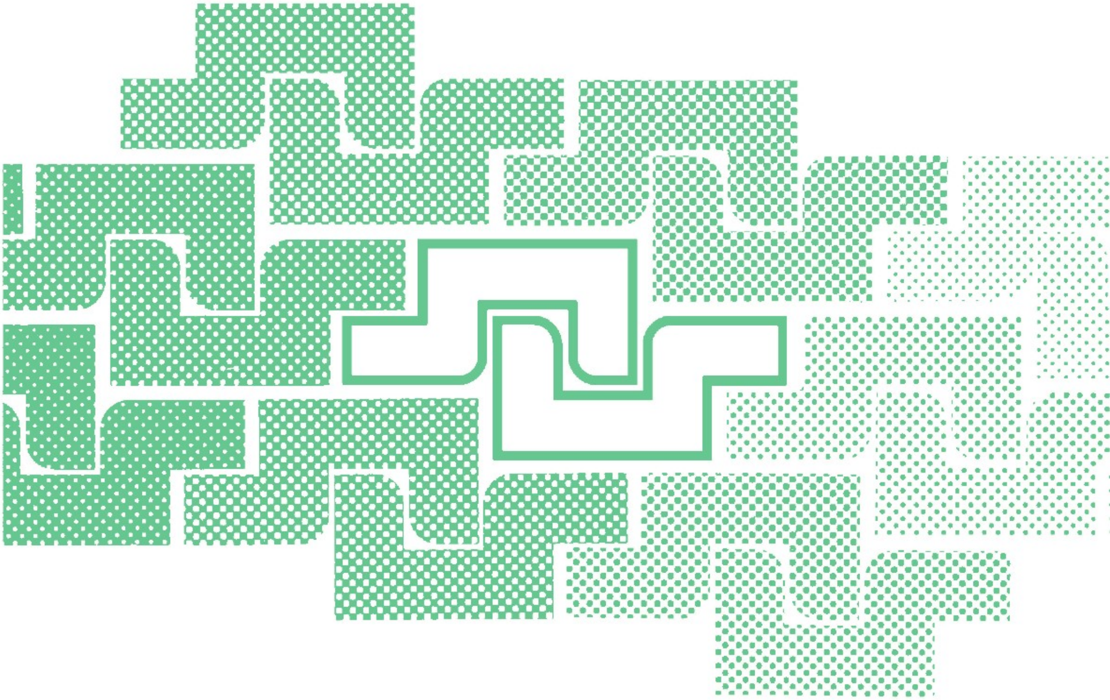

Impact of the Environment on Human Migration in Eurasia

Edited by

E. Marian Scott, Andrey Yu. Alekseev and
Ganna Zaitseva

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IV. Earth and Environmental Sciences – Vol. 42

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FOREWORD

This book is a collection of the articles presented at the NATO Advanced Research Workshop (ARW 979859) held in St.Petersburg, from the 15-18 November 2003 in the Hermitage Museum. The title of the workshop was "The impact of the environment on Human Migration in Eurasia". More than 40 scientists from Russia, Ukraine, Kazakhstan, Poland, Germany, Switzerland, The Netherlands, United Kingdom, Belgium, Finland, Lithuania and Latvia took part. The themes of the workshop focused on the origin, development, interactions, and migrations of prehistoric and ancient populations, specifically the Scythians, in Eurasia and their relationships with the environment of the time. The discussion of these questions necessitated the participation of specialists from a wide range of academic fields. Beyond any doubt, the environment played an important role in the life of ancient nomadic populations, forming the basis of their economies and influencing various aspects of their mode of life. In this respect, the collaboration of specialists in the Humanities and Science is essential for the solution of scientific questions concerning these peoples.

Over the past few years, a large amount of new proxy data related to environmental changes during the Pleistocene and the Holocene and their impact on human life has become available. Our discussion was predominantly limited to environmental changes related to the Holocene. In this period of about 10000 years, the main focus was on the 1st millennium BC. Apart from global-scale environmental changes, our discussions concentrated on the local environment, which included the physical landscape features of the geographical areas of interest: forest, steppe, forest-steppe and so on.

From the huge landmass of Eurasia, the region of interest to the workshop was the Eurasian steppe belt. This area being predominantly defined by grassland formation has several important common characteristics in soils, climate, and animal life and forms a huge latitudinal belt stretching from Central Europe, via Ukraine, the South Urals, northern Central Asia, Southern Siberia, and further into Mongolia and China.

During the 1st millennium BC, important cultural processes occurred throughout the steppe belt, which eventually resulted in the emergence of 'Scythian-type' cultures which played an important part in the history of world culture. The Scythian sites have been investigated since the 18th century, resulting in the discovery of outstanding archaeological assemblages and works of art which are displayed in the best museums of the world. Yet notwithstanding dramatic achievements in Scythian studies, numerous puzzles related particularly to the Scythians' origins, interactions, migrations and their detailed chronology remain poorly understood and need further discussion.

It is important to note that the beginning of the 1st millennium BC corresponded to important social and cultural transformations that marked the transition from the Bronze Age to the Iron Age. The sites belonging to this period were unevenly distributed over the steppe belt of Eurasia. Both the European sector of this belt, and several regions in Western Siberia, are rich in Bronze Age sites. Yet several large areas of the mountainous regions of southern Siberia became actively populated only at the beginning of the Iron Age, contemporary with the appearance of Scythian-type cultures. The question arises as to when, how and from where the Scythian cultures arrived in that area? One of the possible explanations may be sought in environmental changes. The entire 1st millennium BC was marked by intensive human migrations directed both from the east to the west, and backwards. These migrations may be at least partly linked with environmental changes. The changes that have become apparent due to multidisciplinary studies conducted in that area, are of considerable interest to a broad scientific community involved in the problems of global climate change.

The key objectives of the ARW consisted in gaining a better understanding of the following issues:

1. The history of development of the Scythian cultures in Eurasian territories,
2. Methodological problems connected with the development of the chronology of these cultures caused by fluctuation in atmospheric radiocarbon;
3. Environmental and climatic changes during the time of the formation and development of the Scythian cultures in Eurasia;

The book is therefore subdivided into three sections reflecting the three key themes: Archaeology, Chronology and Environment.

The book opens with the archaeological section. It contains papers linking archaeology of different sites and interprets them in the light of possible impacts of environmental and climatic changes on human behavior in the context of the Scythian cultures. Among the most important Scythian monuments discovered in various parts of Eurasia, a particular importance is attached to the Arzhan-2 Barrow, a new site discovered in 2001 in the Republic of Tuva. The significance of this discovery is difficult to underestimate, as this monument remained intact from its construction. The unusual abundance of all kinds of archaeological materials throws a completely new light on Scythian history and culture. The preliminary results of the investigation of the materials from Arzhan-2 are discussed in the article by Russian and German archaeologists who discovered the site (K.Chugunov, H.Parzinger and A.Nagler).

The current state of research on 'Classical' (i.e. European) Scythia is the subject of the papers by A.Yu.Alekseev (Russia) and S.Makhortykh (Ukraine).

The wide panorama of the history of settlement of the Southern Siberian regions (Khakassia Republic) beginning from the early Bronze Age is considered in the article by N.Bokovenko. Both Alekseev and Bokovenko in their papers also consider the problems of defining the radiocarbon chronology for these cultures.

It should be noted, that in spite of the long history of investigations of Scythian cultures, the problems of their chronology are not fully resolved. For a long time, the chronology of the European Scythian cultures was based on typological comparisons and historical sources while that of the Asian Scythian cultures, was largely based on radiocarbon dating. Only relatively recently, were the first radiocarbon dates obtained for European Scythian monuments. As a result, it has become possible to compare the chronological position of these cultures in Europe and Asia, and to develop a unified radiocarbon time-scale which can be used with other scientific evidence.

The second section focuses on the current state of the Scythian chronology and the means by which it may be improved. The difficulties in defining a precise chronology are related to the plateau in the ^{14}C calibration curve around 2500 BP and the fact that the atmospheric radiocarbon concentration which is the basis of the ^{14}C chronology, fluctuates in time due to variations in cosmic rays, solar activity, and related phenomena. Several approaches to overcome this difficulty were proposed, including the use of tree-ring chronologies and sophisticated curve-matching techniques (‘wiggle matching’)(papers by van der Plicht, Hajdas, Zaitseva, and Gorsdorf).

The third section of the book focuses on environmental changes, environmental reconstructions and the influence of climatic changes on the behavior of ancient populations. This chapter includes a wide spectrum of studies. The articles by Dergachev and. van Geel include new data from different isotopic methods related to cosmic rays and solar activity. For the reconstruction of climatic change and its nature, different approaches are often used: traditional pollen analyses combined with geological evidence (Dirksen, Kalnina, and Gaigalas) and geochemical investigation supported by statistical factor analysis (Koulkova). Papers by Aleksandrovski, Porotov and Shishlina used geomorphologic and soil analyses for reconstruction of the environmental setting during the Eneolithic period in the Northern Caucasus. A paper by van Strydonck used stable isotope studies based on $\delta^{13}C$ and $\delta^{15}N$ in bones to assess past diet and environment. A comparative analysis of horse bones from the Arzhan-1 and Arzhan-2 monuments was shown in the article of Bourova who suggests that the changes in the anatomy of the horses could reflect landscape changes and the availability of fodder. New evidence concerning the role different toxins play in the life of ancient humans, and their connection to environment and adaptation are presented by Derham.

Several papers discussed the problems of migrations and their possible connection to environmental changes. Various models of migrations were discussed in the paper by Dolukhanov, based on a statistical analysis of radiocarbon dates, including Upper Palaeolithic, Neolithic and Bronze Age sites.

This book brings together for the first time many new results and new, often non-orthodox ideas and approaches in the studies of the relationships between ancient humans and nature. Therefore we hope that this book may be useful and of interest to a wide circle of readers in various fields of knowledge.

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The editors are very appreciative of the financial support by NATO Science Committee (ARW 979859) for the workshop and this publication, and to the directors of the Hermitage Museum and the Institute for the History of Material Culture, RAS for their support.

E Marian Scott, Andrey Alekseev, Ganna Zaitseva
Glasgow and St Petersburg
May 2004.

Chapter 1

CHRONOLOGY AND CULTURAL AFFINITY OF THE KURGAN ARZHAN-2 COMPLEX ACCORDING TO ARCHAEOLOGICAL DATA

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ABSTRACT

This article presents the study of the famous Scythian monument Arzhan-2 discovered in Central Asia, Tuva Republic, in 2001. The main focus is the analyses of the different archaeological materials including typology, analogy, burial tradition etc to determine the chronological place of this monument in the nomadic world. The analyses of the artifacts is primarily concerned with the horse harness and its comparison with the materials from other monuments located in this region and the neighbouring territories. It is shown that in spite of the originality of the archaeological materials, they reflect the local culture and the earlier Scythian tradition. Thus the Arzhan-2 monument can be associated with the so-called aldy-bel culture dated to the 7th -6th centuries BC.

Key words: Scythian time, archaeological artifacts, burial tradition, typology, analogy, harness, Central Asia, Tuva Republic.

INTRODUCTION

The study of the Arzhan-2 burial mound is a result of a joint investigation, conducted by the Central Asian expedition of the State Hermitage and the Eurasian Department of the German archaeological Institute. The site is situated in the mountainous and steppe Uyuk hollow, in the northern part of the Republic of Tuva. Here the outstanding burial mounds are concentrated, some of them of especially large size. In the early 1970-s one of the largest ones – namely Arzhan-1– was investigated by the expedition headed by M.P. Gryaznov. The kurgan had been robbed, but the

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materials which remained raised heated debates among specialists, which are still in progress. It is not strange because the main problem – the dating of the complex either to the boundary of 9th-8th centuries BC, or to a later time – has a key significance for the early iron age archaeology of the Eurasian steppe. The solution to the problem enables a new consideration of the role of Tuva and Central Asia in the genesis of the Scythian type cultures.

AREA STUDIED

The burial mound Arzhan-2 is located 9 km from Arzhan-1, it is 80 m in diameter and 2 m high. Numerous stone ring-shaped structures and other ritual objects have been revealed around it. The main reason that this barrow was selected for investigation was the fact that surrounding area had been destroyed by the road built nearby. The excavation of the burial mound was started in 2000 and finished in 2003.

The four-year investigation showed that in spite of some robbing attempts in ancient time and the later destruction of the kurgan, all the burials related to the main complex remained intact. This was mainly due to the unusual planigraphy of the site, where the major tomb was located not in the center, but was shifted to its northwestern side. Besides the primary burial, 11 graves containing more than 17 people, a burial site containing 14 horses and two complexes containing horse tack have been studied.

The main burial was set up in a double chamber of larch constructed like a log house, placed into a deep pit (4,5 m), filled with clay. The chamber had a double ceiling of logs and up to the point of excavation the earth had not penetrated. Due to this fact a special microclimate existed in the chamber, promoting good preservation of all wooden artifacts as well as other vegetative remains. But on the contrary, it was also the reason for the poor preservation of other organic materials (including bones).

Numerous artifacts found in the grave were made in the Scythian Siberian animal style. The great majority of them were made of gold. All weapons, accompanying the buried people, were made of iron. Some objects – an “acinaces”, knives, a battle-axe and even arrowheads were decorated with gold ornament. Before now objects made of iron were considered to have appeared in the region of Tuva rather late – no earlier than the second half of the VI century BC. Among the art objects there were some belonging to the same period according to common views on animal style development. These were the reasons for the preliminary dating of the site to that time (Chugunov et al., 2002; Parzinger, 2002).

Good preservation of some organic materials in the tomb allowed radiocarbon dating of a great number of samples to begin, first of all wooden items and seeds. The burial chamber itself (especially the inner timber) was preserved so well that it was possible to simply remove it from the pit. At present the dendrochronology for the site is being worked out at the laboratories of the German Archaeological Institute and the Institute for Archaeology and Ethnography of the Siberian branch of the Russian Academy of Sciences. However, apart from the scientific methods, the complex should also be considered in terms of archaeological data, available at present time in both Tuva and neighbouring regions. Despite the unique character of most of the items from the primary grave, a number of artifacts associated with the local early-Scythian cultural tradition were also found.

DISCUSSION

Before the Arzhan-2 investigation, sites with special burial rites and attendant items, containing typologically archaic articles, were known in Tuva. These burials were linked to the aldy-bel culture and dated to the 7th - 6th centuries BC (Grach, 1980).

In the aldy-bel common burials of Tuva, specific articles – earrings with grain-covered cone caps, some of them having enamel inlays – were repeatedly found (Semyonov, 1999). Due to identical earrings, found in the accompanying tombs of Arzhan-2, the number of these artifacts in Tuva has been doubled. Gold and bronze pectorals are also available in the aldy-bel sites, though with no decoration. For instance, they were found in some female graves of the burial ground Copto (Chugunov, 1998).

The correlation with aldy-bel burials is also observed in the burial structures of the Arzhan-2 accompanying graves. The slab chambers of the latter correspond to the aldy-bel tradition, where they were one of the most common ways of interment.

To identify the cultural affinity of the complex within the region a fragment of a belt with bronze frame-shaped plaques (Fig.1-1) is the most representative.

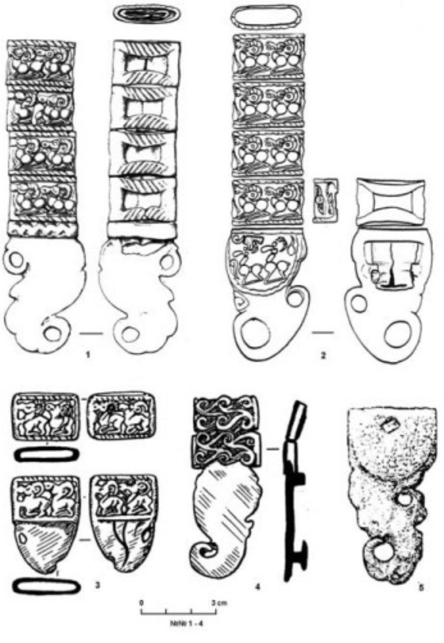

Figure 1. The belt fragment with plaques from Arzhan-2 and its analogies from other sites. 1 – Arzhan-2, grave .26; 2 - Ust'-Khadynnyg I, barrow .4, graves .3; 3 – Sypuchy Jar, barrow.4, graves .1; 4 – Temir-Sug II, barrow.1, grave.1; 5 – Gilevo-10.

It has analogies in the materials of two aldy-bel burials in Central (Fig.1-3) and Western (Fig.1-2) Tuva (Vinogradov, 1980; Semyonov, 2001). Plaque decoration of another belt from one more aldy-bel barrow is identical with gold ornaments from the primary tomb of Arzhan-2 (Fig.1-4).

A considerable number of weapons were found in the male burials, including bronze socketed battle-axes, knives and arrowheads. They are of great importance for the dating of Arzhan-2. Arrow-sets with various types of heads – socketed tetrahedral, tetrahedral-two-blade, tanged thrilobate, bullet-like made of horn – are of particular significance (Fig.2).

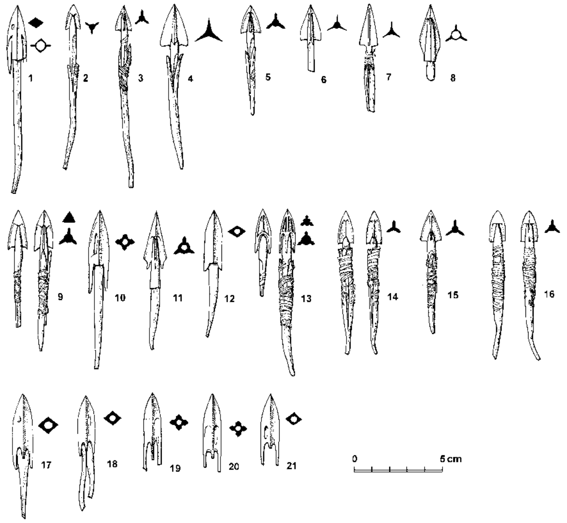

Figure 2. Bronze arrowheads from Arzhan-2 accompanying burials. 1 – 8: grave .26; 9 – 21: grave 25.

Unique kinds of bronze arrowheads, found in Arzhan-2, have not occurred in Tuva before, but they have analogies in the western regions of the Scythian world (Fig.2-8). Iron arrowheads with encrusted gold ornaments from the primary tomb had three-edged heads and a special method of fixation with short sockets and two clamping blades to press shafts between. This special kind of fixation is known for bronze specimens coming mainly from Tuva and found as individual specimens in the sites of Kazakhstan, Aral sea region and Pamir (Chugunov, 2000a, p.165, 166). The bronze arrows from the aldy-bel burial ground named Saryg-Bulun (kurgan 2, grave 5) provide the closest analogue for these artifacts (Semyonov, Kilunovskaya, 1990, p.43, Fig.4-6,8, 9; Chugunov, 2000, Fig.2-5,6). They are similar for their leaf-like head contour and clamping way of fixation as well as curvilinear decoration on the edges. Beside the clamping arrows, found in the quiver from the Arzhan-2 “tsar” tomb, there were bullet-like exemplars made of horn and tetrahedral rhombic in section arrowheads, made of iron. Despite the unusual material, in terms of typology all these arrows are limited by the early-scythian period. The peculiarity of the main tomb quiver-set is its complete absence of tanged arrowheads. At the same time the accompanying tombs of Arzhan-2 present roughly equal quantities of socketed and tanged bronze arrowheads, which is in complete agreement with aldy-bel arrow-sets (Chugunov, 2000a).

Of crucial importance for placing Arzhan-2 on the chronological scale is the horse tack, separate elements of which, as far as we know, were changing very quickly at the beginning of the early nomadic epoch. Three pits, containing harness fittings, and a pit with bridle ornaments only were discovered in the kurgan. Besides, one bit with stirrup-like endings was placed on the ceiling of the paired male burial, located under the mound stone fence.

The main set of horse tacks was found in the burial of 14 horses. Every horse was bridled. One of the horses had a stirrup-shaped bit with additional rings and three-hole cheek-pieces. 13 other bridle-sets were rather standardized: they were bits with rectangular endings and special projections to fix the bits into cheek-pieces and matching cheek-pieces with long central loops (Fig.3-1, 2).

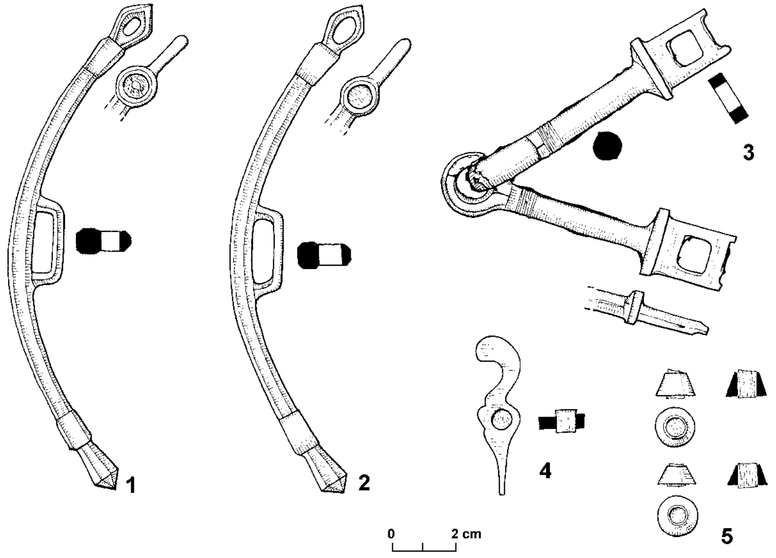

Figure 3. Bridle fittings from Arzhan-2, the 14 horses burial (horse 9).

