanians form a "cluster" of its own outside any other cluster. There are a few exceptions: Romanians, Aromuns and Sicilians lie outside the Romanic cluster while Estonians join the Slavic cluster. In both cases the geographical distance (remoteness for Romanians and Aromuns, proximity for Estonians) had probably a stronger impact on genetics than the linguistic affiliation.

Among the non-Indo-European populations of Europe the Basques found their place outside any other cluster but close to the Romance one (not surprisingly, considering the geographic proximity again). Finno-Ugric and Turkic speakers are not shown on this plot because of their extreme genetic variation, but on another plot they lie apart from Indo-Europeans.

This linguistic structuring of European mitochondrial DNA follows a remarkable "flower shape" pattern: all clusters looking like petals around the "core" of the flower. The possible explanation of this pattern is that genetic and linguistic differentiations were parallel processes or, in better words, – two aspects of the same process, related to the multiplication and differentiation of proto-Indo-European population in Europe. It is well known, that in many particular cases distribution of genes is opposed to distribution of language (especially in cases of the language replacement by the elite dominance model). However, in very general view, almost all Europe is populated by speakers of one linguistic family and almost all Europe is genetically homogenous. This allows speculations (like our flower-like interpretation of the genetic plot) which consider genetic and linguistic evolution as generally parallel processes, disregarding partial exceptions. Such speculations inevitably oversimplify both processes but could serve as a starting point for more detailed studies.

Therefore, one can accept as a working hypothesis the differentiation of proto-Indo-European language into linguistic groups being accompanied by genetic differentiation resulting in a clear clustering pattern (fig 4). This allows one to introduce time frames into the formation of the European mitochondrial landscape. It would coincide with origin and differentiation of European branches of IE family, i.e. covers the last 5-6 millennia (Starostin et al., their linguistic database is avalable at http://starling.rinet.ru /main.html). This does not necessarily imply the Neolithisation (for example, major changes during the Bronze Age is one of alternative explanations), but lends credence to the hypotheses advocating a relatively recent origin (or at least late major reshaping) of the mitochondrial pool in Europe.

One may note that the significance of the linguistic factor is quite obvious on the graph (Fig 4 A). However, the idea of a single proto-population totally depends on the flower-like structure of this graph (Fig 4 B) and should be therefore considered as one of the plausible hypotheses.

Y chromosomal landscape of the Europe

While the "homogeneity" is the principal feature of mitochondrial pool, the Y chromosomal pool is characterized by a high heterogeneity. As with mtDNA, there are seven Y chromosomal haplogroups dominating in Europe. But while frequencies of mitochondrial haplogroups are quite similar across Europe, Y chromosomal haplogroups follow a clear geographical pattern (fig 5). Neither classical markers, nor mitochondrial haplogroups demonstrated such obvious and elegant trends. Therefore, Y chromosome became an effective instrument in population genetics.

One should remember that European gene pool cannot be homogeneous and heterogeneous at the same time. The question is to what degree different markers are able to reveal the existing degree of variations. Having dozens of autosomal markers, classical population geneticists achieved reasonable resolution in assessing the variation between populations (Cavalli-Sforza et al., 1994). Mitochondrial DNA failed to reveal a difference between populations and successfully operates only at a higher hierarchical level: separating regions (Richards et al., 2002) and linguistic groups (present study, fig. 4). Y chromosome operates much better and separates even subpopulations within the same ethnic group (Balanovsky et al., 2008). Recent studies based on half of million autosomal markers became able to separate even individuals within subpopulations (Novembre et al., 2008).

This high differentiation power of Y chromosome (i.e. clear geographical clines of its haplogroups) was revealed already in the early large-scale studies (Semino et al., 2000; Rosser et al., 2000). These clines have been recently summarized in a panel of frequency distribution maps (Balanovsky et al., 2008). Two main haplogroups, accounting altogether almost for a half of the total European Y chromosomal pool are distributed along the west-to-east axis. Haplogroup R1b accounts for roughly 50% of the Y chromosomal pool in Western Europe and decreases eastward, while R1a reaches the same high frequency in the east (fig. 5) and decreases westward.