In 2003 one further complex containing a horse tack was discovered. It was placed as a ritual treasure between vertical slabs of the mound fence facing. It consisted of 49 articles – a bit, cheek-pieces, belt plaques, saddle-girth buckles et al., most of them decorated with feline predator images. The type of the bridle is the same as the 13 sets mentioned above. Only the cheek-pieces differ from those found in the horse burial – they are flat and have loops instead of holes. Large saddle-girth buckles, including one with a horseshoe design, are typical for the early-scythian cultural complex.

The cheek-pieces and the special bits, typical for Arzhan-2, were the first finds of that type in Tuva as well as in the Sayano-Altay region in general. As it is known, in Arzhan-1 another kind of cheek-pieces – three-hole ones of various types were found (Gryaznov, 1980). In the aldy-bel burials the cheek-pieces of У-shape to be used with stirrup-shaped bits are mainly found. Three-hole cheek-pieces (Semyonov, 2001, p.170) and two-hole ones (Grach, 1980) have been found as individual specimens. As for the bits with fixing projections and the matching cheek-pieces, they were found at the sites of the tasmolin culture of Central Kazakhstan and in the early-sakas burial grounds of the Aral sea region. The date of such types of the bridle are given as the end of 8th -7th centuries BC (Gorbunova, 2001, p.193, 194). Considering that the whole body of materials from Arzhan-2 correlates with the aldy-bel culture, the predominance of this special type of bridle cannot be explained only on the basis of chronology. This may suggest contacts (probably of ethnogenetic character) between Tuva and Kazakhstan during the early-scythian time. One of the stone vessels from the main burial, the so-called "beak-shaped censer", testifies to the same links. Stone vessels of the same shape were found in the complexes of Tagisken and Uygarak in the lower current of the Syr-Darya river (Vishnevskaya, 1973, table XXIV-4, 5; Itina, Yablonsky, 1997, Fig.22-6, 55-10, 65-7). Connections between Tuva and Kazakhstan during the early-scythian period are supported by many other materials, including those coming from the territories situated between these regions. As an example one can cite the buckle from the Gilevo-10 burial ground (Fig.1-5), which has been studied recently lying between the steppe Altay region («Altaysky kray») and Kazakhstan (Shulga, 2002, Fig.2).

CONCLUSION

In conclusion we would like to emphasise the subject of art and show by an example, the prematurity of relative chronological determination based on solely stylistic peculiarities. Images of horses with their legs folded underneath their bodies were traditionally considered as a later tradition compared to deer standing "on tiptoe". But in Arzhan-2 both images decorated one and the same artifact – the headdress of the male person from the primary tomb. Examination of the art objects from Arzhan-2 is still ongoing and other complexes, undiscovered as yet, are likely to be dated according to these materials.

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Chapter 2

SOME CHRONOLOGICAL PROBLEMS OF EUROPEAN SCYTHIA: ARCHAEOLOGY AND RADIOCARBON

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ABSTRACT

This paper is devoted to some problems of correlation between archaeological and radiocarbon dates in Scythian archaeology. Modern radiocarbon dates which are used to support an independent non-archaeological chronological system, in some cases provide evidence to narrow existing archaeological dates or show a good agreement with archaeological dates, and in other cases do not contradict them. The findings of chronological studies are clearer now: the accepted archaeological dates of early Scythian monuments (9th - 6th centuries BC) are found as the later limits of their calibrated calendar age (^{14}C), whereas archaeological dates of classical antiquities (5th - 4th centuries BC) are found in the earlier parts of their calibrated age range. For example, the "royal" Alexandropol barrow which was dated by archaeologists to the period 330-300 BC., has radiocarbon dates in the interval 2300-2080 BP, which corresponds to the 4th – 1st century cal. BC.

Key words: Scythia, Scythians, history, chronology, chronological periods, archaeological dates, radiocarbon dates, "royal" barrows

INTRODUCTION

Dynamics of the historical development of Scythia (and not only European Scythia but "Siberian" Scythia also) are determined by modern archaeological research only in the most general aspects. The development of so-called European Scythia through the millenium of its history (from ca. 700 BC to 300 AD) was not a continuous and fluent evolution of a certain single-ethnic culture, but an intermittent process. It is nowadays possible to imagine

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no less than three clusters of archaeological cultures and groups of monuments that successively existed in the same region within the limits of steppe, forest-steppe and the foothills of the western and northern Pontic area and northern Caucasus: (1) Archaic Scythia (ca. 700 – 525 BC); (2) Herodotus' Scythia (ca. 530/500 – 300/285 BC); (3) Scythae Minores in the Crimea and western Pontic area (ca. 300/200 BC – 200/300 AD). The paper presents the first and the second clusters that cover a historical phenomenon known as Scythia Magna. Detailed elaboration was achieved first of all for a few monuments from the group of so-called "royal" barrows, which dated from the 7th to the 4th century BC., and marked the main chronological points. Dating of several Scythian tombs (Kelermes, Solokha, Chertomlyk, Oguz, Alexandropol barrows) allow them to be quite reliably located on a historical scale (Alekseev 2003).

Tthe following major periods in the history of European Scythia based on archaeological and written sources can be identified.

1st period. Late 8th century – ca. 680 BC (about 40 years, as long as one or two generations): the period of distant migrations and excursions; intrusion of nomadic groups (known as Scythians of Aristeas and Diodorus of Sicily) from Central Asian territories into northern Caucasus and northern Pontic area; penetration of the first group of nomads (known as Greek *Κιμμεριοι*, Akkad. *Gimiraia*, the country of *Gamir*[*ra*]) into Transcaucasia and Iran.

2nd period. Ca. 680 – 670/660 BC (about 20 years, as long as a generation): the period, which comprises/covers a) the late 8th century BC record of Cimmerians in Assyrian written sources, b) arrival of "the first generation of Scythians" to Transcaucasia and Iran (Akkad. Ašguzāia, Iškuzāia – the Kings' Išpakāi and Bartatua = Προτοθύης period) and c) their subsequent outflow to northern Caucasus.

3rd period. Ca. 650 – 600 BC (about 60 – 70 years, as long as two or three generations): the final period of Cimmerian and Scythian occupation within Central Asia and "supremacy" of the second generation of Scythians (the reign of king Madius = Μαδύης). It is also the time when full-scale development of northern Caucasus foothills and the Dnieper forest-steppe territories started.

4th period. Ca. 600 – 550/525 BC (about 60 – 70 years, as long as two or three generations): to a great extent a "dark age" in the history of archaic Scythia, which in its later period was characterised with an unstable situation in northern Pontic area and long-distance movements of tribes. Greek and the forest-steppe cities were intermittently attacked, life in some of them came to an end. The period may be possibly prolonged up to 515/512 BC, till the parry of the blow that king Darius struck against western and northern parts of Pontic region.

5th period. Ca. 550/525 – 480 BC (about 30 – 40 years, as long as one or two generations): this period should be regarded as a frontier one between the existence of two Scythian cultures – the ancient and the classical one, also known as Herodotus' Scythia. It is characterised with circulation of a new set of artefacts in the Caucasus and Pontic area possibly caused by the influx of a new group of nomads from the east. Local centres of Scythian-like cultures appeared in the Volga and the Don basins as well as in some other regions.

6th period. Ca. 480 – 430 BC (about 50 years, as long as two generations): the period of formation of the new Scythian society characterised with the military and political pressure put upon Greek poleis.

7th period. Ca. 430/420 – 360 BC (about 70 years, as long as two or three generations): the dawn of stable co-existence of Scythia and Greek cities from time to time briefly interrupted by instability within Scythia proper and in some Greek territories (mainly in the Crimea).

8th period. Ca. 360 – 300/290 BC (about 60 – 70 years, as long as two or three generations): the final stage in the history of Scythia Magna, the period of wars and conflicts outside Scythia, marked with a new influx of another nomadic group from the east.

But there are a lot of difficulties with the establishment of the key chronological points in Scythian history – first of all the beginning and the end of Scythia Magna. There are several archaeological views which can be reduced into two basic systems of chronology: a "short" and "long" one.

DISCUSSION

It is supposed, guided by historical data, that Scythian migration from the unknown region of Central Asia to the East Europe took place at the end of the 8th or in the beginning of the7th century BC. The archaeological monuments connected to this event are not numerous and there are no reliable archaeological methods for their exact dating. The ^{14}C dates produced for some of them (for example, Steblev barrow 15), which was established as the oldest Scythian grave in the Dnieper region (1st period) dated by V.I. Klochko and S.A. Skory according to the archaeological data to the late 8th (Klochko, Sskory 1993: 71 - 84) or, may be, to the early 7th century BC (Alekseev 2003: 60) testify to the earlier Scythian association but within a long chronological range (2660-2530 BP). The combined radiocarbon date (Alekseev, et al 2002: 146) of some samples from this barrow give us the date in the range of the 8th century BC, but the 7th century BC also probable (Fig. 1).

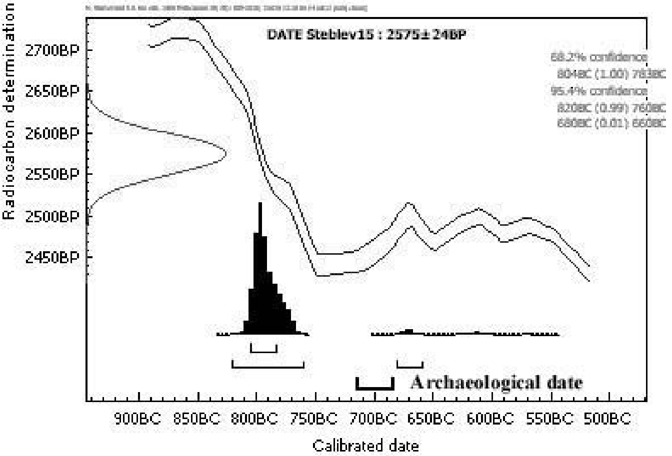

Figure 1. Combined ^{14}C and archaeological dates for the Steblev barrow No 15 and their position on the calibration curve

But we can be sure now that the earliest Scythian monuments in Europe appeared later than the earliest Scythian barrows in Central Asia which can be dated by ^{14}C (the most important for us is the Arzhan barrow with different archaeological pre-Scythian and early-Scythian materials, including Animal Style, bridles, weapons, etc. (Gryaznov 1980), which can be dated by archaeologists in the interval of 10th-7th century BC (Alekseev 2003), but radiocarbon dating testify that this burial mound was erected during the 9th century cal BC, 2800-2660 BP (Fig. 2) (Marsadolov 1996; Marsadolov, et al 2003).

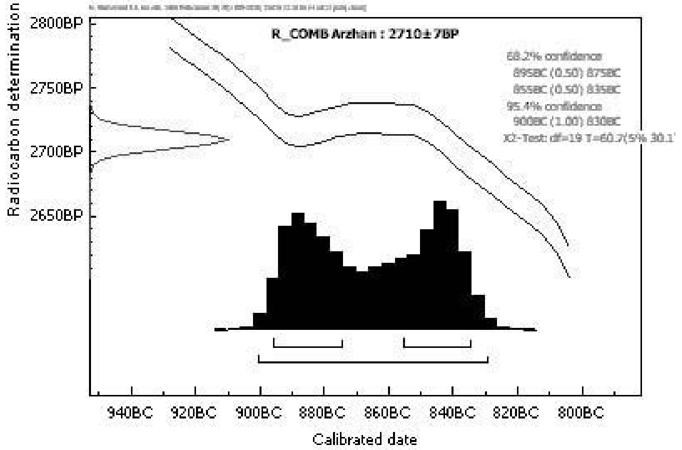

Figure 2. Combined ^{14}C date for the Arzhan barrow and its position on the calibration curve

Monuments which belonged to the next stage of Scythian history (2nd and 3rd periods) are a little bit better dated according to Near East chronological tradition and some artifacts of near-eastern origin. Many famous barrows in the Northern Caucasus region (Kelermes, Krasnoe Znamya, Novozavedennoe, etc.) are dated by archaeologists to the period ca. 660/650 - 600/580 BC. For example, the most important Kelermes barrows (two groups: early and late) dated by archaeological materials to the second half of the 7th century BC (Galanina 1997: 172-193). ^{14}C dates produced for Kelermes barrows lay in the interval from 2690-2380 BP which corresponds mainly to the 9th – 6th century cal. BC.

Five dates have been produced (wooden and bone samples) for the early Kelermes barrow 31 (Alekseev, Kuznetsova 2001; Alekseev 2003: 107; Alekseev, et al 2001: 1095-1096), and the combined date (2556±24 BP) corresponds to the period 810-760, 690-560 cal BC (2 sigma) (Fig. 3).

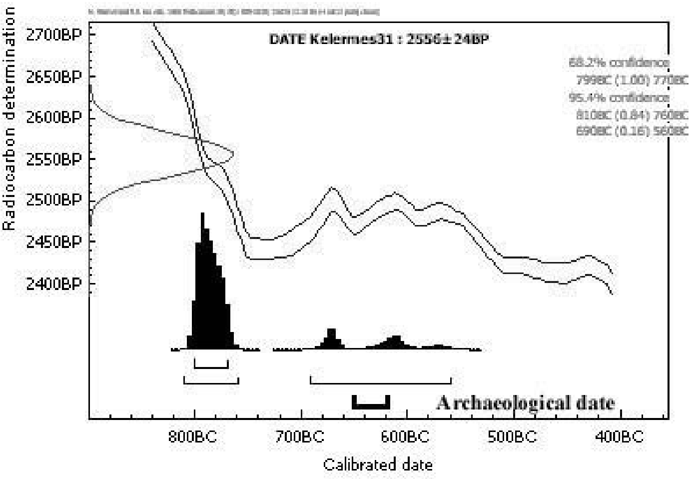

Figure 3. Combined ^{14}C and archaeological dates for the Kelermes barrow No 31 and their position on the calibration curve

It is very important that one of the latest Pre-Scythian barrows which belonged to the classical, key type of the so-called “Novocherkassk” culture – Uaskhito barrow (Erlikh 1994) in the North-Western Caucasus (archaeological date: late 8th – first half of the 7th century BC) has combined radiocarbon dates which are very close to the dates of Kelermes-31: 2540±35 BP, which corresponds to 810-750, 700-530 cal. BC. (Fig. 4).

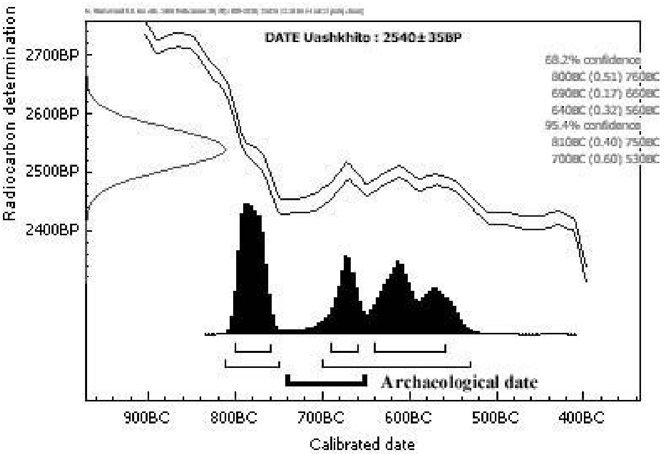

Figure 4. Combined ^{14}C and archaeological dates for the Uashkhitu barrow and their position on the calibration curve

The combined ^{14}C date of the late Kelermes barrow 24 (Galanina, Alekseev 1990; Alekseev 2003: 107) is 2399±40 BP which corresponds to 770-680, 660-630, 600-580, 560-390 cal BC (2 sigma) (fig. 5).

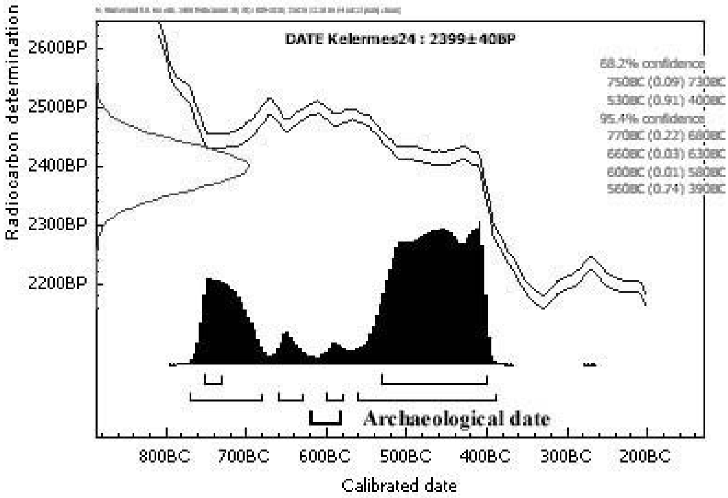

Figure 5. Combined ^{14}C and archaeological dates for the Kelermes barrow No 24 and their position on the calibration curve

One of the most important events in Scythian history took place in the second half of the 6th century BC (5th period). Some archaeological and narrative data shows a lacuna about ca. 550-500 BC, and proves discontinuity of European Scythia's development. We can suggest that a new *steppe* nomadic force with a new Asiatic element in their material culture probably came from the east, replaced the "Early Scythians" from the *forest-steppe and foothills* zones, and began to exert pressure on the Greek settlements.

Due to the occurrence in Scythia in the 5th - 4th century BC of a great number of Greek imported items (amphoras, vases, jewelry etc.), researchers have reduced the chronological intervals of dating to several decades and even to ten years. For example, very interesting results have been obtained for the Solokha "royal" barrow (7th period). According to archaeological data, this barrow can be dated to 410-375 BC (Alekseev, et al 2002: 145; Alekseev 2003: 259 – 261). The combined ^{14}C date from the eleven individual dates is 2333±15 BP which corresponds to 403-390 cal BC (2 sigma). These results are generally in good agreement with the archaeological data and one of the most useful examples of radiocarbon dating of Scythian "royal" barrows (Fig. 6). Moreover, according to both archaeological and radiocarbon dates the opportunity to identify some of the famous barrows of Scythian nobles with the tombs of Scythian kings known from written sources (Herodotus 4. 78 - 80) has even appeared. So, it is supposed that in the earlier grave of Solokha kurgan (ca. 420/410 - 400 BC) Oricus, the younger brother of king Octamasades, was buried, whereas Octamasades was buried in the same barrow, but later in the period of ca. 400-375 BC .

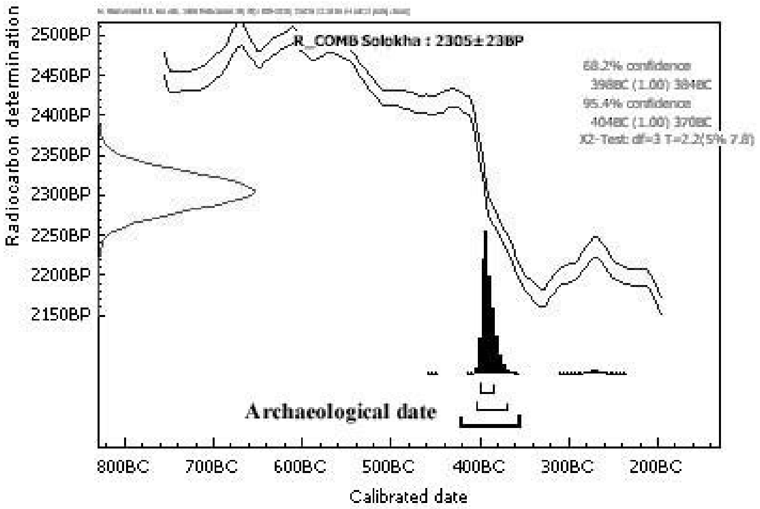

Figure 6. Combined ^{14}C and archaeological dates for the Solokha barrow and their position on the calibration curve

Another example concerns the main grave of Chertomlyk (8th period) barrow which was dated by archaeologists to the second half of the 4th century BC, and according to narrative sources to the period of ten years 339-238 BC (Rolle, Murzin, Alekseev: 165 – 166; Alekseev 2003: 267 – 269; Boltrik, Phialko 1995). Unfortunately radiocarbon dates give a calibrated interval which is too wide and corresponds with the archaeological one only in the oldest part (Fig. 7).

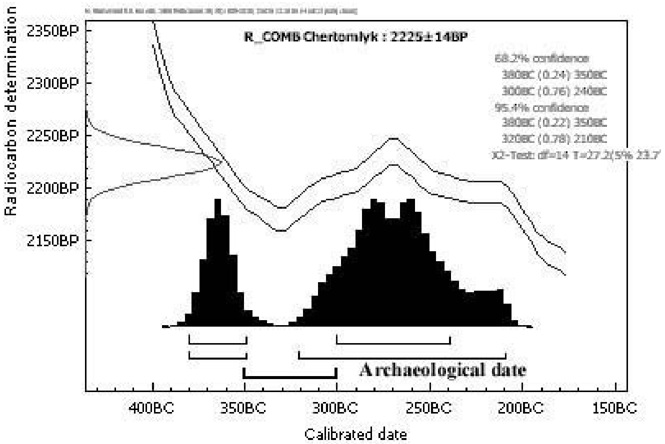

Figure 7. Combined ^{14}C and archaeological dates for the Chertomlyk barrow and their position on the calibration curve

One of the latest Scythian barrows is Alexandropol kurgan (8th period) which was dated by archaeologists to the last three decades of the 4th century BC (Alekseev 2003: 270). Radiocarbon dating shows also a wide calendar period but as one can see in any case this date is later than for Chertomlyk barrow and this fact is in a good agreement with archaeological evidence (Fig. 8).

But thus the problem of the establishment of the time of disappearance of the so-called Scythia Magna, which in the last period of its history covered a vast territory of the steppe and forest-steppe zone and declined sharply about 300 BC for reasons, is still unresolved. None of the reasons taken by itself (Sarmatian military pressure, natural and climate changes, palaeo-ecological factors and economic crisis) explain the phenomenon comprehensively. According to archaeological data it took place either right at the end of 4th century BC, or already in the 3rd century BC. ^{14}C dates do not allow one to be preferred to another. Ryzhanovka barrow which was situated in the forest-steppe region of Scythia must show us the real time of this event. The archaeological date of this monument is the late 4th or early 3rd century BC (Chohorowski, Kovaljuch, Skripkin 1998; Alekseev 2003: 271 – 273).

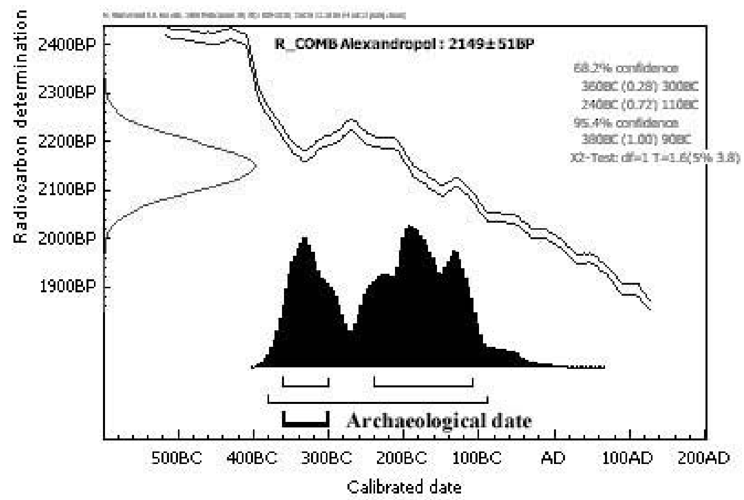

Figure 8. Combined ^{14}C and archaeological dates for the Alexandropol barrow and their position on the calibration curve

CONCLUSION

So, the radiocarbon dates used to support an independent non-archaeological chronological system, in some cases provide evidence to narrow existing archaeological dates or show good agreement with archaeological dates (Arzhan, Solokha barrows), and in some cases do not contradict them (Chertomlyk, Oguz, Alexandropol, Ryzanovsky barrows). Unfortunately, in general the calibrated curve in the range of Scythian epoch is really useful for radiocarbon dating only for the periods of the 9th - 8th century and the first half of the 4th century BC. At the same time we must pay attention to the details of the agreement between archaeological and radiocarbon dates. The accepted archaeological dates of early Scythian monuments (9th - 6th centuries BC), as a rule, are found in the later limits of their calibrated calendar age (^{14}C), whereas archaeological dates of classical antiquities (5th - 4th centuries BC) are found in the earlier parts of their calibrated age range. For example, the "royal" Alexandropol barrow which was dated by archaeologists to the period 330-300 BC., has radiocarbon dates in the interval 2300-2080 BP, which corresponds to the 4th – 1st century cal. BC. So, questions about the reasons for this phenomenon arise. Is it the conformity to natural laws connected with the features of using radiocarbon dating in the period of Scythian archaeology (1st millennium BC), or can it provide a reason for preferring some intervals within the calibrated calendar age (latest for earliest Scythian monuments and vice versa) in the case when exact archeological or historical dates are absent?

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Chapter 3

MIGRATIONS OF EARLY NOMADS OF THE EURASIAN STEPPE IN A CONTEXT OF CLIMATIC CHANGES

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ABSTRACT

This article is devoted to the periodic migrations of Asian nomads (Saka - Scythians, Hsiung-nu - Huns, Turks and Mongols), which can be traced from the beginning of the first millennium BC up to the 13th century AD according to archaeological and written sources. This correlates with periods of increasing humidity in the steppes during ancient times. While it is difficult to define the reasons for these migrations, it is possible, that climatic changes may have promoted them.

Keywords: Early Nomads, horseman, migration, climate, Eurasian steppes, Central Asia

INTRODUCTION

The Eurasian steppes stretch for 9 thousand kilometers in the east and from the Middle Danube plain up to the plateaux of Central Asia. In ancient times, they represented a unique region which has played a significant role in the formation of cultural - economic systems of various peoples.

Having a stable ecosystem, the steppe region stimulated the creation of different economic systems by ancient populations according to climatic changes but also depending on them (Mordkovich, Giljarov, Tishkov, Balandin 1997).

At the end of the 2nd millennium BC, Eurasian steppe nomadic cultures created their own economic system – cattle breeding (with horizontal and vertical migrations), in which the structure of herds was basically formed by horses and fine cattle that did not require stocks of forage for winter. Many nomadic peoples have preserved this convenient economic system up to the

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present without any particular changes. The system was a progressive phenomenon and not completely static. It gave new opportunities for growth in the well-being of people and for the formation of their culture, stimulating a social stratification and a development of the structure of authority. At the beginning of the first millennium BC significant progress in horse-breeding was made, new forms and more reliable types of bronze bridle were made, being the basis for formation of a society of horsemen in the form of centaurs (Bokovenko 2000). In the steppe zone of Central Asia, numerous nomadic cultures of the Scytho-Saka type appeared too (Tagar, Aldy-Bel', Maiemir, Tasmola cultures etc.). The early stages of its development are precise: according to archaeological data, they are fixed in the 9th-8th centuries BC in the Central Asia. The Scythian culture is known from numerous rich barrows in the Black Sea region dating to the 7th century BC. The cultures of the Asian nomadic tribes, in many respects are similar in material aspects with the Scythian culture, but they remained in their shadow and were considered as a lesser culture compared to the "brilliant" world of the Scythians.

RESULTS

The Asian connections with the Scythian culture are not so easily traceable, even though the theory of the eastern origin of the Scythians goes back to Herodotus. Many scholars contributed to its development (Rostovtzeff 1929; Borovka 1928; Jettmar 1967 etc.). There, however, was little evidence for these connections. Only after the "royal" barrow of Arzhan in Tuva (Central Asia) had been excavated did it become possible to prove the reality of the facts narrated by Herodotus (Herodotus, IV, 11).

Arzhan was excavated by M.P.Gryaznov and M.H.Mannai-Ool in 1971 - 1974 in the Uyuk high-altitude hollow of the Western Sayan, 150 km to the North-West from the center of Asia (the Piy-Khem region, the republic of Tuva, Russia).

The barrow is a huge stone structure, cylindrical in shape, with a diameter of 120 meters and a height up to 4 meters (Fig.1: 1). On the outside it is shored up with a slab casing. Under a massive stone embankment a complex wooden structure consisting of 70 big log frames (a square of area 15-130 sq. m and height of 2,5-3 m) made of huge larches was found. The log frames are also covered with a thick layer of wood on all sides. According to M.P.Gryaznov, it must have taken no less than 1500 men and 7-8 days to erect the whole structure. Buried within the central double frame were "the king", "the queen" and around them 6 horses were buried too. Other burial chambers contained a further 15 "nobles" - all wearing clothes and weapons. Laid with the "nobles" were 160 saddle horses (2 - 30 in each block) in full harness: with bronze bits, gold and bronze badges on the bridle and bone suspenders made of wild boar's tusks. In this rich diversity of finds it was possible to distinguish 24 types of bridles which were simultaneously used during that period.

Unfortunately, the mound had been partly robbed in ancient times and a good deal of opulent precious objects from the royal burial have been lost forever, but even the remaining clothes, the oldest carpet in the world, decorations made of gold and silver and magnificent bronze castings testify that the person buried there must have been very rich and powerful, probably the leader of a group of nomadic tribes. Apart from the Scythian type weapons (daggers, stamps, arrowheads) and numerous horse harnesses the mound contained a number of objects executed in the Scythian-Siberian animal style (Gryaznov 1980; Grjaznov 1984).(Fig.2).

Another important facet of the nomadic artistic endeavors is monumental art - represented in Arzhan by the so-called Deer Stone. It is one of the widely known standing stone monuments especially characteristic of Central Asia, which used to be installed in sanctuaries and burial structures. Most of such finds occur in Mongolia and Sayan-Altai and only individual finds are known in Europe. Dendrochronological and radiocarbon dating indicate that Arzhan dates to the end 9th - beginning 8th century BC (Zaitseva, Vasilev, Marsadolov, Sementsov, Dergachev, Lebedeva, 1996).

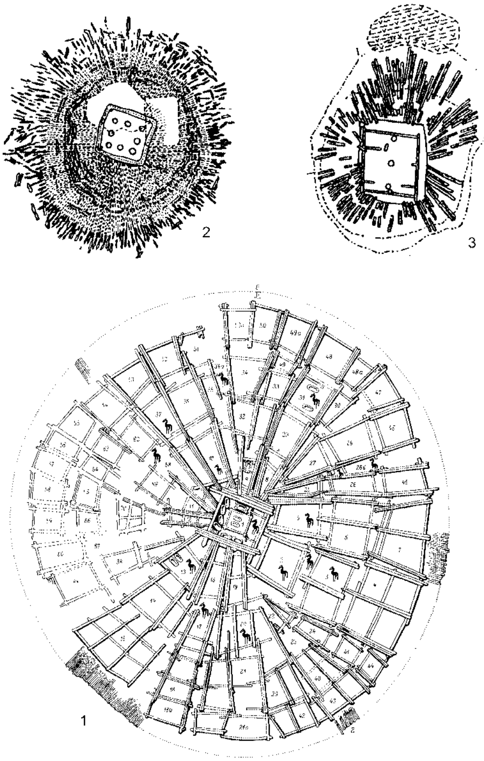

Figure 1. Tent-shaped funeral construction: 1 - Arzhan, Tuva; 2 – Flyarkovka, Northern Black Sea; 3 – Durovka, Northern Black Sea.

Arzhan is an ethno-cultural important site because it is possible to develop a typological analysis of the main categories of the artifacts. These include horse harnesses, weapons and works of art. It is possible to define the areas of origin of the gifts offered to the powerful leader. Offerings found in the northern timber graves came from the eastern areas of Kazakhstan, the Altai Mountains, and the Minusinsk Basin. In the southern burials offerings came from Tuva and Mongolia (Bokovenko 1986). The burial tradition in the kurgan involving a great number of horses is reflected indirectly in the written sources. The Massagetae worshipped the sun by sacrificing their horses as "he [the sun] is the swiftest of the gods and therefore they give him the swiftest of mortal things" (Herodotus, I, 216). The area inhabited by the Saka and Massagetae, apparently, is to the east up to Tuva and Mongolia. There is a hypothesis that Kazakhstan was the original country of the buried people of the Arzhan Kurgan (Kyzlasov, 1977). The final solution of this problem is yet to come. The complex has been dated to the 9th-8th century BC according to dendrochronological and radiocarbon analyses and to typology of artifacts. Arzhan can be called the earliest "royal" funeral site of the Scythian culture in the steppes of Eurasia. We could think that maybe this kurgan was built for the chief of a confederation of tribes of Central Asia. 30 years after Arzhan 1 was discovered, in same valley the "royal" barrow Arzhan 2 was excavated (Chugunov, Parzinger, Nagler 2001). This site is dated to about the 7th century BC.

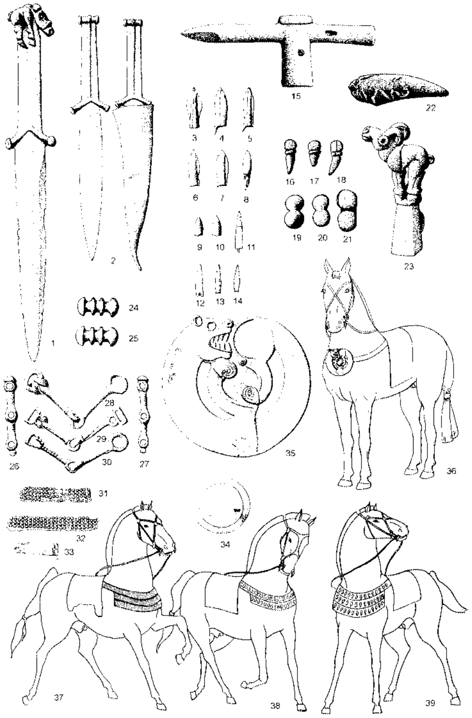

Figure.2. Royal barrow Arzhan 1: funeral artifacts. 36-39 - Reconstruction of the horse equipment of the horse (reconstruction by the author)

This indicates that the archaeological sites of Scythian type of Central Asia pre-date the 7th century BC Scythian sites found in the Northern Black Sea region.

All the main elements of Scythian culture are represented in the burials of the site. They include typical Scythian forms of weapons, horse harnesses, and the animal style decorative arts. A similar situation is also traced in other cultures of Central Asia (Tagar, Maiemir cultures etc.).

In some scholars' opinion in the pre-Scythian period there were already limited groups of settlers coming from the East to what later became European Scythia (Terenozhkin 1976). They were followed by larger groups of horsemen of nomadic peoples, their migrations becoming more and more systematic in Scythian time.

In most cases the character of these intrusions is not clear, as well as the origin of the intruders "coming from somewhere in Asia". We can only note certain elements in the culture of European Scythia which doubtless have an Asiatic origin and are connected with the cultures of Asia.

Figure.3. Eurasian stag images : 1 - Bronze knife Karasuk culture (end II mill.BC), Mar'yasovo, Krasnoyarsk region; 2 - Barrow Arzhan, Tuva; 3,8 - Turan,Tuva; 4 - Mozola-Khomuzhalyg, Tuva; 5 - Ortaa-Sargol, Tuva; 6 - Boyary, Khakasia (Minusinsk steppes); 7 - Bukhtarma, Western Altai; 9 - Ujgarak, Kazakhstan; 10 - Aksyutintsy, Ukraine; 11 – Dagestan, Northern Caucasus; 12 - Voitika, Northern Caucasus.

In many scholars' opinion it is necessary to distinguish the following cultural components of European Scythia genetically tied with the East: daggers with butterfly-shaped guards, arrowheads early forms, helmets of the Kelermes type, spiked battle-axes, horse-bits, cheek-pieces of the

Chernogorovo and Zhabotinsk type, bordered mirrors, bronze cauldrons of the Beshtaugor type and "stag-stones". We can follow the development of some animal style images (deer, boar, and panther) from east to west. There are elements of stylization and degradation on the objects from the western part of the Scythian World (Jettmar 1964; Terenozhkin 1976; Il'inskaya, Terenozhkin 1983; Kossak 1987; Klochko, Murzin 1987; Bokovenko, 1989; 1996; Medvedskaya 1992; Alekseev 1992; Kurochkin, Subbotin 1993 etc.) (Fig.3-4). This list of cultural components deriving from Central Asian prototypes can be extended. During the past few years, new monuments were discovered in the eastern parts of the Eurasian steppes and new groups of objects studied, which open new possibilities to trace the origin of some of the Scythian cultural components.

So, the Arzhan-type tent-shaped construction at the ancient surface level can be found in Northern Kazakhstan (the Kenes burial grounds, barrow 1). There it is dated to the Early Scythian period (Habdulina 1987).

Those few tent-shaped complexes of the Northern Black Sea area (Kvitki and Flyarovka in the Cherkassk region, the Tyasmin basin, etc.) are dated to the same period. The earliest are dated to the 7th century BC, the rest - to the 6th-5th centuries BC (Kovpanenko, Gupalo 1984, p. 56-57; Kovpanenko 1984, Murzin 1984) (Fig.1: 2-3).

Burials of the Northern Black Sea area have similar tent-shaped constructions in rich barrows (the Ula and Kostroma barrows) - in the last case it is difficult to trace the features of these constructions in full detail relying on the available archaeological records. Accompanying horse-burials are also numerous: at the level of the ancient surface level, remains of tens or even hundreds of horses are found. Burials of warriors with horse-bridles become characteristic of the partially wooded steppe zone of the Northern Black Sea area in the 7th-5th century B.C. (Il'inskaya, Terenozhkin 1983) - in this connection they find certain parallels with the five variants of burials of Kazakhstan and the Sayan-Altai region, where mounted warrior burials become traditional among the nomads from the 8th century or even earlier.

N.L. Chlenova has proved the typological succession of mushroom-pommel daggers with no guards and of long daggers and swords with straight guard (the so-called Karasuk-Cimmerian type) in all regions of the Sayan-Altai and Kazakhstan (Chlenova 1976). Certain transitional forms penetrated to the Northern Black Sea Area (Subbotovo, Gerbino, Kiev, Obukhovka). The same is true of the 7th-6th century BC Scythian swords with butterfly-shaped guards: in Siberia several variants of design for guards and hafts are found (Kulemzin 1974, fig.32), but only one of these variants is found in the west. It should be mentioned, however, that some scholars derive Scythian akinaks from the Northern Caucasus and the Transcaucasian region, looking for prototypes among local daggers of the earlier period (Makhortyk, 1991), though it is not always possible to prove this typologically.

The analysis of harnesses reveal the types of horse-bits and cheek-pieces preceding those from Arzhan (Bokovenko 1986). The great number and variety of stirrup-shaped bits in South Siberia and Kazakhstan, as well as the discovery of a 10th-9th century B.C. workshop producing them at the site of Kent, also testify to their Kazakhstan-Siberian origin. There are many works dealing with the ties between the Siberian and European Scythian art. The most authentic animal-style representations doubtless originating from the Asiatic Bronze Age images are stags, curled up feline animals and birds of prey. The mapping of these images reveals the development of their penetration to the west and at the same time of their gradual schematization (ears, paws and tails turning into circles). Up to the present time over 600 representations of stags engraved on rocks have been recorded in Central Asia (the so-called "stag-stones"), the earliest of them dating to the end of the second - beginning of the first millennium BC (Volkov 1981). Their style is very close to that of the Early Scythian stags of the Northern Black Sea area. Images of curled up panthers appear not only on stag-stones of the Arzhan stage (Kilunovskaya, Semenov 1995), but were executed in bronze and in gold. A large pectoral plaque of the Arzhan type, but typologically preceding the Arzhan stage, was found in Mongolia (Majdar 1981, p.32-33)(Fig.4: 3). The appearance of these early examples, their gradual spread to the west along with the tendency to become more schematized suggests their origin was the highlands of Central Asia.

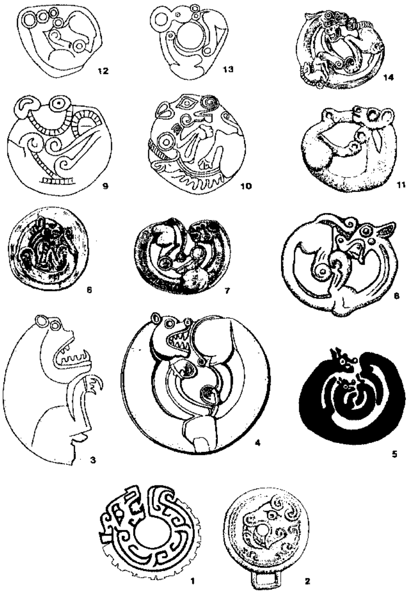

Figure 4. Curled-up feline animals in steppes of Eurasia: 1 - China, grave Fu Khao (XIII -XII cent.B.C.); 2 - China, epoch Western Chou; 3 – Mongolia; 4 - Barrow Arzhan 1, Tuva; 5 – Kosh Pei, stag-stone from the Arzhan valley, Tuva; 6 - Maiemir, Altai; 7 - Siberian collection of the Peter the Great; 8 - Barskoon hoard, Kyrgyzstan; 9 - Sardis, Asia Minor; 10 - Ziviya, Asia Minor; 11 - Ujgarak, Kazakhstan; 12 - Kelermes, Northern Caucasus; 13 - Temir-mountain, Crimea (Northern Black Sea Region); 14 - Kulakov barrow, Crimea (Northern Black Sea Region).

DISCUSSION

The arguments presented above suggest that the nomadic peoples of Asia took an active part in the creation of European Scythia and other later nomadic cultures. Different stages marking the intrusion of eastern elements into the Northern Black Sea area can be distinguished: the 9th-8th century BC - Arzhan stage, the 1st-4th centuries AD - Huns-Hsiung-nu stage, the 6th century AD - Turks stage, the 13th century AD - Mongols stage). These transitions to the west towards Europe can be traced in archaeological and written sources. It should be mentioned that in each case migrations of certain population groups are traceable. Initially these were not numerous, disappearing quickly into the local environment; later larger groups came, leaving more substantial evidence of their presence in local cultures. These migrations were gradual, with certain loss of the old cultural features and the acquisition of new ones, and with the involvement of other tribes into this stream on the way. There were two principal routes used by the Asiatic nomads: the northern one, through the steppes of Western Siberia, the Urals, the Volga basin and along the Northern Black Sea coast. The military complexes of Central Asian origin can be seen in an extensive territory from Mongolia up to Europe at a number of sites, such as Ak-Chij III, Ziwiya, Persepolis, Mush, Kaplantu, Norshutepe, Gamtepe, Sardis etc., in our view, to guard the southern ways against incursion by groups of armed horsemen (Kossack 1987 etc.). The earliest Scythian sites are concentrated in this partially wooded steppe zone of the lower Don and the Northern Caucasus. The reasons for these migrations, are caused not only by the internal development of those nomadic cultures (horse domestication, rider driven, creation of optimum types of bridles and so on), but probably, by certain climatic changes in this period. Recent research in palaeoclimate show evidence of some warming and humid periods in the steppe zone of Eurasia, which coincides with migrations of the nomads (Fig.5).