Analysis of another type of Y chromosomal markers (microsatellite variation) also proved the western and eastern domains to be main features of the Y chromosomal pool (Roewer et al., 2005). As it was stressed above, the "interpretation by association" should be made with caution. That is why attributing these domains to Late Palaeolithic re-colonisation from two principal refugia (the south-western and south-eastern ones) can be considered as a possible but not yet proven hypothesis. (One of other possibly hypotheses is attributing these genetic domains to descendants of Late Neolithic Bell Beaker and Corded Ware cultures).

These two principal European haplogroups R1b and R1a are shared between Europe and other regions (Central Asia, Near East, India and North Africa). But two other haplogroups, I1 and I2a (according to previously used nomenclature the same haplogroups were labelled as I1a and I1b, respectively) are restricted to Europe, where they had likely originated.

While R1b and R1a occupy the west and the east, I1 and I2a predominate in the Europe's north and south, respectively. I1 which is frequent in Scandinavia and southern Baltic area has attracted less attention due to obviously late colonization of this region. In contrast, the distribution of haplogroup I2a (Balkan haplogroup) has been widely debated. As southeast European autochthonous haplogroup it could not be attributed to Neolithic immigrants (or any other immigrants) into Europe. We will discuss it in more details below.

Three remaining haplogroups (E, J, and N1c) are not evenly spread across the entire Europe but are restricted to distinct areas. For this and other reasons they are believed to mark later migration waves into Europe which did not cover the entire continent.

The haplogroup N1c (N3 or TAT, according to previous nomenclatures) is restricted to north-east Europe (mainly Finnic speakers) and Siberia. During the last decade it remained unclear whether is marks an eastward migration from Europe or the opposite westward migration trend. In 2007 Rootsi and colleagues have shown that this haplogroups could be deeply rooted in East Asian phylogeny and therefore the occurrence of this haplogroup in Europe may be