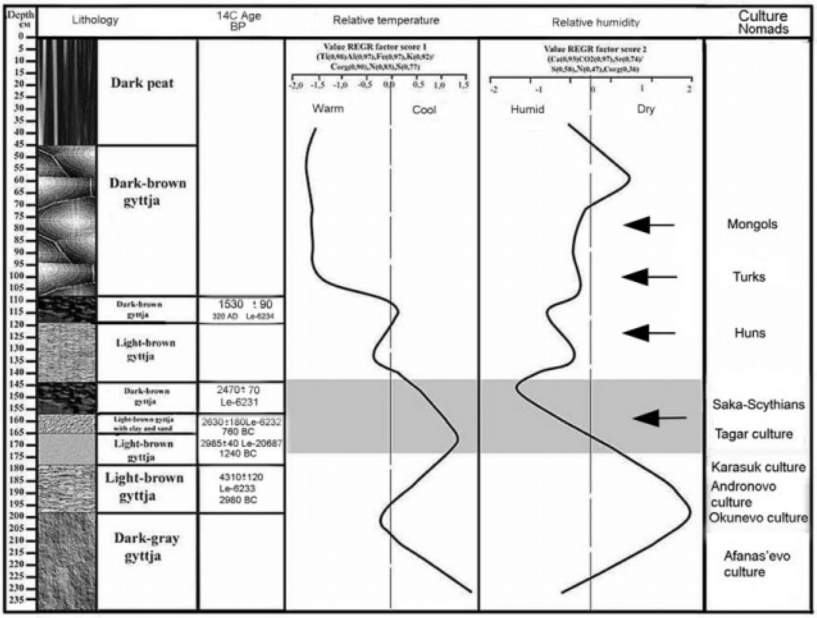

Figure .5. Paleoclimate geochemical records from Kutuzhekovo Lake and stages of cultural development in the Middle Yenisei area.

Geochemical research of lake deposits (the Kutuzhekovskoe and White lakes) and the loess-soil cross-sections from archaeological sites (Tepsei, Arzhan 2 etc.) of Central Asia have shown significant changes of the climate in various periods. Thus, during the Bronze Age (3rd-2nd millennium BC) the climate of Central Asia was much drier and colder than now (Dirksen, this volume). The stage of maximum humidity and temperature increase was in the 9-8th century BC. The expansionist cultures of the Iron Age (nomadic cultures of the Scythian time – Tagar culture) occurred in the 1st millennium BC too. Evidence of some cool and humid climatic conditions are found about 1600 years ago (3rd-4th centuries AD). The existence of the Tashtyk culture in this area was dated to the 1st century BC to 4th century AD (Koulkova, Bokovenko, B. van Geel, Dergachev, Dirksen, J. van der Plicht, Zaitseva 2003). In the later time, evidence for armed groups of Hsiung-nu – Huns and Turks in East Europe - is found in archaeological and written sources (Werner 1956; Gumilev 1967; Zaseckaja, Bokovenko 1994; etc.)(Fig.6).

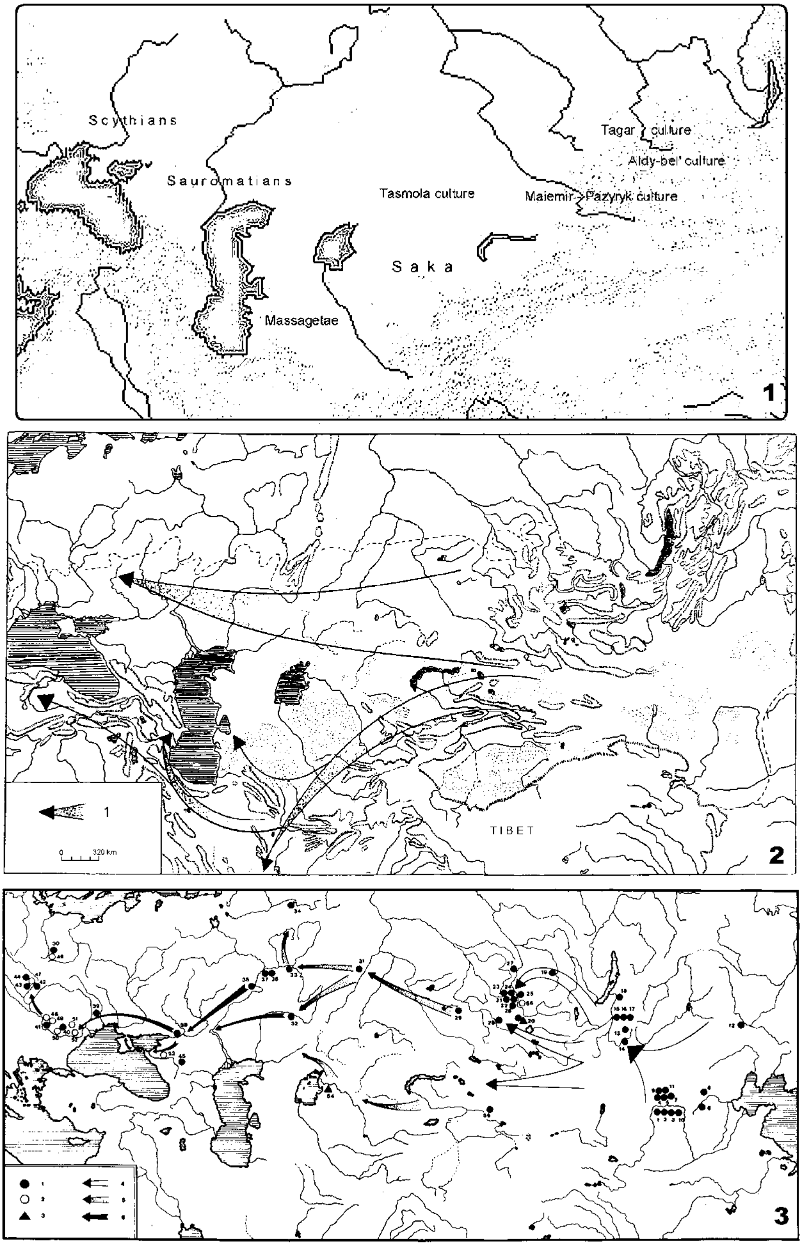

Figure 6. Maps of the Central Asian tribes in the 1st mill. BC (1) and reconstruction of migrations trajectories of ancient nomads: 2 – Scythians (Bokovenko 1996), 3 - Hsiung-nu – Huns (Zaseckaja, Bokovenko 1994).

A significant increase in humidity and a temperature rise in the steppe (growth of biomass production) about the 1st millennium BC probably became global. This has been traced from western Central Asia to western Siberia (Levina, Orlova 1993). In Europe a warm climate is replaced by a colder and wetter climate at this time (Kilian et al., 1995; van Geel et al., 1996, 1998), which probably stimulated movement of the nomads over large distances.

CONCLUSION

Thus, from the beginning of the 1st millennium BC, periodic migrations of a part of the population of Asian nomads (Saka-Scythians and Sarmatians in the 9th-3rd centuries BC, Hsiung-nu - Huns in the 1st-4th centuries AD, Turks in the 6th century AD, Mongols in 13th century AD) to the west towards Europe is traced in archaeological and written sources. This correlates with periods of increasing humidity in the steppes.

The origin of these migrations is not yet clear. They may be caused by political ambitions. But there are no doubts that climatic changes played an essential role by stimulating the move of numerous nomads over great distances.

ACKNOWLEDGMENTS

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Chapter 4

THE NORTH BLACK SEA STEPPES IN THE CIMMERIAN EPOCH

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ABSTRACT

The article is devoted to the consideration of the initial stage of history of the Cimmerians, who were the first historically known nomadic people in Eastern Europe. The early 1st millennium B.C. was characterized by the formative development of nomad pastoralism throughout the Eurasian steppes. During this time specialised nomadic economies developed based on the horse, so that most of the steppe regions were occupied by groups of nomads with their mobile way of life.

It is proposed that the appearance of the first nomadic horse-riding groups on the historical arena coincided with considerable changes of the environment in the Final Bronze Age. Worsening of climatic conditions had a negative effect on the Pontic steppes archaeological cultures with a mixed pastoral-agricultural economy. Steppe populations adjusted to the new conditions by adopting a new nomadic way of life as well as by developing new lands.

The migrations of nomadic tribes from the steppe zone were not single events but rather a continuous process. Depopulation of the Pontic steppes was accompanied by intensive cultural and economic development of other territories, for example, the area north of the Caucasus Mountains, the Krim Peninsula, the regions of the middle Dnieper and also the Great Hungarian Plain. These new centers were located in areas of wetter climate and their situations allowed them to play an important role. Cimmerians played a vital part in the transmission of horse riding and in the development of a new bridle technique. Both innovations were to have a major impact on European history.

Keywords: Early Iron Age, Pontic steppes, Cimmerians, climatic change, migration, horse riding, horse gear.

E.M. Scott et al. (eds.), Impact of the Environment on Human Migration in Eurasia, 35-44.

INTRODUCTION

The Cimmerian period, marked by considerable changes in economic and social life of population of Eastern Europe, belongs to an extremely important time in ancient history of this region. The considered period was called by the name of the people- the Cimmerians, who were the first historically known nomadic tribes in Eastern Europe.

The necessity of studying the Cimmerians' history and culture is determined by the significant role of this nomadic people in historical development of Eastern and Central Europe as well as the Near East. Without detailed examination of Cimmerian antiquities it is impossible to solve many questions of Scythian history too, because these antiquities not only preceded the appearance of Scythians monuments but served as one of the main sources in the formation of Scythian culture.

The Cimmerian problem has many aspects, but taking into account the theme of the current proceedings, this chapter will focus on such questions as the role of environment and migration in the development of Cimmerian history and culture.

Mankind's dependence on the environment is unquestionable. Although the degree of this dependence is estimated nobody denies a close connection of the economic activities of ancient people with landscape and climate. Landscapes, similar to ethnic groups, have their own history and dynamics of development. When a landscape changes considerably, people should either adapt to new conditions, or die out, or else find a new homeland. Below I will try to show the relationship between natural-climatic and cultural changes, which took place in Eastern Europe in the Final Bronze Age and at the beginning of the Early Iron Age.

RESULTS AND DISCUSSION

According to present data, between the 15th – 12th centuries BC the territory of Eastern Europe experienced a relatively wet and cool climate (Spridonova, Lavrushin, 1997). In these favorable climatic conditions, the population of Pontic steppes experienced economic growth. Archaeological evidence for this time is represented by large, long-term settlements with stone, clay and wooden architecture; its economy was based on settled agriculture reflected in the continuous use of the same land (Chernyakov, 1985). It is characteristic for this period that many settlements were located in regions which today experience regular shortage of water and are often uninhabited.

About the 11th century BC, in Eastern Europe a period of long climate aridity began (Gerasimenko,1997; Spiridonova, Lavrushin,1997). The evidence for these changes is represented by sea level changes and the regressions of the

Black Sea and the Caspian Sea (Zolotun, Kukhnev, 1984; Varushenko, Klinge, 1987). These climatic changes were even more dramatic in the territory of the Kazakhstan steppes, where different zones of vegetation moved almost 200 km to the north (Khabdulina, Zdanovich, 1984). As a result of these changes in the ecosystem, the population of the Black Sea and Aral-Caspian steppe regions were affected by a common ecological crisis.

Worsening of climatic conditions had a negative effect on the Pontic steppes archaeological cultures with mixed pastoral-agricultural economy. The crisis might also have been strengthened by anthropogenic influence on the local environment, too (intensive ploughing, destruction of steppe vegetation due to pasturing of the animals, etc).

The collapse of such large Late Bronze communities as the Belozerka and Post-Srubnaja cultures was a result of this ecological crisis (Makhortykh, 1993). The population of these communities had a complex economy dependent on agriculture and cattle-breeding. The increasing aridity of the climate forced the steppe inhabitants to move to nomadic cattle-breeding. Probably, already in the Late Bronze Age the cattle breeding direction in the economy, which gradually took a more mobile form, began to strengthen. The crisis in agriculture was also growing simultaneously. In these conditions the role of horse grew. This created the necessary preconditions for the transition to nomadic and to semi-nomadic pastoralism, which was soon spreading amongst the inhabitants of Pontic steppes, but also on the huge steppe regions of Eurasia.

At the end of the Bronze Age, the number of settled dwellers was gradually declining in the southern part of the steppe zone. In addition, simplification of house-building, bronze working and agricultural tools, as well as the revival of the flint industry took place. During the period of increasing climate aridity and decreasing steppe productivity, the early nomadic economy, probably, experienced a crisis in the 11th –10th centuries BC. A considerable part of the population was forced to leave the Pontic steppes and to move into areas with more suitable environment, corresponding to their way of life. It should be pointed out, that these migrations had not led to total steppes desolation because a part of the inhabitants continued living in places, favourable for life, for example, near large rivers such as the Dnieper, Dniester, etc.

The given thesis could be illustrated by some examples. The number of archaeological sites in the steppe area, between the Danube and the Don rivers, decreased ten-fold in 12th –10th centuries BC, in comparison with the previous Sabatinovka period (Machortych, Ievlev 1992) **(**Fig.1; 2).

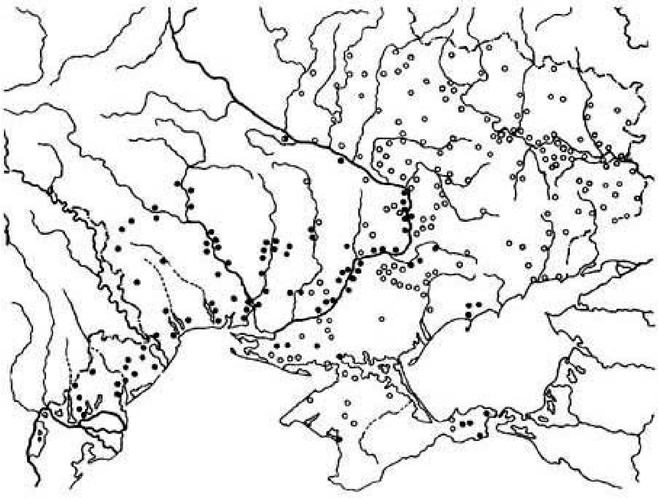

Figure 1. Map of archaeological sites in the Pontic area in the 14-12 centuries BC.
● Sabatinovka culture, ○- Srubnnaya culture

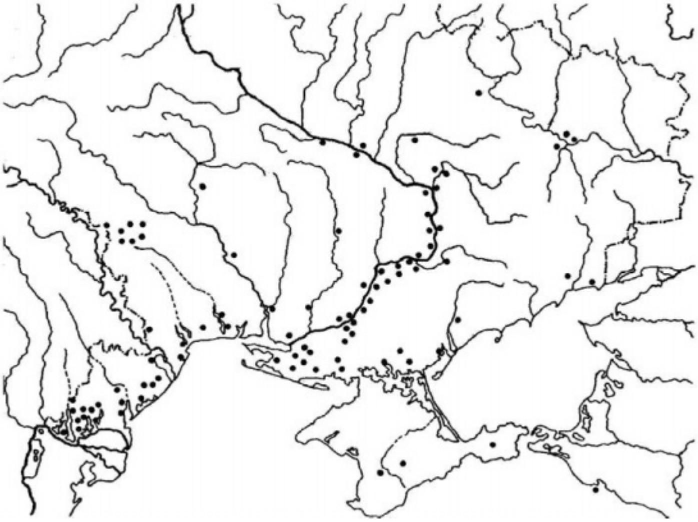

Figure 2. Map of archaeological sites in the Pontic area in the 12th -10th centuries BC
●- Belozerka culture

The same tendency of depopulation can be traced in the Pontic steppes in the succeeding Cimmerian epoch, which is characterized by lack of settlements and permanent cemeteries on this territory. The period of steppe desolation continued and later into the Early Scythian time (7th –6th centuries BC), when the main Scythian centers were located on the Northern Caucasus and in the middle Dnieper forest-steppe zone (Mazurin,1984; Makhortykh, 1991; Skory,1996).

From the above reasoning, it is clear that the appearance of Cimmerians on the historical arena coincided with climate changes in Eastern Europe. A considerable part of the population, already involved in nomadic cattle breeding, moved from the Pontic steppe region to areas with a more favorable environment. These migrations were probably realized in several steps and characterized by continuous or camp type roaming with a non-closed cycle of excursions. Such a form of pastoral nomadism is an exception in the nomadic way of life. It existed in conditions of ecological crisis caused by lack of forage during the drought periods, or during military events (Rudenko,1961). Nomadic, semi-nomadic, or semi-sedentary forms of pastoralism were chosen by the Cimmerians and their choice was determined by the ecological niche occupied by them.

Migration of Cimmerians took place in several directions (Fig.3). First of all they moved to areas which were located in zones with a positive balance of humidity.

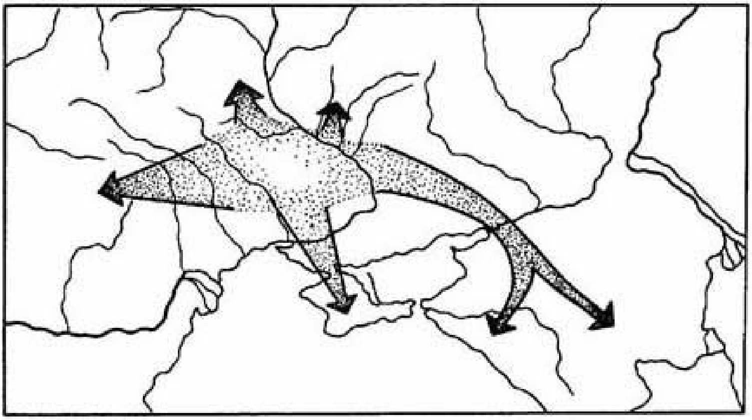

Figure 3. Cimmerian migrations from the Pontic steppes in the 10th 9th centuries BC

Among these areas were the Dnieper forest-steppe zone, the Crimea Peninsula, the Northern Caucasus and the Great Hungarian plain. These new centers were placed in areas of wetter climate and their positions allowed them to play an important role.

Cimmerian migrations find their confirmation in archaeological data. So, among the evidence of early military aggression of the Cimmerians are the destroyed settlements of the Chernolesskaja and Bondarikha cultures (the Subbotovo, the Buzovka etc.) in the forest-steppe zone between the Dnieper and the Don Rivers (Trenozhkin,1976). An assumption that the southern areas of the forest-steppe zones were occupied by the Cimmerians is also confirmed in physical anthropology data from the Cimmerian burials excavated there (Romashko, 1990).

The sharp increase in the number of cemeteries in the Trans-Kuban Region during the pre-Scythian time, testifies to the Cimmerians' migration in the Northern Caucasus (Makhortykh, 1994). In these cemeteries can be traced such nomadic features as interments in supine position as well as steppe types of weapons, horse gear, adornments, etc (Dudarev, 1999; Leskov, Erlikh,1999). Close interaction between the early nomads and the local North Caucasian population was one of the main factors in the formation of the well-known "Novocherkassk Group" of pre-Scythian monuments.

The Cimmerians' migration is also fixed in the west - on the territory of the Great Hungarian plain, which forms the most western part of the Eurasian steppe belt. The Hungarian plain served as a natural corridor leading in the western direction and convenient for nomadic cattle breeding. Here, we are dealing with such cultural phenomenon as the Mesoczsat Group (Patek 1974; Kemenzei,1986; Chochorowski, 1993). It is important to note that the cemeteries associated with this Group (Fuzesabony, Mezocsat, etc) did not display cremation burials, which was the practice in other territories of the Carpathian basin. Mezocsat graves are always inhumations. In many graves cattle or sheep bones were included. Richly ornamented bone plates are typical grave goods too. This group was the important factor in transmitting "eastern" cultural concepts and aspects of material culture to Central Europe.

From the above reasoning it is clear that development of Cimmerian culture was a fairly complicated process. It was realized in conditions of a radically changing economy and way of life, ethnic mixture and a broad spectrum of interactions.

The increase of the Cimmerian influence initiated historical and cultural changes in different parts of Eastern and Central Europe, and it is represented by the reorientation of long-distance exchange networks and changes in the centers of metal production.

The nomadic impact on the Early Iron Age cultures can be seen in the increasing importance of the horse. The appearance of horse riding in the 1st millennium BC brought about a revolution in communications. The horse could be used to explore new territories, in raiding and trading. A mobile life-style helped to create a new set of cultural and social patterns of behavior. The great importance of horses and horse riding is evident from the number of finds related to horse gear discovered in the Cimmerian graves and hoards (Fig.4-6).

These changes not only had a technological aspect but influenced economy (the changes in the structure of the breed of animals), warfare (the use of cavalry in battle requiring well-trained horses and riders), religious practices (the distribution of the inhumation graves with horse harnesses), and social structures (the appearance of the elite groups of mounted warriors who benefited from trans-regional exchange) .

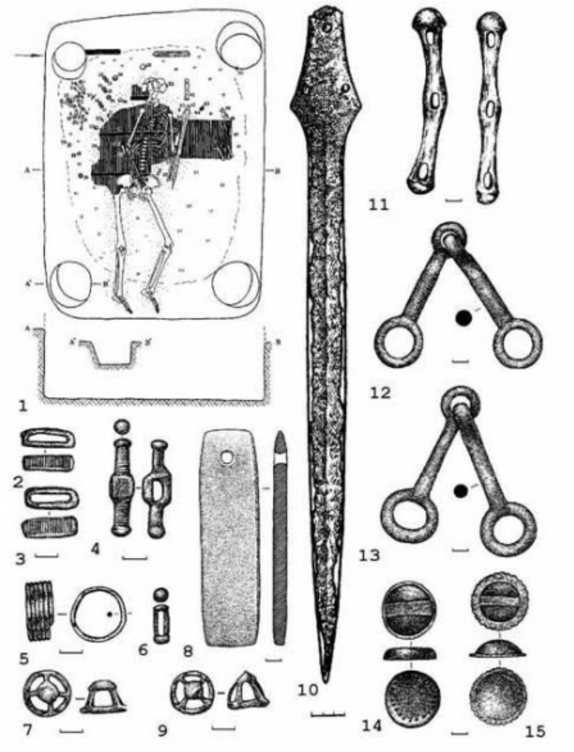

Figure 4. Cimmerian burial from Slobodzeva (middle Dniester Basin)

By the size and power of their influence on the outside world, the Cimmerians are the forerunners of further transformations which happened, on a large scale, in Eastern Europe in the following Scythian epoch.

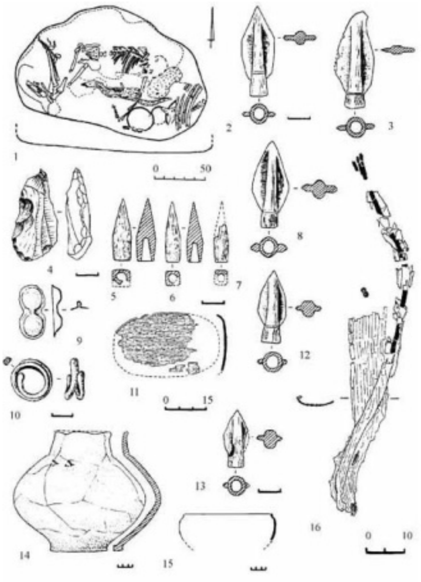

Figure 5. Cimmerian burial from Zimogor’e (Eastern Ukraine)

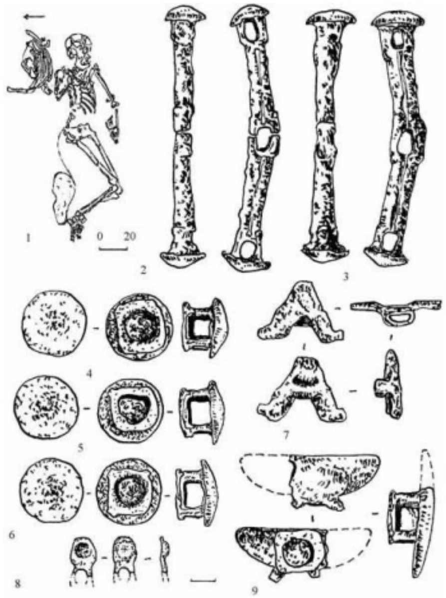

Figure 6. Cimmerian burial from Birukovo (Eastern Ukraine

CONCLUSION

The material collected during the last years should be summarized taking into account all the evidence using the most recent achievements in both methodological and sources studies.

The mapping of the pre-Scythian antiquities of the Northern Black Sea regions allows us to select six sub-groups of Cimmerian monuments in the territory under study among them the Danube-Dniestre, Southern –Bug, Pre- Dnepr. Samara-Orel, Crimean and the Eastern- Ukrainian groups. The subdivision of the archaeological monuments was based on a geographical principle starting from the concentration of the monuments in the places of most spread, for example, the basins of the big rivers such as the Dnepr, Dniestr or the Southern Bug. In spite of common features each group selected has peculiarities in their burial construction, the orientation in the people buried and the accompanying inventories.

The analysis showed both common and local peculiarities in the different territorial sub-groups, the dynamics of the cultural development and the direction of the cultural contacts inside the Cimmerian monuments of the Northern Black sea region.

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Chapter 5

RADIOCARBON, THE CALIBRATION CURVE AND SCYTHIAN CHRONOLOGY

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ABSTRACT

Interpretation of Radiocarbon dates can be rather complex. For example, variations in the natural ^{14}C content cause the ^{14}C clock rate to vary throughout time, causing the need for calibration of the ^{14}C timescale. For the Scythian epoch, there is a problematic range in the ^{14}C calibration curve. Radiocarbon dates of around 2450 BP always calibrate to ca. 800-400 BC, no matter the measurement precision.

In order to establish reliable chronologies, both state-of-the-art scientific and archaeological dating methods need to be employed. This includes high precision ^{14}C dating and AMS, enabling dating of small samples such as from museum collections or other precious materials.

Key words: chronology, radiocarbon, calibration curve, archaeology, Scythian, environment

INTRODUCTION

Radiocarbon (^{14}C) dating is the most common scientific dating method, as opposed to archaeological dating based on e.g. pottery or cultural association methods. It allows the measure of past time with a defined yardstick. This yardstick can be connected with (pre)historic ages by calibration of the Radiocarbon timescale (e.g., van der Plicht and Bruins, 2001).

The method enables chronological comparison of different areas at an excavation site and also between sites and regions, independent of cultural deliberations. This is essential for proper interpretation of archaeological layers and association with data from other fields. While the method is basically simple, it is complex in detail and errors in matters such as sampling and association are easily made. Therefore, quality control is necessary to build up a reliable ^{14}C chronology. Important aspects of quality control involves regular laboratory intercomparisons, multiple measurements of samples, issues such as conventional versus AMS, sample

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selection, association, and others (van Strijdonck et al., 1998; Boaretto et al., 2003).

The chronology of Scythian cultures during the first millennium BC is very important. The beginning of the Scythian epoch in Eurasia is not yet well established, mainly because for European Scythian cultures this is based on archaeological reasoning (typological comparisons) and historical sources, while for Asian Scythian cultures radiocarbon dating has been used (Alekseev, 2001).

Only recently ^{14}C dates became available for the European Scythian monuments. In addition, cooperation with western laboratories introduced the AMS dating technique in Russia, enabling the dating of small samples from museum collections or intrinsically small samples.

Issues of quality control and proper calibration of the ^{14}C dates yields a better understanding of changes in migration and environment during the Scythian epoch. Unfortunately, the ^{14}C dating method is hampered for a crucial timerange during the Scythian epoch because the calibration curve shows a very large plateau (the “Hallstatt” plateau; Becker and Kromer, 1993) from ca. 800-400 BC (at 2450 BP). Just before and after the plateau, calibration is accurate; during the plateau only techniques like wiggle matching yields useful calendar ages. This wiggle-match dating technique can be applied to well defined stratigraphical sequences, tree rings and organic deposits. Environmental changes can be dated accurately, enabling teleconnections with migrations caused by climate change (van Geel et al., this conference).

THE ^{14}C DATING METHOD

Definitions

The naturally occurring isotope ^{14}C (Radiocarbon) is continuously produced in the earth’s atmosphere by cosmic radiation. Radiocarbon is radioactive and decays with a half life of 5730 ± 40 years (Godwin, 1962). A stationary state of production, distribution between the main carbon reservoirs (atmosphere, ocean and biosphere) and decay results in a more or less constant ^{14}C concentration in atmospheric CO_2 (Mook and Waterbolk, 1985; Mook and Streurman, 1983).

However, it has been known for some time that the ^{14}C concentration of atmospheric CO_2 has not always been the same in the past. In tree rings, natural variations of the atmospheric $^{14}CO_2$ abundance were discovered on a time scale of one decade to a few centuries (de Vries, 1958). Later it was discovered that these variations can be attributed to variations in solar activity (Stuiver, 1965), which in turn influence the production of ^{14}C in the atmosphere. Also changes of the geomagnetic field strength influence the production of ^{14}C in the atmosphere (Bucha, 1970). This is understood because both solar activity and geomagnetic field strength determine the amount of cosmic radiation impinging on the earth. In addition the atmospheric $^{14}CO_2$ concentration also depends on exchange between the atmosphere and ocean.

Because of these variations in the natural ^{14}C concentration, the ^{14}C clock runs at a varying pace, different from real clocks: ^{14}C time ≠ historical time. Therefore, the ^{14}C timescale is *defined* and has to be *calibrated* to establish the relationship between ^{14}C time and historical time.

By definition, the ^{14}C timescale is expressed in BP = Before Present, where "Present" is the "standardyear" 1950 AD (Mook and van der Plicht, 1999). Radiocarbon measurements are always measured with respect to a standard (=Oxalic Acid with a radioactivity of 0.226 Bq/gC) which corresponds to that year. By convention, this definition includes correction for isotopic fractionation (to ^{13} δC = - 25‰) and uses the original value for the ^{14}C halflife (5568 years), used in the early days of the ^{14}C dating method (Libby, 1955).

The correction for isotopic fractionation is essential when dating materials with $\delta^{13}C$ strongly deviating from the standard value –25‰. Since 1‰ in $\delta^{13}C$ corresponds to 16 BP, this correction is also crucial when performing "high precision" dating with errors (1σ) down to 15 BP.

Calibration

Calibration involves measuring samples by both the ^{14}C method (in BP) and another method. Ideally this other method has to be independent from ^{14}C, yielding absolute dates (in AD/BC), and the samples have to be terrestrial (atmospheric).

The most ideal samples for calibration are tree rings, because they can be dated absolutely by means of dendrochronology. Following the early work of Suess et al. (Suess, 1978), the ^{14}C community has issued special issues of the journal *Radiocarbon* with calibration curves based on dendrochronology. The latest and presently recommended calibration curve is INTCAL98 (Stuiver et al., 1998), to be updated and replaced by INTCAL04 (Reimer et al., 2002).

Because of the irregular shape of the calibration curve, the translation of a ^{14}C age (in BP) into a calendar age is not straightforward. Special calibration software has been developed, producing calibrated age ranges with 1σ or 2σ confidence intervals (Bronk Ramsey, 1998; van der Plicht, 1993; Stuiver and Reimer, 1993). Calibrated ages are reported in calBC or calAD (Mook, 1986). In addition, calBP is used, where calBP = 1950-calAD, i.e. calibrated or calendar years before1950 (="Present").

INTCAL04 is a calibration curve back to 26 ka calBP. The tree-ring part of INTCAL04 now extends back to ca. 12 ka calBP, well into the Younger Dryas. Back to 26 ka calBP, the curve is "marine derived". It is based on corals dated by both ^{14}C and U-series isotopes (Bard et al., 1998; Burr et al., 1998), and on ^{14}C dated foraminifera from a varved sediment from the Cariaco basin (Hughen et al., 1998).

The new INTCAL04 calibration curve is shown in Fig.1: the dendrochronological part (both absolute and floating) and the marine derived part, separated at 12 ka calBP. The calibration dataset is decadal, i.e. has a resolution of 10 calendar years. The uncertainties plotted are 1 σ.

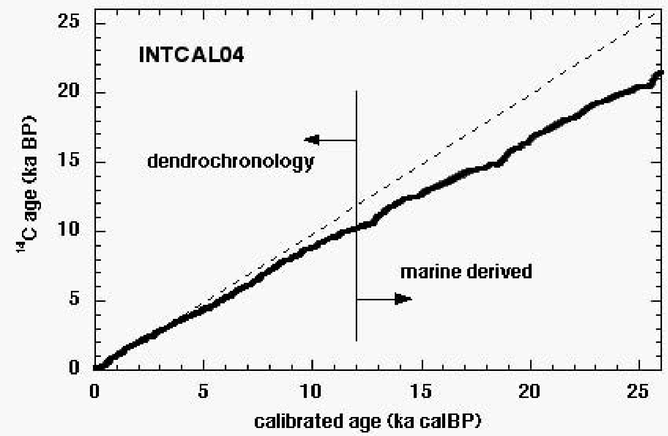

Figure1 The radiocarbon calibration dataset INTCAL04. The data are based on dendrochronology back to ca. 12.000 years ago; beyond, the data are based on paired ^{14}C / U-series datings of Pacific corals, and foraminifera dated with high resolution from the Cariaco basin laminated marine core.

When zooming in on details, wiggles are readily visible showing the "elastic" nature of ^{14}C time, such as is shown in Fig.2 (a and b). Fig.2a shows the INTCAL04 calibration curve for the first millennium BC. The Hallstatt plateau is apparent between 800 and 400 calBC. In Δ^{14}C space, the same data are plotted in Fig.2b. Δ^{14}C denotes the atmospheric ^{14}C content expressed as the per mil deviation of the ^{14}C content of the oxalic acid standard, after correction for radioactive decay and fractionation (Mook and van der Plicht, 1999).

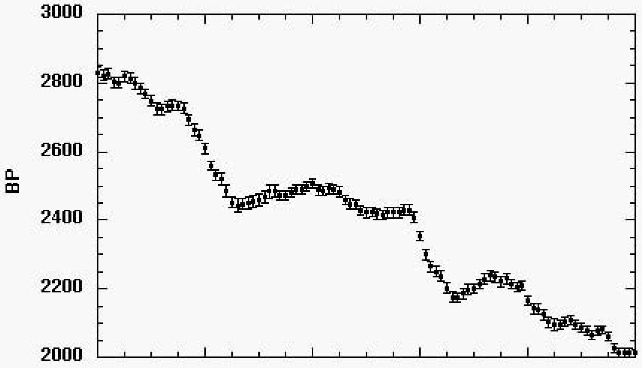

Figure 2.a. Part of the ^{14}C calibration curve INTCAL04: the first millennium BC. Plotted as radiocarbon ages in BP vs. calBC.

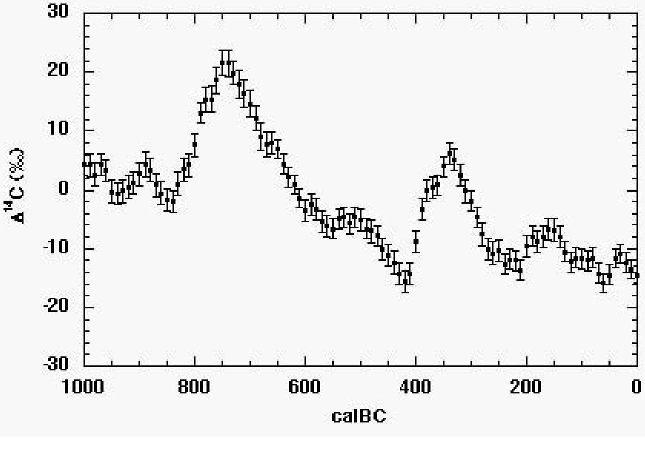

Figure 2.b. Part of the ^{14}C calibration curve INTCAL04: the first millennium BC. Plotted as $\Delta^{14}C$ vs. calBC.

Techniques

Radiocarbon measurements can be performed by applying two intrinsically different techniques: radiometry and mass spectrometry.

Radiometry is the conventional method, measuring the radioactivity by either Proportional Counters or by Liquid Scintillators. The technique of AMS (Accelerator Mass Spectrometry) is based on measuring the $^{14}C/^{12}C$ abundance ratio. Determining the ^{14}C concentration rather than the decay comes to measuring a system 6 orders of magnitude larger. This implies that much less carbon is required for obtaining the same precision, i.e. a few milligrams instead of grams. In addition the measuring time is much shorter. This allows ^{14}C dating of selected materials such as specific plant remains, museum collections, intrinsically small samples etc.

It is noted that the conventions and definitions for ^{14}C dating (like the BP timescale, standards and $\delta^{13}C$ fractionation correction) apply to both AMS and conventional techniques.

More technical details can be found in the proceedings of series of conferences – ^{14}C and Archaeology, Radiocarbon and AMS. For Groningen, we refer to Mook and Streurman, 1983 (conventional); Aerts et al., 2001 (AMS sample handling) van der Plicht et al., 2000 (AMS accelerator).

Quality control

Quality assurance is essential for ^{14}C dating. Over the years, this issue has been discussed in great detail. For example, van Strydonck et al. (1999) define a "^{14}C event" as "the isolation of some carbon containing substance from the reservoir(s) from which its carbon was obtained"; i.e., the ^{14}C event starts the radiocarbon clock. This is usually the "death" of some organism. Questions to be answered are: what is the ^{14}C event for each the materials to be dated; how is each ^{14}C event associated with the human event; what is exactly the archaeological or human event of interest; can ^{14}C provide the age information required; and, finally, does the material for which the ^{14}C event has been identified meet the requirements for a conventional ^{14}C age ?

Such questions can be translated to issues "in the field" and "in the laboratory". In the field, the most important issues are association and / or stratigraphy, contamination, preservation, sample selection. In the laboratory, quality amounts to control of standards, background, corrections for fractionation, calibration, precision, comparability and intercomparison.

The intercomparison issue was part of the FIRI program. The FIRI (Fourth International Radiocarbon Intercomparison) was performed with the following aims:

- evaluation of the comparability of routine analysis of both AMS and conventional ^{14}C laboratories;
- quantification of the extent and sources for any variation;
- investigation of the effects of sample size, precision, and pretreatment on the results. The results are reported by Boaretto et al., 2003 and Scott, 2003.

Samples to be dated by AMS need to be treated with particular caution, since the smaller the sample the greater the effect of any contaminant present (Lanting and van der Plicht, 1993/94). Contamination of samples with older or younger material can occur in the field and/or while taking and handling the samples in the laboratory.

This has consequences for the strategy for choice of ^{14}C dating method - “AMS versus Conventional” . The specific advantages of AMS are clearly demonstrated. But if sufficient material is available, samples can be more cheaply and at least as accurately be dated by conventional means. The possibility of disappointment in the form of an unexpected date is great when isolated small fragments of charcoal are used, and certainly if these have not been found in a clearly defined feature or in close association.

In addition, high precision measurements ($\leq$ 2 ‰ precision) are thus far only demonstrated by conventional methods, using large (also by conventional standards) amounts of material.

An example of a state-of-the-art application of ^{14}C dating to archaeology is shown by Bruins et al. (2003), employing both conventional and AMS techniques. Well suited datable material was selected (short lived grains) in well stratified contexts. Large quantities of single year material were available for high precision conventional dating; smaller samples had to be dated by AMS but this was done in multiple measurements in order to increase precision.

RESULTS

The Groningen ^{14}C datelist

In Table 1, ^{14}C dates measured by both Groningen laboratories (conventional: GrN and AMS: GrA) connected with the “Scythian projects” are listed. Reported are the measured ^{14}C dates in BP, stable isotope ratios δ^{13}C in ‰, and the Carbon content (in %). The latter (δ^{13}C and %C) are indicators for quality of the sample material.

Table 1. List of the ^{14}C dates of the Scythian monuments measured by the Groningen Laboratory

lab nr.	site	material	^{14}C age, BP±1σ	pre-treatment	δ^{13}C ‰	content C %	calBC, 1σ range
GrA-21532	Arzhan-2, grave 13a	cloth	2240±45	AAA	-19.79	40.7	380-350, 315-205
GrA-21533	Arzhan-2, grave 13a	fur	2555±45	AAA	-19.95	44.1	800-760, 680-560
GrA-21534	Arzhan-2, grave 13b	leather	2330±45	AAA	-17.47	42.7	480-470, 410-360, 275-235
GrA-21341	Arzhan-2, grave 13b	felt	3010±70	AAA	-24.98	1.3	1375-1130
GrA-21526	Arzhan-2, grave 16	grass	2100±60	AAA	-24.50	18.8	200-45
GrA-21527	Arzhan-2, grave 20	deposit	2500±50	AAA	-26.44	12.1	785-755, 720-520
GrA-18910	Arzhan-2, grave 5	grain	2520±40	AAA	n/a	n/a	790-760, 685-545
GrA-18931	Arzhan-2, grave 5	grain	2465±40	AAA	-27.30	44.7	760-415

GrA-18948	Arzhan-2, grave 5	grain, *duplo*	2485±40	AAA	-27.01	46.0	765-520
GrA-18932	Arzhan-2, grave 5	leather	2565±40	AAA	-20.75	41.6	800-760, 680-665, 615-565
GrA-18962	Arzhan-2, grave 5	leather *duplo*	2520±45	AAA	-20.90	39.3	790-755, 685-545
GrA-18920	Arzhan-2, grave 5	textile	2540±45	AAA	-20.17	40.8	795-760, 685-545
GrA-18939	Arzhan-2, grave 5	textile *duplo*	2455±45	alkali fraction	-21.57	39.3	760-640, 590-410
GrA-18938	Arzhan-2, grave 5	soil	2535±45	AAA	-26.50	43.9	795-760, 685-545
GrA-18935	Arzhan-2, grave 5	wood	2470±40	AAA	-27.86	62.9	760-515, 460-415
GrA-18949	Arzhan-2, grave 5	grain	2565±40	AAA	-9.66	40.1	800-760, 680-665, 615-565
GrA-18928	Arzhan-2, grave 5	bone	2590±80	none	-26.40	0.9	835-755, 685-540
GrA-18941	Arzhan-2, grave 5	bone *duplo*	1940±50	A	-22.73	0.2	5-125 calAD
GrA-19036	Arzhan-2, grave 5	char-coal	2740±45	AAA	-23.95	39.6	915-830
GrA-19216	Arzhan-2, grave 5	cord	2515±45	AAA	-20.59	43.2	790-755, 685-540
GrA-19219	Arzhan-2, grave 5	grains	2480±45	AAA	-23.48	3.0	760-520
GrA-19028	Arzhan-2, grave 5	leather	2605±45	none	-21.24	39.5	825-765
GrA-19029	Arzhan-2, grave 5	leather *duplo*	2570±45	AAA	-20.46	44.9	805-760, 680-665, 630-565
GrA-19025	Arzhan-2, grave 2	wood	2475±45	none	-23.22	41.9	760-520, 460-455
GrA-19026	Arzhan-2, grave 2	wood *duplo*	2490±45	AAA	-23.22	46.1	765-520
GrA-19220	Novozavedennoe-II, grave 7	wood	2615±45	AAA	n/a	n/a	830-770
GrA-19221	Novozavedennoe-II, grave 16	wood	2410±45	AAA	n/a	n/a	755-720, 540-405
GrA-10203	Chertom-lyk	wood (arrow point)	2320±50	AAA	-23.87	42.5	410-355, 285-215
GrA-10204	Chertom-lyk	wood (arrow point)	2350±50	AAA	-24.31	40.6	515-365, 270-265
GrA-10059	Chertom-lyk	wood (arrow point)	2180±40	AAA	-22.30	40.7	355-290, 260-175
GrA-10060	Solokha, grave 4	wood	2325±40	AAA	-22.40	41.4	405-365, 270-265
GrA-10159	Solokha, grave 5	wood	2270±50	AAA	-23.10	42.8	395-355, 290-210
GrA-10160	Solokha, grave 6	wood	2350±50	AAA	-23.64	43.3	515-265
GrA-	Oguz,	grass	2170±40	AAA	-29.51	67.0	355-295,

10163	grave 9						255-165
GrA-10164	Pastak, grave 10	wood	2330±50	AAA	-24.44	47.3	495-355, 285-235
GrA-12895	Gumarovo	deposit	2500±70	AAA	-21.94	9.9	785-520
GrA-16829	Gumarovo	leather	2500±50	AAA	-21.41	28.9	785-520
GrA-16831	Temir	wood	2250±50	AAA	-25.54	64.8	385-355, 315-205
GrA-16832	Aksenovka	wood	2660±50	AAA	-24.26	53.5	895-880, 835-795
GrA-16833	Katkovo	bone (horse)	1245±45	Longin	-21.19	42.3	690-860 calAD
GrA-15907	Berel	felt	3870±60	AAA	-25.07	53.9	2460-2285, 2245-2210
GrA-15908	Berel	felt	2170±60	AAA	-20.60	43.8	355-115
GrA-15860	Filippovka	wood (base of gold deer)	2940±50	AAA	-25.02	29.5	1255-1050
GrA-15862	Filippovka	wood (base of gold deer)	2320±50	AAA	-24.33	31.2	410-355, 285-215
GrA-19222	Filippovka	wood (base of gold deer)	2275±45	AAA	n/a	n/a	395-355, 290-210
GrN-22497	Tuekta, T- 15	wood	2454±16	AAA	-24.16	50.7	755-690, 540-515, 460-415
GrN-22504	Tuekta, T- 22	wood	2463±16	AAA	-24.60	51.0	760-685, 660-645, 545-520
GrN-22511	Tuekta, T- 29	wood	2452±15	AAA	-24.63	53.1	755-700, 540-515, 465-415

The $\delta^{13}C$ values in the AMS datelist are measured by the Stable Isotope Mass Spectrometer, online connected to the automatic combustion system (Aerts-Bijma et al., 2001). The AMS ^{14}C dates however are corrected for isotopic fractionation using the $^{13}C/^{12}C$ ratios as measured by the AMS itself; these values are not very precise and not listed in the table.