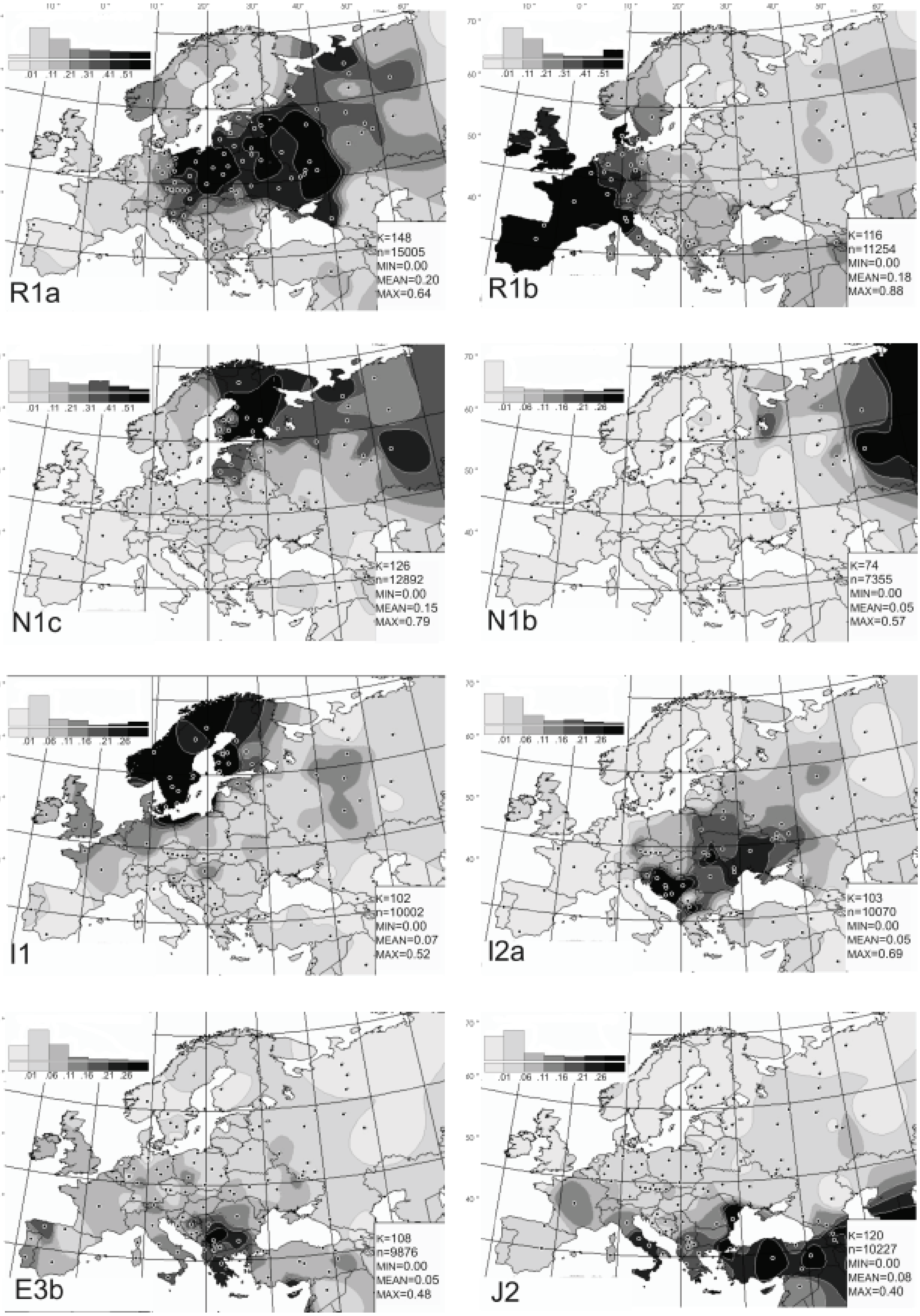

Figure 5. Geographical distribution of European Y chromosomal haplogroups (modified from Balanovsky et al., 2008). K – number of studied populations; n – number of studied individuals; MIN, MEAN, and MAX- minimal, mean and maximum frequency on the map.

attributed to the Asian influence. Authors supposed step-by-step migration from North China to Eastern Europe, which started in early Holocene and underwent a secondary expansion on its long way. Derenko and colleagues (2007) studied microsatellite variation associated with this haplogroup in more detail and tried to estimate its age. They identified two variants, one of which migrated into Europe 6-10 ky ago, while the second (less frequent) variant was shown to come by the way of a smaller and more recent migration, 2-4 ky ago. Although these time estimations should be taken with great caution, the both studies (Rootsi t al., 2007; Derenko et al., 2007) agree that north-east Europe had a significant (or even predominant) genetic legacy in South Siberian/Central Asian populations.

This creates a problem for "two systems" approach, because from mitochondrial perspective Siberian/East Asian haplogroups appeared in low frequencies and only in the eastern edge of Europe and did not account for a significant portion of the gene pool anywhere else in Europe. (When low frequency of typical East Asian haplogroup F was found on Croatian isles and in even lower frequencies on Croatian mainland, this was considered as a paradox and a special paper (Tolk et al., 2001) tried to explain it by possible medieval gene flow caused by trade routes of Venice). That is why a significant Asian presence in Europe, concluded from haplogroup N1c remains one of the main inconsistencies between Y chromosomal and mitochondrial genetic systems. From our point of view, this problem could be resolved if one takes into consideration the fact that *genetic* boundary between Europe and Asia lies much eastern than Ural Mountains. The western Central Asia (the Altai Mountains in particular) could be therefore considered as a genetically intermediary in present time and primary "European" zone in the past. This view explains why Y chromosomal haplogroup N (despite its origin in East Asia 20-30 ky ago) in pre Neolithic or Neolithic times could be the characteristic haplogroup for Caucasoid populations in Eurasian steppe west from the Altai and also for Mongoloid populations east from the Altai. From the western part of this area the haplogroup N1c could spread northward and north-westward by a number of migrations suggested for this area. This view also explains why these migrations did not bring East Eurasian mitochondrial haplogroups into Europe: the source area having mainly Western Eurasian haplogroups even in the contemporary gene pool. It was more the case in earlier times before Turkic speakers brought East Eurasian haplogroups by their expansion into this area two millennia ago onward.

Two last Y chromosomal haplogroups to be discussed are E and J. They predominate in North Africa and Near East, and in Europe they are found mainly in Mediterranean area. Not all sub-branches of these two haplogroups reached Europe, but mainly one branch of haplogroup E (namely, E-V13) and two branches of haplogroup J (J-M241 and J-410).