The chemical pretreatment is in general AAA (Acid-Alkali-Acid) (Mook and Streurman, 1983). The temperatures and duration of the pretreatment varies, depending on matters like the delicacy of the sample material. For bone, the datable fraction is collagen, extracted according to the Longin recipe (Mook and Streurman, 1983).

For Arzhan-2, most dates are acceptable as being “Scythian”. They scatter around 2500 BP with some exceptions. Some more results are available from the laboratories in Tucson (AA) and Uppsala (Ua), with in general similar ^{14}C dates. All together the averaged date is ca. 2515 BP. Unfortunately, this corresponds with the Hallstatt plateau so that the calibrated age range is very large (ca. 800-550 calBC). From the archaeological point of view, the Arzhan-2 monument should date to the 6th-7th century BC.

A peculiar result, not on the ^{14}C date but concerning the stable isotope ^{13}C, is the δ^{13}C value of grains from grave 5 (GrA-18949). The $\delta^{13}C = -9.66$ ‰, measured in duplo; the grains therefore must originate from C4 type plant material, most likely millet (*Panicum miliaceum*). This observation also stresses the importance of correction of ^{14}C dates for isotopic fractionation; when we would not correct, the error in Radiocarbon years would be 240 BP.

There are a few problematic dates, which can readily be seen from the table. The problems arise from the poor quality of the sample material. For example, GrA- 21341 (felt from grave 13b, Arzhan-2) shows a very old date. However the organic carbon content of the sample was very low, too low to consider the date reliable. The material likely consisted mostly of soil components, which is also indicated by the δ^{13}C value.

The bone from Arzhan-2, grave 5 is also not datable according to our quality standards. The organic carbon content is extremely low, and the δ^{13}C value deviating. The bone was very delicate, so it was decided to date without any pretreatment (GrA-18928). The resulting ^{14}C date does look reasonable; however, a duplicate analysis with partly preatreatment (A only; GrA-18941) makes the bone too young.

For a sample of grains (Arzhan-2, grave 5), the carbon content is also much too low (GrA-19219). Nevertheless, both the ^{14}C date and the δ^{13}C value are as expected; apparently the pretreatment, removing contaminants, was effective for this material.

Textile is often a difficult material to date what can be caused by various contaminations by penetrated preservatives. In addition, the dated organic material may not be homogeneously distributed in the textile as well. An example of a textile date that does yield a good result, is from Arzhan-2 grave 5. The AAA treated sample (GrA-18920) yields a reasonable good ^{14}C date; the alkaline fraction of the same material (GrA-18939) gives the same date, within error.

A peculiar observation is the relatively young date for the grass sample GrA-21526. The grass was found in the mouth of one of the horses from the collective horse grave no.16. A preliminary date on bone from one of the horses (measured in St. Petersburg) also is young. This will be investigated in more detail in the near future.

The calibrated ages in the table are reported in calBC. They are calculated by the Groningen calibration program (van der Plicht, 1993) using the intcal98 dataset (Stuiver et al., 1998), and are rounded off to the nearest 5 years.

A more complete datelist (including measurements by other laboratories: Russian conventional, and Tucson, AA plus Uppsala, Ua for AMS) can be found in Alekseev et al. (2001, 2002).

THE 1ST MILLENIUM BC

During the 1st millennium BC, the radiocarbon calibration curve shows a large “plateau” between 800 and 400 calBC, the Hallstatt plateau (fig.2a). Unfortunatly, this coincides for a large part with the Scythian epoch. The Scythian archaeological chronology (Alekseev, 2001) is based on typological dating of artifacts, dating of imported Greek ceramic and amphorae, historical-biographical writings, and stratigraphy. The following periods are recognised:

1st period: 9th – 7th century, pre-Scythian & initial Scythian epoch;
2nd period: 7th – 6th century, Early Scythian epoch;
3rd period: 5th – 4th century, Classical Scythian epoch.

Isolated ^{14}C dates – even when measured with high precision – around 2500 BP do not provide accurate historical information. On the other hand, dates which fall on the steep slopes on either side of the plateau can be calibrated very accurately.

An example of the latter is the ^{14}C dating of Solokha (Alekseev, 2002).

The classical Scythian royal tomb Solokha is one of the greatest Scythian barrows in the Northen Black Sea region. The tomb construction occurred during a rather short period of time. According to achaeological data, this barrow dates to 400-375 BC. Eleven ^{14}C dates are available by two laboratories - 3 AMS dates (Groningen, GrA) and 8 conventional dates (Kiev, Ki). Most samples were wood from a sword, but also grass rope and leather has been dated (see datelist). All the dates show very good overlapping results, averaging to 2333 ± 15 BP. This calibrates to 400-395 calBC (1σ) and 405-390 calBC (2σ), which is in excellent agreement with archaeological reasoning. In terms of calibration, this can be considered “good luck”: the ^{14}C date (averaged, a high precision result) calibrates very accurately because it falls on the steep slope of the calibration curve, directly following the Hallstatt plateau.

An example which can be considered as “bad luck” is the ^{14}C dating of the Tuekta monument. The Tuekta monument is located in the Altai region of Southern Siberia.Wood from the barrow has been dated by conventional means in St.Petersburg (Le) and Groningen (GrN), the latter with high precision. A representative result is 2460 ± 15 BP, exactly on the Hallstatt plateau. Calibration of such a date, whether measured with high precision or not, will always result in a calibrated age range between 760 and 400 calBC, almost 4 centuries long – see Fig.3.

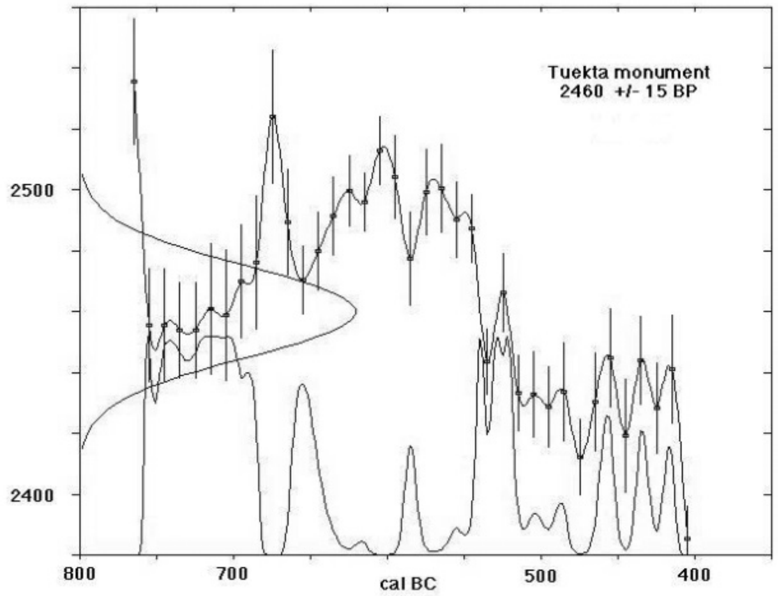

Figure 3. Calibration at the Hallstatt plateau: 2460 ± 15 BP.
The graph shows the calibration curve (spline function through the data), the Gaussian probability distribution corresponding to the ^{14}C age 2460 ± 15 BP along the vertical axis, and the calibrated calendar age probability distribution along the horizontal axis.

Nevertheless, techniques like Wiggle Matching can enhance the application of ^{14}C dating during this era, as will be discussed below.

Wiggle Matching: archaeology

The wiggles which complicate calibration of a ^{14}C date, can be used to our advantage by considering a series of ^{14}C dates from an organic sample that has accumulated through time. For example, a series of ^{14}C dates whose real spacing in time is known, such as dates for every nth annual ring of an (undated) piece of wood. Such a series of ^{14}C dates constitutes a short section of the calibration curve, and can be matched against the full calibration curve. Depending on the characteristics of the wiggles in the calibration curve at the appropriate interval, a series of ^{14}C dates can be matched to within a few years on the calendar axis (see e.g. van der Plicht et al., 1995; van der Plicht and McCormac, 1995).
Wood samples can be used in a straightforward way for wiggle matching, because they show a constant growth (1 annual ring per calendar year).

A first attempt to apply WMD for Scythian chronology is the Tuekta monument. We dated wood from tree D24 from the barrow Tuekta-1. This tree constituted 30 rings. Only 3 contained sufficient wood (≈ 20 gram or more) for the large Groningen counter – ring numbers 15, 22 and 29 (see datelist). The samples are dated around 2460 BP with a precision (1σ) of 15-16 BP. As will be obvious from fig.3, even WMD for this dataset results in a large calibrated age range of almost 4 centuries.

However, using these dates in a special statistical model does provide a match with the calibration curve, within a certain error. Floating trees were dated in St.Petersburg (Le) for Tuekta-1 and other Scythian barrows, Arzhan-1 (Tuva, Central Asia) and Pazyryk (Altai region, Southern Siberia). A total of 11 dates (including the 3 high precision GrN dates) for Tuekta, combined with 8 dates from Arzhan and 10 from Pazyryk together provide a most likely chronology (Zaitseva et al. 1998): Arzhan-1: ca. 810 calBC, in accordance with archaeology; Tuekta-1: ca. 655 calBC, about 1 century older than previously believed; and Pazyryk: ca. 380 calBC, in accordance with archaeology.

Wiggle Match Dating: the environment

Apart from wood samples where WMD is relatively straightforward (growth = 1 ring per calendar year), the technique can also be used with peat deposits of which the deposition rate can be estimated (van Geel and Mook, 1989). In this case, the "growth" is the peat accumulation rate (in cm per calendar year). The "floating" stratigraphic depth series of peat chronology AMS dates can not only be moved along the calendar axis (such as with treerings), but also stretched or compressed to match the wiggles in the calibration curve. The stretching and compressing corresponds to higher and lower peat accumulation rates, respectively. The simulated peat accumulation rate will apply to the complete series of dates with the assumption that these rates have remained constant over the dated depth interval. Wiggle Match Dating (WMD) on peat requires ^{14}C dating by AMS because selected plant materials (pollen or macrofossils) need to be used (e.g. Kilian et al., 2000; Speranza et al., 2000; Blaauw et al., 2003; Mauquoy et al., 2004).

In a study of AMS - WMD of selected macrofossils from organic deposits at ca. 850 calBC (the SubBoreal - SubAtlantic climatic transition), van Geel et al. (1998) found based on palaeoecological, archaeological and geological evidence, the following phenomena:

i) in European raised bog deposits, the changing spectrum of peat forming mosses indicate a sudden change from relatively dry and warm to cool, moist climate;

ii) there was a fast and considerable rise of the groundwater table so that peat growth started in areas that were already marginal from a hydrological point of view;

iii) the rise of the groundwater table in low lying areas of the Netherlands resulted in the abandonment of settlement sites;

iv) the contemporaneous earliest human colonization of newly emerged marshes (starting living on mounds).

Later, WMD on peat deposits showed similar phenomena during the Little Ice Age (LIA) (Mauquoy et al, 2002) and the PreBoreal Oscillation (PBO). The LIA is of particular interest because of the absence of sunspots during the Maunder minimum; the PBO era is linked with ice cores ($\delta^{18}O$ climate proxy) and another cosmogenic isotope (solar activity proxy) ^{10}Be (van der Plicht et al., 2004).

In general, WMD of peat deposits show important teleconnections between climate cooling (more wet plant species), migrations, an increase in the cosmic ray flux (^{14}C and ^{10}Be), and reduced solar activity.

In central South Siberia, an acceleration of cultural development and population density of nomadic people took place after 850 BC. Van Geel et al (this conference) hypothesize that this is connected with an abrupt climatic shift towards increased humidity, after a decline in solar activity; newly available steppe areas allowed the expansion of horse-riding Scythian cultures, a stimulus for migration in western direction towards Europe.

Climate models are shifting now from a "less oceanocentric" orientation to allow solar forcing scenarios (Kirkby, 2001; Magny, 1993).

The ^{14}C excursions during the LIA, around 850 calBC, etc are part of the so-called Millennial Scale Oscillations, observed throughout the whole Holocene. The strongest evidence for solar forcing of climate change to date is observed by Bond et al. (2001). The North Atlantic climate (as observed in IRD, Ice Rafted Debris which is a cooling proxy) has warmed and cooled several times in the last 12000 years in step with waxing and waning of the sun (as observed in both cosmogenic isotope fluxes, ^{14}C and ^{10}Be). This is shown in fig.4.

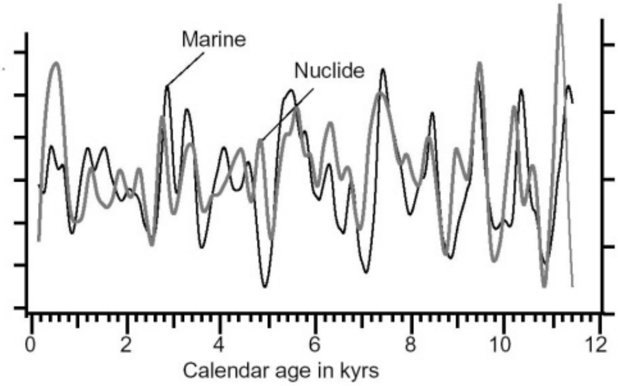

Figure 4. Synchroneity of fluctuations in Ice Rafted Debris and ^{14}C, suggesting that a varying sun can cause millennial climate change.

Apparently, the deep water formation does oscillate, but the timing is influenced by the inconstant sun (Kerr, 2001).

CONCLUSIONS

Methodological problems concerning the chronology of Eurasian Scythian cultures rely for a large part on scientific methods such as good quality ^{14}C dating.

A ^{14}C date (despite inherent limitations) does provide a universal physical measurement of time, independent of cultural-historical viewpoints and associative reasoning. Such information is of irreplacable value as both an independent and unifying data set in a variety of disciplines (like archaeology and environmental sciences).

Radiocarbon dates need to be calibrated in order to obtain historical (calendar) ages. Accurate decadal calibration curves are available for this purpose.

Unfortunately, the Scythian era coincides with a large "plateau" in the calibration curve between ca. 800 and 400 BC. Therefore, the best that ^{14}C has to offer needs to be applied in order to obtain useful chronological information.

Modern techniques like Wiggle Match Dating, statistical models, high precision (i.e. $\leq$ 2‰) conventional measurements, AMS analysis of small unique sample material, and quality control issues enable a better understanding of the origin, migration and disappearance of the Scythian cultures in Eurasia.

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Chapter 6

THE OCCUPATION HISTORY OF THE SOUTHERN EURASIA STEPPE DURING THE HOLOCENE: CHRONOLOGY, THE CALIBRATION CURVE AND METHODOLOGICAL PROBLEMS OF THE SCYTHIAN CHRONOLOGY

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ABSTRACT

This article is devoted to the chronology of the occupation of the Southern steppe regions of Eurasia during the Holocene based on radiocarbon data. The steppe regions of the European and Asian steppe are compared. The main attention is given to the southern Siberia and Central Asia regions. These areas are typical inner regions not influenced by the Arctic and Atlantic Oceans. These locations and their environment impact on the development of ancient populations. On the contrary, for the European steppe the occupation of these regions in the Holocene began only in the Eneolithic epoch when the first ancient nomads penetrated from other territories and the more intensive occupation was seen during the Scythian time. Such phenomenon can be connected to the environmental changes which made the territories very attractive for a nomadic economy. The character of the calibration curve confirms the abruptness of the environment changes about 4600 BP and 2600 BP.

KEYWORDS: Eurasian steppe, Neolithic, Mesolithic, Bronze age, Scythian time, chronology, environment changes, calibration curve

INTRODUCTION

Chronological research plays an important role in reconstruction of cultural developments in the past. Chronology helps to solve questions about the origin, cultural connections, and the direction of migrations of ancient cultures. The database of ^{14}C dates of archaeological sites, built up at the

E.M. Scott et al. (eds.), Impact of the Environment on Human Migration in Eurasia, 63-82.

Institute for the History of Material Culture, consists of more than 7000 age determinations, which can be used for chronological comparisons and to study the chronologies of occupation histories.

We focus on the southern regions of the Eurasian steppe and forest-steppe zones because these regions were settled practically uninterrupted since the Palaeolithic. We study the steppe area of southern Eurasia, located between 48^0-55^0 N and 26^0-110^0 E. At present the landscape of the vast Eurasian steppe has an irregular character. The European part is a practically continuous steppe belt of varying width, but the Asian steppe territory is represented by steppe islands, forest-steppes, semi-deserts, the foothills of Kazakhstan, the southern Ural region, Western Siberia, Altai, Tuva (Uyuk hollow), and the Minusinsk hollow in southern Siberia.

Each geographical region has its own characteristics, but they have in common that they once were occupied by ancient populations. The European and Asian territories have different environmental conditions. In the European part there is still some influence of the Atlantic Ocean, while some Asian steppe regions are more isolated territories because the Altai-Sayan mountain ridges form a barrier for moist air masses from the Atlantic Ocean. We compared the Eurasian steppe and forest-steppe territories during the Holocene to determine the analogies and differences in their occupation by different cultures. Special attention in the present study has been given to the Minusinsk and Uyuk valleys, located between 52-56 N^0 and 89-95 E^0 (Fig.1).

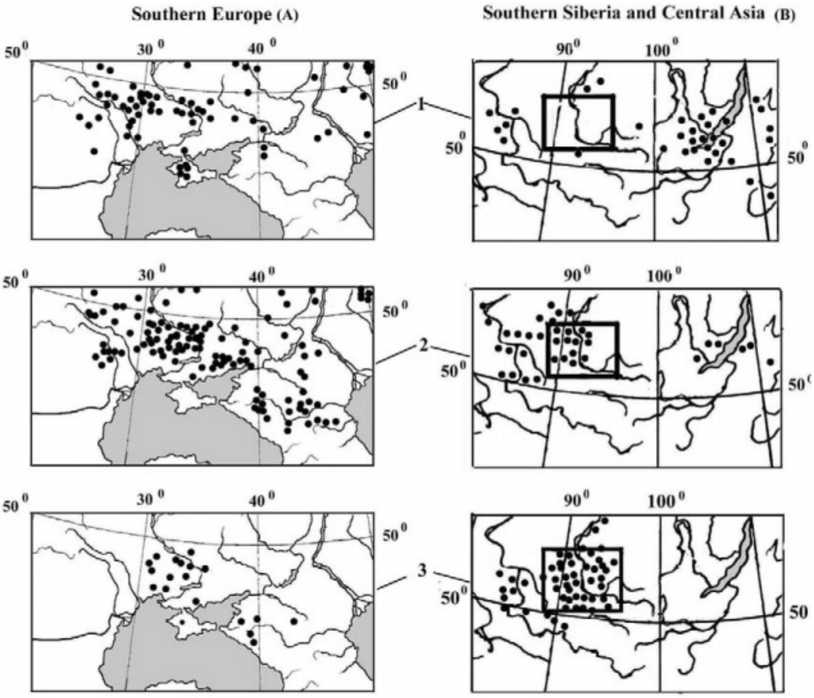

Figure 1. Map of the spreading of the archaeological sites dated by 14C method.
A- Southern European part, B- Southern Siberia and Asian part
1-Mesolithic and Neolithic, 2- Bronze Age, 3- Scythian time

These isolated mountain depressions in Southern Siberia and Central Asia form part of the Eurasian steppe belt. They are relatively flat with valleys of the rivers Yenisey, Abakan, Chulyma and others. Hollows are covered by forest.

The Tuva Republic is located in the center of Asia, to the north of western Mongolia. The environmental conditions in Tuva differ from the neighboring Krasnoyarsk district and Transbaikal territory. The actual differences are also reflected in the prehistoric occupation of the territory.

In this chapter the main focus will be on characteristics of the occupation of the different Eurasian territories, on comparisons of the occupation in different periods and the possible connections between the spread of different ancient cultures and environmental changes.

THE CHRONOLOGY OF HOLOCENE SITES IN EURASIAN SOUTHERN REGIONS

Mesolithic and Neolithic

It is necessary to note here that the Mesolithic and Neolithic periods are better elaborated for the forest zones of Eurasia than for the steppe zones (Timofeev et al., 1998; Zaitseva et al., 1998a and b; Dolukhanov, 2003). Our investigation is based on sites with radiocarbon dates. As most of the key sites were ^{14}C dated, one can assume that the dataset gives a representative picture of the occupation history. The ^{14}C dates for the Mesolithic-Neolithic sites of the Eurasian steppe are presented in Table 1. The distribution map of these sites is shown in Fig.1 (1) for European (A) and Asian (B) parts.

It is remarkable that there are only very few Mesolithic and Neolithic sites in the Khakassia and Tuva regions, in spite of the long history of archaeological investigations in these regions. Only towards the end of the Neolithic did population begin to develop in the steppe depressions of the Yenisey River Basin. Isolated Neolithic finds have been discovered near the steppe lakes of Khakassia (Lisitsyn, 1988). Some remarkable Neolithic finds were discovered in Tuva. The earliest Neolithic site in Tuva is the Ust'Khemchik –3 site, dated by ^{14}C to 6500 ± 110 BP (Le-1014) (Astakhov and Vasiliev 200l). Recently some Mesolithic-Neolithic sites were found in caves in Tuva (V. Semenov, oral information). The Neolithic layers were found on the multilayer Palaeolithic site Maina, located in the South of the Krasnoyarsk district, near the border with Khakassia. Major developments of the Mesolithic-Neolithic cultures of Khakasia and Tuva are discussed below. Usually Neolithic cultures originate from local Mesolithic populations. The low amount of Mesolithic-Neolithic sites in the Khakassia and Tuva regions might be related to adverse (too dry) environmental conditions (van Geel et al., this volume). The economy of the Mesolithic-Neolithic population was partly based on hunting and fishing. Probably, the climatic conditions of these regions did not allow further development of this economy. With the present state of knowledge it is rather difficult to discuss and to compare the character of the environmental conditions of European and Asian territories during this time. Palaeo-environmental studies of the southern Asian regions (Khakassia and Tuva) only started recently and future results may help to explain the occupation history.

Table 1. The Neolithic and Mesolithic sites of the Eurasian southern regions dated by ^{14}C method

No.	Lab. index	14C age, BP	Site	Co-ordinates		Intervals of calibrated age, cal BC	
				NL	EL	1σ	2σ
MESOLITHIC							
EUROPE							
1.	Ki-6267	8750±55	Buran-Kaya	45.01	34.41	7950-7650	8000-7600
2.	Ki-6267a	11460±70	Buran-Kaya	45.01	34.41	11550-11230	11900-11200
3.	Ki5823	10210±80	Shpan-Koba	44.31	33.50	10200-9700	10700-9300
4.	Ki-5821	7600±45	Shpan-Koba	44.31	33.50	6464-6415	6570-6380
5.	Le-1417	5250±70	Storunya-1	48.50	33.50	4230-3970	4260-3940
6.	Ki-6257	6930±50	Igren-8	48.24	34.36	5840-5730	5920-5710
7.	Ki-956	9290±110	Igren-8	48.24	34.36	8690-8320	8800-8250
8.	Ki-638	7620±230	Laspi-7	44.25	33.44	6750-6100	7100-6000
9.	Ki-951	9100±130	Laspi-7	44.25	33.44	8550-8000	8750-7800
10.	Le-1703	7050±60	Girzhevo	46.41	30.10	5990-5840	6030-5770
11.	Le-1648	7200±80	Mirnoe	45.38	29.32	6210-5920	6230-5890
12.	Bln-1799	7285±70	Kukrek	44.59	33.55	6220-6070	6260-5990
13.	Ki-6340	7450±380	Mys Troizy	44.23	33.57	6700-5800	7400-5500
14.	Ki-6261	7875±50	Ryzhy ostrov	50.38	29.44	6980-6640	7040-6590
15.	Ki-5222	9600±50	Vyazivok-4	49.57	32.56	9170-8810	9220-8790
16.	Ki-6263	9580±70	Senchizy-5	51.53	25.50	9150-8800	9220-8790
17.	Ki-6264	9680±80	Vishennoe-1	48.08	34.36	9250-8840	9280-8790
18.	Le-4981	7950±140	Satanay	44.19	40.39	7060-6660	7300-6450
19.	GIN-57	10590± 230	Molodovo-5	48.35	27.05	11000-10150	11200-9700
20.	GIN-7088	8470±100	Lebyazhinka-4	53.31	50.24	7600-7350	7750-7150
21.	Ki-6262	11200±70	Krug	45.01	34.41	11400-11060	11850-10950
URAL and SIBERIA							
22.	Le-1753	8910±60	Kulevchi-1	53.25	60.57	8220-7960	8270-7830
23.	BashGi-76	9620±20	Kholodny Kluch	53.48	55.06	9170-8850	9270-8810
24.	SOAN-2990	7340±175	Kornachak-2	53.48	84.52	6390-6020	6500-5800
25.	Le-1226	8485±240	Kazachka	56.07	95.51	7950-7100	8300-6800
26.	SOAN-2947	9250±180	Eleneva cave	55.56	92.29	8740-8260	9200-7900
27.	SOAN-2948	10485±310	Eleneva cave	55.56	92.29	11000-9800	11100-9300
28.	SOAN-3171	8720±210	Ityrkhey	53.00	106.52	8200-7550	8300-7200
29.	SOAN-1647	10580±155	Studenoe	50.15	108.37	10950-10350	11100-10000
30.	SOAN-3337	9360±95	Sagan-Nuge	53.08	107.12	8790-8450	9150-8250
31.	SOAN-3340	8280±150	Berloga	53.02	106.50	7520-7080	7600-6800
32.	Le-2405	8640±80	Ust-Menza-	50.15	108.37	7760-7580	7950-7540

			1				
33.	Le-1951	8980±90	Nizhnjya Dzhilinda	52.26	116.52	8280-7970	8450-7800
34.	SOAN-3035	9500±470	Mukhino	52.50	111.00	9700-8200	10400-7500
35.	Le-2403	11670±100	Altan	42.29	111.32	11880-11510	13100-11200
36.	SOAN-2990	7340±175	Kornachak-2	53.48	84.52	6390-6020	6500-5800
NEOLITHIC							
EUROPE							
37.	Ki-6686	6200±55	Babshin	48.28	26.34	5260-5060	5300-4990
38.	Ki-6652	7160±55	Bazkov ostrov	48.05	28.28	6160-5920	6170-5890
39.	Ki-6651	7235±60	Bazkov ostrov	48.05	28.28	6210-6010	6230-5990
40.	Le-3594	5110±60	Bernashovka	48.33	27.30	3970-3800	4040-3760
41.	Le-3799	6880±100	Bernashovka	48.33	27.30	5850-5660	5990-5660
42.	Ki-648	3600±90	Besez-2	53.25	33.54	2130-1770	2200-1650
43.	Lu-2620	6090±160	Varfolomeev-skaya	50.00	48.11	5230-4800	5500-4600
44.	GIN-6546	6980±200	Varfolomeev-skaya	50.00	48.11	6030-5660	6250-5450
45.	Ki-6776	6220±60	Vasilievka-5	45.25	29.30	5300-5070	5320-4990
46.	Ki-6773	6675±65	Vasilievka-5	45.25	29.30	5660-5520	5710-5480
47.	Ki-6677	6180±60	Voronoviza	49.07	28.42	5260-5040	5300-4950
48.	Le-640	5300±60	Vulkaneshty-2	45.42	28.25	4230-4000	4230-3980
49.	Ki-6687	6640±50	Gard-3	47.42	31.12	5625-3325	5640-5480
50.	Ki-6655	6930±55	Gard-3	47.42	31.12	5850-5730	5980-5710
51.	Ki-6683	5860±45	Grenovka	48.08	30.31	4790-4620	4850-4590
53.	GIN-9042	5010±50	Gundorovka	53.25	50.09	3940-3700	3950-3660
53.	GIN-9039	5130±50	Gundorovka	53.25	50.09	3990-3800	4040-3790
54.	Ki-6778	6145±55	Derievka	48.55	33.46	5210-4960	5280-4850
55.	OxA-6161	7270±110	Derievka	48.55	33.46	6230-6010	6390-5910
56.	Le-2564	6100±70	Dzhangar	47.39	45.46	5210-4850	5260-4800
57.	Ki-6694	7540±65	Zankovzy	48.35	29.18	6460-6260	6470-6230
58.	Ki-521	4450±120	Zaporozhje	47.56	35.07	3340-2920	3550-2850
59.	Ki-635	6710±150	Igren-8	48.24	34.36	5730-5480	5900-5350
60.	Ki-406	3690±95	Iljichevka	49.20	30.24	2210-1920	2450-1750
61.	GIN-6226	6000±150	Kombak-te	46.58	47.44	5210-4710	5300-4500
62.	Ki-6675	6270±55	Korman	48.34	27.14	5320-5080	5370-5060
63.	Le-3195	3410±30	Kryniza	51.19	26.27	1750-1640	1870-1610
64.	GIN-7248	6660±50	Lebyazhinka-3	53.31	50.24	5720-5470	5850-5300
65.	GIN-7088	8470±100	Lebyazhinka-4	53.31	50.24	7600-7350	7750-7150
66.	Le-3743	5310±110	Lipezkoe ozero	53.25	39.41	4320-3990	4400-3800
67.	Ki-6684	5905±60	Luka Vrublezkaya	48.33	26.39	4850-4710	4940-4610
68.	Ki-6672	5905±60	Majdanezkoe-2	48.48	30.41	4850-4710	4940-4610
69.	Ki-6779	7550±80	Marievka	48.21	35.18	6470-6250	6570-6220
70.	Le-1217	7180±70	Matveev kurgan	47.32	38.35	6160-5920	6220-5890
71.	Le-882	5400±200	Matveev kurgan	47.32	38.35	4450-3980	4700-3750
72.	Le-3052	6940±300	Medinovo	51.34	45.57	6200-5500	6500-5300

73.	Ki-101	4620±120	Nikolskoe	47.34	33.05	3650-3100	3650-2900
74.	Ki-6603	6160±70	Nikolskoe	47.34	33.05	5230-4990	5300-4850
75.	Ki-6647	6690±55	Okopy	49.58	26.32	5670-5530	5720-5480
76.	OxA-6168	7675±70	Osipovka	49.56	30.24	6590-6440	6650-6410
77.	Ki-6604	7545±80	Osipovski Liman	48.52	34.55	6460-6250	6510-6220
78.	Ki-6692	7260±65	Pechera	48.56	28.42	6220-6020	6230-5990
79.	Ki-6693	7305±50	Pechera	48.56	28.42	6220-6080	6240-6020
80.	Le-725	4770±60	Podzorovo	52.52	40.17	3650-3380	3660-3370
81.	Le-5325	5150±400	Pugach-2	47.51	31.14	4500-3500	4900-2900
82.	Ki-6656	6895±50	Pugach-2	47.51	31.14	5840-5720	5880-5660
83.	Le-5428	4180±100	Rakushechny Yar	47.33	40.40	2890-2620	3050-2450
84.	Ki-6476	7930±140	Rakushechny Yar	47.33	40.40	7040-6650	7300-6450
85.	Ki-6680	6075±60	Sabatinovka-2	48.09	30.11	5060-4850	5210-4790
86.	Ki-6737	6100±55	Sabatinovka-2	48.09	30.11	5210-4850	5210-4840
87.	Ki-6654	6985±60	Savran	48.07	30.01	5980-5790	5990-5730
88.	IGAN-726	7460±200	Samsonovskoe	43.40	40.45	6480-6070	6750-5840
89.	Ki-6689	7125±60	Semenovka	46.17	30.08	6060-5910	6160-5840
90.	Ki-6695	7375±60	Skibnizy	48.34	29.21	6380-6090	6390-6070
91.	Ki-6697	7470±60	Sokolzy-2	48.43	29.07	6400-6250	6440-6220
92.	Ki-6691	7245±60	Surskoi ostrov	48.19	35.04	6210-6020	6230-5990
93.	GIN-6177	5500±150	Tentek-sor	46.31	48.28	4500-4050	4700-3950
94.	Le-1013	5080±125	Universitetskay	51.39	39.13	3980-3710	4250-3600
95.	AA-12571	6200±85	Khvalynsk-1	52.31	48.03	5300-5040	5340-4850
96.	Ki-2180	7140±150	Khvalynsk-1	52.31	48.03	6210-5840	6400-5700
97.	GrN-7197	4430±60	Zariza	49.13	42.29	3310-2970	3340-2910
98.	Le-4784	7940±140	Chekalino-4	53.53	50.56	7050-6650	7300-6450
99.	Le-4781	8990±100	Chekalino-4	53.53	50.56	8290-7960	8450-7750
100	Le-1987	5710±60	Cherkasskoe	50.55	39.48	4670-4460	4720-4390
101	Ki-201	4320±170	Shkarovka	49.44	30.09	3350-2690	3500-2400
102	Ki-6790	5860±75	Yasinovatka	48.49	32.03	4840-4610	4910-4520
103	OxA-6163	6455±60	Yasinovatka	48.49	32.03	5480-5360	5520-5300
URAL and SIBERIA							
104	IGAN-218	7400±130	Berezki	52.54	59.30	6400-6090	6470-6000
105	SOAN-2498	5635±70	Kaminnaya cave	52.16	84.49	4540-4360	4680-4340
106	SOAN-2315	6620±600	Kaminnaya cave	52.16	84.49	6200-4800	6800-4000
107	Le-1796	5440±60	Kara-Tenesh	51.02	86.17	4350-4220	4450-4040
108	SOAN-2927	5050+45	Nizhnetytkes-ken	53.08	85.32	3950-3790	3960-3710
109	SOAN-2926	5440±105	Nizhnetytkes-ken	53.08	85.32	4440-4050	4460-3590
110	SOAN-3169	6525±100	Berloga	53.02	106.50	5310-5050	5500-4850
111	GIN-3330	6780±80	Lokomotiv-10	52.18	109.15	5740-5560	5840-5530
112	GIN-3329	6870±70	Lokomotiv-8	52.18	109.15	5840-5660	5890-5620
113	GIN-3877	4240±50	Semenovo	53.02	103.15	2910-2700	2930-2620

114	GIN-3878	6040±100	Semenovo	53.02	103.15	5060-4790	5300-4700
115	GIN-4070	4190±70	Ulyarba-2	52.57	106.46	2890-2660	2970-2570
116	GIN-4071	4600±100	Ulyarba-3	52.57	106.46	3520-3100	3600-3000
117	GIN-4065	4100±50	Ust-Belaya	52.50	103.31	2860-2500	2880-2490
118	GIN-4126	6760±160	Ust-Belaya	52.50	103.31	5800-5510	6010-5380
119	Le-1014	6500±110	Ust-Khemchik	51.44	91.49	5610-5360	5460-5250
120	GIN-4125	3900±40	Shumilikha	52.55	103.36	2470-2310	2480-2200
121	GIN-4100	6370±60	Shumilikha	52.55	103.36	5470-5300	5480-5260
122	GIN-4128	6350±50	Phophanovo	52.05	106.45	5470-5260	5480-5210
123	GIN-4129	7040±100	Phophanovo	52.05	106.45	6010-5800	6080-5120
124	Le-1414	8640±100	Bukhta Kocherikov	52.22	100.36	7810-7570	8200-7450
125	Le-1923	3250±40	Darasun	51.41	113.56	1610-1570	1630-1420
126	Le-2064	3760±40	Egorkina cave	49.58	107.46	2280-2050	2300-2030
127	SOAN-3341	5680±60	Ityrkhey	53.19	106.52	4600-4400	4690-4360
128	GIN-4049	3640±80	Nizhnee Seredkino	53.19	103.21	2140-1880	2300-1750
129	GIN-3885	4600±100	Nizhnee Seredkino	53.19	103.21	3520-3100	3650-3000
130	Le-1957	6720±80	Nizhnyaya Dzhilinda	52.26	116.52	5720-5550	5740-5480
131	GIN-1611	4590±90	Olkhon	53.08	107.12	3510-3100	3650-3000
132	SOAN-1376	5160±55	Sagan-Zaba	51.12	99.05	4040-3810	4220-3790
133	SOAN-1572	6000±40	Sagan-Zaba	51.12	99.05	4940-4800	5000-4770
134	Le-2782	3630±40	Sagan-Nuge	53.08	107.12	2110-1920	2140-1880
135	Le-2775	3250±40	Ulan-Khada	53.06	106.51	1610-1440	1630-1420
136	Le-2783	6310±70	Ulan-Khada	53.06	106.51	5370-5140	5470-5060
137	SOAN-845	5990±40	Khuzhir	53.13	107.24	4940-4800	4960-4730

Eneolithic - Bronze Age time

The Bronze Age is subdivided into the following periods: Early Bronze Age, Middle Bronze Age and Late Bronze Age (Kushnareva et al, 1994; Matyushin, 1996). In the European part of the steppe zone the local Neolithic-Eneolithic cultures developed into the local Bronze Age culture. However, in Southern Siberia and Central Asia (Minusinsk and Uyuk hollows) the Bronze Age culture came from other regions because Neolithic cultures were almost absent.

For the southern territories of Asia (Khakassia and Tuva) the Bronze Age is subdivided according to the names of the following ancient cultures: Aphanasievo, Okunevo, Andron, Karasuk (Gryaznov 1999; Bokovenko et al.1992. 2000). Here only major developments will be considered. In both the European and Asian regions the Eneolithic and Bronze Age periods are characterized by a significant increase in the number of sites, compared with the preceding periods (see Fig.1 (2) in Table 2). From Fig.1 (2) one can see the differences in the occupation of the European and Asian territories. In the European part the Eneolithic-Bronze Age cultures appeared after the Neolithic. The important phenomenon for the Minusinsk valley in Southern Siberia is the appearance of the Aphanasievo culture which belongs to the Eneolithic or earlier Bronze Age period and is dated to the 4th- 3rd millennium BC. The Aphanasievo culture has no local roots. The nomads came to Southern Siberia from other regions, possibly from Europe (for example, from the Pit Culture in Ukraine). According to the archaeological evidence this culture has some analogies with the Eneolithic cultures of the Caspian-Black Sea steppes (Teploukhov 1929; Vadetskaya, 1979). According to Bokovenko (2000) the Aphanasievo population came from the Caspian Sea region and from the foothills of Pamir and Tien-Shan mountains. But it is still an enigma from where the Aphanasievo culture population arrived in the Minusinsk valley. The subsequent Bronze Age culture is the Okunevo culture (Middle Bronze Age). For the Uyuk valley (Tuva) there are only traces of the Okunevo population. This culture is not genetically connected with the Aphanasievo culture because there are significant differences in the burial tradition and the anthropogenic characteristics. Late Bronze Age cultures (Andron, Karasuk) occupied these territories and the amount of sites increased and culminated during the Scythian time (Chlenova 1972).

Table2 The Eneolithic-Bronze Age sites of southern Eurasia.