While J-410 follows the separate pattern, the other two haplogroups (and also haplogroup I2a, mentioned above) are concentrated in the Balkans and have not been found in neighbouring regions with any significant frequencies. The ages of these haplogroups estimated from their STR diversity are: E-V13 from 4 to7,5 ky; J-M241 from 3,5 to 6 ky; I2a from 5,5 and 10 ky (Battaglia et al., 2008). This roughly coincides with time of Neolithic transition in this part of Europe. The model suggested by Battaglia and colleagues states that Neolithic cultural package was adopted by local Mesolithic populations of the Balkans which started grow in numbers, expanding farming across the entire Balkan peninsula and later transmitting this package to other Mesolithic populations of Europe. This model explains why these three haplogroups are restricted to the Balkans, why they exhibit decreasing frequency towards other part of Europe and why their age is similar to that of the Neolithic transition.

However, the internal logic of this model is opposite to those applied by Richards and colleagues in relation to mitochondrial DNA. Indeed, Richards and colleagues proved that mitochondrial haplogroups whose diversity was accumulated in Europe *in situ* are of *Palaeolithic* age; and from this fact they concluded that present-day Europeans are descendants of Palaeolithic population of Europe (Richards et al., 2000). Eight years later, Battaglia and colleagues proved that Y chromosomal haplogroups whose diversity was also accumulated in Europe *in situ* are of *Neolithic* age; but from this contrasting fact they concluded also that present day Europeans are descendants of Palaeolithic population of Europe (Battaglia et al., 2008). Both studies are reasonably substantiated and their conclusions look correct. However this example illustrates that genetic studies need more robust and universal logic, at least when dealing with such complex process like the Neolithisation. In this particular case the possible logical compromise lays in the fact that concept of Battaglia and co-authors actually implies both, cultural diffusion and demic diffusion models. Although the authors did not formulate this explicitly, their concept implies, that cultural diffusion took place *between* regions (Analolia and Balkans, Balkans and Central Mediterrania) while the demic diffusion occurred *within* regions

Ancient DNA

Analysis of ancient DNA (aDNA) provides direct data on the former European gene pool, which are free from assumptions and speculations which often accompany deductions of past genetic processes, based on the contemporary genetic pattern. This advantage of aDNA may trigger a revolution in population genetics and if this did not happen so far, this was due to limited quality and quantity of available aDNA evidence.

Problems with the quality (authenticity) of aDNA data are dramatic because of the possible contamination by modern DNA. . For this reason some aDNA results may be false, and many early aDNA papers were criticized exactly from this point of view. This problem could be partially resolved in few high-standard laboratories only, which have special equipment to minimize risk of contamination. Cross-checking, i.e. independent analysis of the same ancient sample in different aDNA labs is the second condition. The third one is implementing the "modern DNA free" style of excavation into the practice of the archaeological fieldwork. Having these three conditions met, one can reach reasonably degree of authenticity of the aDNA results.

The quantity problem consists in the scarcity and limited sample sizes of the aDNA data. Again, this problem could be solved only partially, by increasing the number of aDNA studies and average sample size per study. Fortunately, both factors tended to increase in the last decade, still trace amounts and high fragmentation of ancient DNA samples hinder its high-throughput analysis.

Because of these limitations aDNA at least presently cannot be the main source of genetic knowledge about the Neolithisation. But it is already one of the important sources on this problem. Indeed, analyses of Neandertal mitochondrial DNA (Krings et al., 1997; Ovchinnikov et al., 2000), though being criticized for probable mistakes in sequencing, put an end to a lengthy discussion of the possible assimilation of the Neandertal populations by anatomically modern humans. Specificity of Neandertal mitochondrial type (Currat, Excoffier, 2004) and absence of this type in present day Europeans (Behar et al., 2007) allow to root European gene pool in AMH colonization of the Europe, disregarding the previous epochs.

Direct genetic data on first Neolithic groups in Europe are of course most promising source for choosing between the demic and cultural diffusion models of Neolithisation. Such data are now available for Neolithic population of the Iberian peninsula (Sampietro et al., 2007) and Neolithic population of the Central Europe (sites of Linear Band Ceramic with age of 7.0 – 7.5 ky; Haak et al., 2005). Iberian Neolithic population was shown to be genetically similar to the present day Iberian population. In contrast, LBK population in Central Europe was shown to be genetically distinct from the present day population of that or any other region of Europe). The most remarkable feature of the Neolithic population was mitochondrial haplogroup N1a found in 6 of 24 individuals. This haplogroup is virtually absent in present-day Europe. The mathematical simulation has shown that if this Neolithic population was source of present-day Europeans they could not have lost this haplogroups by stochastic genetic drift.

It was therefore concluded (Haak at el, 2005) that Neolithic LBK population did not become parental for present-day European gene pool, but became dissolved in pre-existing European populations. This conclusion is therefore in agreement with cultural diffusion model in assuming that since Neolithic farmers arrived in Europe, the farming was adopted by aboriginal populations and first farmers did not leave any considerable genetic legacy in their new homeland.

The study by Haak and colleagues did answer the question: "what happened with first farmers after their arrival in Europe". To address another question, "where these first farmers came from", the consequent study was performed (Haak, pers. comm.). Based on extended dataset (44 individual mtDNAs from different sites of early LBK culture) it was found that this population is genetically similar to present day populations of Northern Mesopotamia, southern Caucasus and eastern Anatolia. Although the genetic composition of this area could be disturbed after the Neolithic period by subsequent migrations, it is reasonable to suppose that inner areas of the Near East were homeland for migrating groups who finally brought these mitochondrial lineages into the LBK population of the Central Europe.

Of course, this data give rise to many new questions, and currently available aDNA data are not sufficient to address them. The moderate optimism is based on increasing number and quality of aDNA data which might allow better chronological and geographical resolution of genetic processes in the near future.

Conclusions

The increasingly accumulating genetic data on extant and extinct (aDNA) European populations are most frequently discussed in terms of two opposite concepts: demic diffusion and cultural diffusion models of Neolithisation. In hands of Cavalli-Sforza and his colleagues the genetic mirror reflected Neolithic expansion across Europe (demic diffusion); but in hands of present-day writers this mirror reflects mainly the Palaeolithic legacy of Europeans and cultural diffusion model is needed to explain spread of farming.

Understanding the genetic history of Europe implies clarifying relative significance and patterns of each of the following processes:

1. The initial dispersal of AMH in Europe (Upper Palaeolithic);
2. The restructuring of the genetic landscape during the Mesolithic repopulation of the Europe from two-four refugia.
3. The importance of the Neolithic expansion viewed as the spread of early farming communities or spread of Neolithic cultural package.

4. The role of post-Neolithic human movements within Europe;
5. The "oriental" influence in different epochs – from Palaeolithic to Medieval times.

To address these questions population genetics operated with autosomal (classical) markers in the past and autosomal (DNA) markers may became the new standard in the future, while the present day studies are based on mitochondrial DNA and Y chromosomal variation.

Analysis of mtDNA demonstrated that most of European haplogroups came from the Near East during the Upper Palaeolithic times and Neolithic migration of Near Eastern farmers did not contribute much to the European gene pool. The south-east – northwest cline within Europe, as established by many genetic markers, is not considered anymore as the trace of Neolithic expansion, because Palaeolithic colonists most likely used the same geographical route.

Y chromosomal data reveal distinct domains of prehistoric movements within Europe. Particularly, two different haplogroups predominate in Western versus Eastern Europe, and one may speculate about two secondary homelands, associating them with Mesolithic refugia or centres of later expansions.

Southeast Europe (the Balkans) which deserves special attention as gates into Europe, is populated by three different Y chromosomal haplogroups exhibiting similar patterns: being autochthonous for Europe these haplogroups started to expand in time frames comparable with the Neolithisation; it was supposed that this expansion might have taken the form of Balkan's Mesolithic population adopting farming from their Anatolian neighbours.

Analysis of ancient DNA indicated that first Central European farmers (LBK) were of Near Eastern origin but did not leave recognisable descendants. The early farmers in Iberia (and possibly in other areas of late Neolithisation) were of aboriginal European genetic type.

Genetic mirror shows a controversial picture: even in this summary "indigenous" Balkan populations adopted farming without immigrant farmers, but "immigrant" gene pool was found in first farmers north of the Balkans (in Central Europe). Nevertheless most lines of reasoning show that Neolithisation did not change the European gene pool drastically and consequently did not involve large-scale population movements. Since, if one would like to obtain further information about these (relatively minor) movements from genetic data it is necessary to be equipped with a large genetic databases and a good dose of scepticism not to rush to conclusions.

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