No.	Lab. index	^{14}C age, BP	Site	Co-ordinates		Intervals of calibrated age, cal BC	
				NL	EL	1σ	2σ
EUROPE							
1.	Le-2324	4340±60	Zhelty Yar	44.50	24.55	3030-2890	3350-2750
2.	Le-5021	4090±80	Ivanie	51.14	26.02	2870-2490	2880-2470
3.	Ki-6745	4530±50	Zhvanez	48.33	26.28	3360-3100	3370-3030
4.	Ki-6751	3960±50	Ziklovizy	48.33	26.30	2570-2350	2580-2300
5.	Le-2165	2800±40	Dnestrovka	48.29	26.49	1000-900	1050-830
6.	Le-2163	3010±40	Dnestrovka	48.29	26.49	1370-1130	1390-1120
7.	Le-3800	5410±60	Bernashovka	48.33	27.30	4340-4160	4360-4040
8.	Ki-6746	4175±50	Sandraki	49.38	28.04	2880-2670	2890-2590
9.	Le-2323	4020±40	Ogorodnoe	44.50	28.18	2580-2470	2840-2460
10.	Le-2636	4950±40	Ogorodnoe	44.50	28.18	3770-3660	3890-3640
11.	Le-2325	3830±40	Kalanchak	45.25	28.19	2400-2200	2460-2140
12.	Le-1060	5100±50	Klischev	49.01	28.30	3970-3800	3990-3770
13.	Ki-6748	4360±55	Troyanov	50.08	28.32	3080-2900	3310-2880
14.	Ki-6750	4430±45	Troyanov	50.08	28.32	3310-2970	3340-2910
15.	Ki-7071	4210±55	Utkonosovka	45.29	28.57	2900-2680	2920-2620
16.	Ki-6752	4495±45	Gorodsk	50.23	29.10	3340-3090	3360-3020
17.	GrN-5099	4651±35	Gorodsk	50.23	29.10	3510-3360	3520-3350
18.	Ki-1439	3800±120	Vishnevoe	45.47	29.15	2460-2040	2600-1850
19.	Ki-7085	4180±60	Novoselovka	45.40	29.16	2880-2660	2900-2580
20.	Ki-7086	4235±55	Novoselovka	45.40	29.16	2910-2690	2930-2620
21.	Le-3218	2960±50	Vasilievka	45.25	29.30	1290-1050	1370-1010
22.	Le-856	3920±50	Borisovka	45.25	29.37	2470-2300	2570-2200
23.	Le-2327	4010±40	Mikhailovka	46.00	29.44	2575-2470	2630-2450
24.	Le-1500	3200±40	Dolmatovka	46.06	30.08	1515-1430	1600-1390
25.	Ki-1758	4400±50	Semenovka	46.17	30.08	3100-2920	3330-2900
26.	Ki-520	5045±105	Shkarovka	49.44	30.09	3960-3710	4050-3640
27.	Ki-6564	4060±55	Ordzhenikidze	47.13	30.10	2840-2470	2870-2460
28.	Ki-6572	3560±55	Ordzhenikidz	47.13	30.10	2010-1770	2040-1740

			e				
29.	Ki-5014	4230±80	Zavadovka	51.01	30.13	2920-2670	3020-2570
30.	Ki-5015	4290±90	Zavadovka	51.01	30.13	3090-2690	3350-2550
31.	Le-2326	3410±40	Mayaki	46.25	30.16	1770-1630	1880-1530
32.	Ki-870	4670±110	Mayaki	46.25	30.16	3640-3340	3700-3000
33.	Ki-7091	3920±60	Dobrovody	48.17	30.22	2480-2300	2580-2200
34.	Ki-7092	4040±55	Dobrovody	48.17	30.22	2630-2470	2870-2450
35.	Le-1179	3310±40	Ilichevka	49.20	30.24	1680-1520	1690-1490
36.	Ki-6717	3865±50	Talyanki	48.48	30.33	2460-2230	2470-2190
37.	Ki-6867	4810±55	Talyanki	48.48	30.33	3660-3520	3710-3380
38.	Ki-5038	4280±110	Krasny Khutor	47.16	30.33	3090-2670	3350-2500
39.	Le-2322	3940±40	Nagornoe	49.20	30.40	2550-2340	2570-2300
40.	Ucla-1642	4333±60	Usatovo	46.31	30.40	3020-2880	3350-2700
41.	Ucla-1671	4890±60	Evminka	50.51	30.49	3760-3630	3800-3520
42.	Le-2944	5080±60	Voronovka-2	47.21	30.59	3960-3800	3980-3710
43.	Le-3005	4630±150	Vinogradny Sad	47.45	31.12	3560-3100	3700-2900
44.	Ki-5012	4320±70	Sofievka	49.35	31.28	3080-2870	3850-2650
45.	Le-659	3340±80	Polesie	51.30	31.30	1740-1520	1880-1430
46.	Gd-1008	4000±80	Turinschina	54.44	32.03	2830-2350	2900-2200
47.	Ki-7117	3990±65	Antonovka	47.31	32.04	2620-2350	2900-2250
48.	Le-1508	4630±40	Oblon	46.16	32.09	3500-3350	3530-3340
49.	Le-1506	4250±60	Shirokaya Balka	46.35	32.12	2906-2690	3020-2620
50.	Ki-549	3980±200	Khrostoforovka	47.15	32.13	2900-2200	3100-1900
51.	Ki-4044	4060±60	Palmira	49.45	32.13	2840-2470	2870-2460
52.	Ki-578	4170±170	Khristoforovka	47.15	32.13	2920-2470	3400-2200
53.	Le-2238	3460±50	Zhelezny Port	46.07	32.16	1880-1690	1920-1630
54.	Ki-7100	3970±50	Pridneprovskoe	49.37	32.20	2580-2350	2620-2300
55.	Ki-483	3660±120	Otradnoe	47.44	32.25	2210-1820	2500-1650
56.	Ki-478	3990±100	Otradnoe	47.44	32.25	2850-2300	2900-2200
57.	Ki-803	4180±120	Chernyavschina	46.36	32.25	2900-2580	3100-2400
58.	Ki-6726	3840±50	Golovkovka	48.34	33.03	2400-2200	2470-2140
59.	Ki-6723	4030±60	Golovkovka	48.34	33.03	2660-2460	2900-2350
60.	Ki-6783	3430±80	Nikolskoe	47.34	33.05	1880-1620	1920-1520
61.	Le-1501	3840±60	Mayachka	45.36	33.12	1870-1680	1880-1630
62.	Le-1504	3640±40	Chervony Yar	48.50	33.20	2120-1930	2140-1880
63.	Le-1714	4180±60	Novokievka	46.21	33.20	2880-2660	2900-2580
64.	Le-1499	4420±50	Podokalinovka	46.29	33.37	3260-2920	3190-2910
65.	Ki-524	4170±110	Pervokonstanti-novka	46.16	33.45	2890-2590	3050-2450
66.	Le-1042	4300±50	Belynez	53.27	33.45	3020-2870	3090-2700
67.	Le-2239	3370±40	Pervomaevka	47.21	34.09	1740-1600	1750-1520
68.	Ki-7098	4015±60	Kamenka Dneprovskaya	47.28	34.23	2630-2460	2900-2300
69.	Le-824	3920±50	Dmotrovskiy burial ground	47.35	34.25	2470-2300	2570-2200
70.	Ki-496	3500±150	Briluvata grave	48.45	34.32	2030-1620	2300-1400
71.	Ki-522	4530±130	Briluvata grave	48.45	34.32	3500-3020	3650-2900
72.	Ki-582	3740±15	Verkhnaya	47.48	34.38	2400-1940	2600-1700

		0	Tarasovka				
73.	Le-1180	3980±70	Verkhnaya Tarasovka	47.48	34.38	2580-2350	2900-2200
74.	Ki-7112	4040±65	Minovka	49.30	34.41	2840-2460	2900-2350
75.	Ki-7073	3930±60	Balkov barrow	47.23	34.52	2550-2300	2580-2200
76.	Ki-606	4370±120	Balkov barrow	47.23	34.52	3330-2880	3400-2600
77.	Ki-7111	4190±60	Augustinovka	48.02	35.02	2890-2670	2900-2580
78.	Ki-6733	3945±50	Protopopovka	48.45	35.05	2560-2340	2580-2280
79.	Ki-7072	4360±70	Zaporozhje	47.56	35.07	3090-2890	3340-2870
80.	Le-2714	2820±40	Akimovka	46.42	35.08	1110-830	1220-810
81.	Le-731	2920±80	Krest	50.03	35.18	1260-1000	1380-910
82.	Le-4144	4290±90	Sosnovka	46.52	35.18	3090-2690	3350-2550
83.	Ki-603	4310±105	Pereschepino	49.02	35.19	3300-2700	3350-2600
84.	Ki-4193	4060±90	Zarechnoe	46.47	35.22	2860-2470	2900-2350
85.	Le-1291	3500±110	Voznesenka	46.48	35.29	2010-1680	2150-1500
86.	Ki-3146	4230±55	Vinogradnoe	47.17	35.37	2910-2690	2920-2620
87.	Le-1732	3290±40	Three brothers	45.12	36.20	1620-1515	1690-1450
88.	OxA-4668	3830±70	Anapskaya-1	44.55	37.20	2460-2140	2470-2030
89.	OxA-4728	4885±75	Anapskaya-1	44.55	37.20	3770-3530	3550-3350
90.	Ki-7077	4170±60	Kremenevka	47.19	37.29	2880-2660	2890-2570
91.	Ki-1708	4260±50	Kremenevka	47.19	37.29	2920-2700	3020-2660
92.	Le-3681	3710±50	Novorossijsk	44.40	37.38	2200-1980	2280-1940
93.	Ki-7102	4120±60	Svatovo	49.24	38.07	2870-2570	2880-2490
94.	OxA-4676	4455±75	Priazovskaya-1	45.49	38.36	3340-3010	3350-2920
95.	Le-3117	4020±60	Olenij-1	45.30	38.37	2630-2460	2900-2300
96.	OxA-4708	4160±75	Dneprovskaya-1	45.37	38.46	2880-2620	2900-2490
97.	OxA-4707	4800±80	Dneprovskaya-1	45.37	38.46	3660-3380	3720-3360
98.	Le-4538	5250±75	Yablonevo	44.57	38.54	4230-3970	4330-3940
99.	OxA-4703	4390±90	Bryukhovezkaya-1	45.46	39.00	3310-2890	3350-2880
100.	OxA-4706	4210±80	Proletarskaya-1	45.30	39.16	2900-2660	3050-2450
101.	OxA-4709	4390±80	Baturinskaya-1	45.48	39.18	3270-2900	3340-2880
102.	Le-4961	3350±70	Pshish-1	44.10	39.29	1740-1520	1880-1450
103.	Ki-2809	4180±90	Astakhovo	48.09	39.31	2890-2620	2930-2470
104.	Le-4531	5475±100	Svobodnoe	45.07	39.35	4460-4160	4500-4040
105.	Le-4530	5400±250	Krasnogvardejsk	45.08	39.36	4500-3950	4800-3600
106.	RUL-136	3870±130	Gireeva grave	47.15	39.52	2560-2130	2900-1900
107.	OxA-4466	3220±120	Guam grotto	44.15	39.54	1690-1320	1900-1100
108.	OxA-4471	4905±90	Guam grotto	44.15	39.54	3890-3540	3950-3500
109.	Le-624	3880±90	Novocherkasskaya	47.30	40.00	2470-2200	2650-2000
110.	Le-4648	2995±80	Kurdzhips	44.26	40.01	1380-1120	1430-990
111.	Le-1073	4030±80	Deguanskoe-Dakhovskoe	44.12	40.12	2860-2460	2900-2300
112.	Le-1725	3510±40	Mosolovskoe	51.26	40.23	1890-1740	1940-1690
113.	Le-3583	3650±40	Klady	44.24	40.24	2130-1940	2140-1890
114.	Le-5033	4260±60	Klady	44.24	40.24	2930-2690	3020-2620
115.	Le-3585	3670±22	Starchiki	44.22	40.24	2400-1700	2700-1400

		0					
116.	Le-3569	4410±170	Starchiki	44.22	40.24	3350-2890	3700-2500
117.	Le-5032	4510±40	Novosvobodnoe	44.18	40.25	3350-3100	3360-3040
118.	Le-5988	4840±200	Novosvobodnoe	44.18	40.25	3950-3350	4100-3000
119.	Le-511	3180±80	Kudinov	47.20	40.33	1530-1310	1680-1260
120.	Le-692	3900±60	Ust'-Dzhagutinskaya-3	44.06	41.58	2470-2300	2560-2200
121.	Le-708	3410±50	Il'men barrow	51.30	42.32	1860-1620	1880-1520
122.	Le-2626	2910±40	Nezhinskaya group barrows	43.55	42.41	1210-1010	1260-970
123.	Le-4597	4190±50	Nezhinskaya group barrows	43.55	42.41	2890-2670	2900-2620
124.	Le-1664	3090±40	Veselaya Roscha-3	44.43	42.51	1420-1260	1440-1210
125.	Le-1668	5130±60	Veselaya Roscha-3	44.43	42.51	3990-3800	4050-3770
126.	Le-4823	3200±80	Ternovka	51.20	42.56	1600-1320	1690-1290
127.	Le-1092	3500±40	Kremenskaya	49.28	43.33	1880-1740	1930-1690
128.	Ki-5213	3690±70	Zunda-Tolga	45.37	44.16	2200-1960	2290-1880
129.	IGAN-1639	5083±381	Zunda-Tolga	45.37	44.16	4350-3350	4800-2900
130.	Le-948	3930±90	Elista	46.17	44.17	2570-2280	2700-2100
131.	IGAN-1424	3075±77	Khar-Zukha-2	45.47	44.20	1430-1210	1520-1110
132.	OxA-4732	4480±75	Khar-Zukha-1	45.47	44.20	3340-3030	3370-2920
133.	Le-1463	2880±60	Chogray-8	45.27	44.27	1190-940	1260-890
134.	GIN-5900	3910±40	Ergeni	47.06	44.28	2470-2310	2490-2230
135.	Le-2521	4030±40	Ergeni	47.06	44.28	2620-2420	2840-2460
136.	Le-1094	3980±50	Zaza	48.11	44.40	2580-2400	2630-2300
137.	IGAN-1005	3360±180	Volga-Chograj, Ergeni	45.29	44.44	1890-1440	2200-1100
138.	GIN-5899	3890±40	Volga-Chograj, Ergeni	45.29	44.44	2460-2310	2470-2200
139.	OxA-3779	4980±120	Galyugaj-3	43.40	44.49	3940-3650	4050-3500
140.	Le-6356	4770±110	Meshoko			3650-3370	3800-3100
141.	Le-6341	5300±60	Meshoko			4230-4000	4520-3980
142.	Le-4824	3460±50	Most	51.30	44.50	1880-1690	1920-1630
143.	IGAN-1269	3395±58	Ulan-Zukha-1	46.07	44.58	1860-1600	1880-1520
144.	IGAN-1104	3703±59	Zagan-Nur	47.22	45.13	2200-1970	2290-1910
145.	Le-661	2860±60	Serzhen-Yurt-1	43.07	45.59	1130-930	1260-840
146.	RUL-258	3480±110	Serzhen-Yurt-1	43.07	45.59	1950-1630	2150-1500
147.	Le-4825	3580±50	Yablonovka	51.04	46.01	2030-1780	2120-1740
148.	Le-1055	3450±60	Kurchaloj	43.12	46.02	1880-1680	1930-1600
149.	Le-1064	3640±60	Gagatlinskoe	42.47	46.17	2140-1910	2200-1820
150.	Le-1091	4050±50	Nikol'skoe	47.45	46.24	2830-2470	2860-2460
151.	Le-1059	3690±60	Kafirkumukhski burial ground	42.49	47.10	2200-1970	2280-1880

152.	Le-1065	3500±60	Isheevski barrow	54.14	48.19	1890-1730	1980-1680
153.	OxA-4258	3450±70	Studenzy-1	52.47	49.12	1880-1680	1940-1530
154.	AA-9875B	3525±50	Krivoe lake	53.34	50.30	1920-1750	2010-1690
155.	AA-9874B	3740±50	Krivoe lake	53.34	50.30	2270-2030	2300-1970
156.	OxA-4307	4075±70	Lopatino-1	53.37	50.42	2860-2490	2880-2460
157.	OxA-4259	3490±70	Spiridonovka-2	53.07	50.43	1890-1690	2020-1620
158.	OxA-4265	3710±80	Potapovo-1	53.44	50.44	2270-1960	2400-1850
159.	OxA-5256	2870±70	Nizhne-Orlyanskaya-1	53.51	50.55	1190-920	1260-830
160.	OxA-5254	4510±75	Nizhne-Orlyanskaya-1	53.51	50.55	3360-3090	3500-2900
161.	OxA-4264	3585±80	Utevka-6	52.54	50.59	2110-1770	2150-1690
162.	OxA-4306	4400±70	Kutuluk-1	53.11	51.11	3270-2910	3340-2890
	Le-5731	4000±70	Baturinskaya	43.48	39.22	2630-2350	2900-2250
URAL region							
163.	Le-548	3010±70	Churakaevo	55.25	55.30	1380-1120	1420-1020
164.	Le-1756	3820±40	Berezovka	52.54	59.30	2340-2140	2460-2130
165.	Le-662	3080±50	Tursumbaj	50.32	59.32	1410-1260	1450-1210
166.	IERZH-47	4380±170	Ustinovo	54.50	59.58	3350-2870	3600-2500
167.	Le-1016	3050±60	Lipovaya Kur'ya	55.00	60.06	1400-1210	1440-1110
168.	Le-633	3590±90	Lipovaya Kur'ya	55.00	60.06	2120-1770	2200-1650
169.	Le-1140	3250±60	Rymnikski barrow	52.30	60.08	1610-1430	1690-1400
170.	Le-2933	3060±40	Sintashta	52.54	60.17	1400-1260	1430-1210
171.	Ki-653	4200±100	Sintashta	52.54	60.17	2900-2620	3050-2450
172.	Le-1547	3560±50	Itkul settlement	56.10	60.34	2010-1770	2030-1740
173.	Le-922	3180±70	Tuktubaevo	54.57	60.57	1530-1320	1620-1260
174.	Le-1751	5120±60	Kulevchi-3	53.25	60.57	3980-3800	4050-3760
175.	Le-1544	4040±40	Korkino-1	54.52	61.20	2620-2470	2840-2460
WESTERN SIBERIA							
176.	Le-1196	3360±50	Subbotinski barrow	54.57	62.31	1740-1530	1750-1510
177.	Le-1129	3910±70	Subbotinski barrow	54.57	62.31	2490-2230	2580-2190
178.	Le-2640	3040±40	Tashkovo-2	55.55	64.25	1380-1210	1410-1130
179.	Le-2639	3780±40	Tashkovo-2	55.55	64.25	2290-2130	2340-2030
180.	Le-1423	3000±40	Verkhnyaya Alabuga	54.33	64.56	2140-1980	2200-1950
181.	Le-1474	5220±70	Verkhnyaya Alabuga	54.33	64.56	4220-3950	4250-3800
182.	Le-1127	3910±60	Raskatikha	55.03	65.11	2470-2300	2570-2200
183.	Le-4178	3090±75	Chernozer'e-1	55.44	73.58	1440-1220	1520-1120
184.	Le-2891	3830±40	Ermak-4	55.10	74.30	2400-2200	2460-2140
185.	SOAN-1673	2850±25	Preobrazhenka-3	55.29	77.02	1050-930	1130-910
186.	Le-1852	3840±40	Bystrovka-4	54.30	82.38	2400-2200	2460-2140
187.	SOAN-1893	3560±30	Elunino	53.26	83.07	2280-2060	2290-2030

188.	Le-2871	3660±40	Elovski barrow	55.56	83.43	2140-1950	2200-2170
189.	SOAN-3217	3760±35	Phyrsovo-14	53.19	83.57	2280-2060	2290-2030
190.	Le-1846	3080±100	Yasashny Lug	54.59	84.21	1490-1130	1600-1000
191.	Le-1849	3520±40	Yasashny Lug	54.59	84.21	1890-1750	1950-1730
192.	SOAN-2312	4130±85	Kaminnaya cave	52.16	84.49	2870-2580	2890-2470
193.	SOAN-3401	5230±90	Kaminnaya cave	52.16	84.49	4330-4040	4350-3980
194.	SOAN-3200	2795±30	Obskie plessy	54.05	85.00	1000-900	1010-830
195.	Le-2669	2820±40	Titovsky burial ground	55.10	85.17	1010-900	1130-830
196.	Le-2666	3000±40	Titovsky burial ground	55.10	85.17	1370-1130	1390-1110
197.	Le-1607	5100±50	Kara-Kot burial ground	50.47	85.29	3970-3800	3990-3770
198.	Le-1609	4410±50	Elo-Bashy burial ground	50.45	85.32	3100-2920	3340-2900
199.	Le-1608	4920±50	Elo-Bashy burial ground	50.45	85.32	3760-3640	3800-3630
200.	Le-1606	4860±60	Nizhni Tyumchin	50.43	86.08	3710-3530	3780-3510
201.	SOAN-1628	4290±20	Kara-Tenesh	51.02	86.17	2906-2887	2915-2882
202.	Le-4121	3120±80	Tanay-1	55.25	86.24	1500-1260	1600-1120
203.	Le-4123	3800±300	Tanay-1	55.25	86.24	2700-1700	3100-1400
204.	Le-2675	3200±40	Vosokovo-5	53.10	86.45	1515-1430	1600-1390
205.	Le-2471	5600±60	Kudyrge	50.42	87.53	4490-4350	4550-4330
206.	Le-2555	2830±40	Tisul'ski burial ground	56.05	88.39	1040-910	1130-860
207.	Le-2560	2940±40	Tisul'ski burial ground	56.05	88.39	1260-1050	1290-1000
EASTERN SIBERIA							
208.	Le-5422	2800±200	Ust'-Parnaya-1	55.24	89.07	1290-790	1500-400
209.	Le-5423	3120±110	Ust'-Parnaya-1	55.24	89.07	1520-1210	1700-1000
210.	Le-4338	2900±90	Airport	55.27	89.08	1260-940	1400-800
211.	Le-3040	3360±40	Ashpil	55.33	89.08	1740-1530	1740-1520
212.	Le-2562	4200±50	Ashpil	55.33	89.08	2890-2680	2900-2620
213.	Le-2866	2850±40	Balalyk-1	55.43	89.16	1110-920	1190-900
214.	Bln-4947	3488±40	Chebaki	54.34	89.20	1880-1740	1920-1680
215.	Bln-4948	3664±37	Chebaki	54.34	89.20	2140-1960	2150-1910
216.	Le-5425	2800±50	Sargozhik	55.18	89.28	1010-840	1130-820
217.	Le-5413	2860±50	Mysy	55.18	89.28	1130-930	1220-890
218.	Le-1529	3740±40	Tora-Dash	51.08	90.16	2210-2030	2290-1980
219.	Bln-4950	3620±35	Ujbat-5	53.43	90.22	2030-1920	2130-1880
220.	Bln-4762	3782±62	Ujbat-5	53.43	90.22	2300-2040	2460-2030
221.	Le-4329	2910±40	Kute'-Buluk	53.42	90.23	1210-1010	1260-970
222.	Le-1178	3410±50	Ust-Kandyrla-1	53.03	90.36	1860-1620	1880-1520
223.	Le-695	2930±60	Karasuk-4	55.00	91.00	1260-1020	1320-930
224.	Le-2209	3840±40	Kirbinski Log	53.16	91.12	2400-2200	2460-2140
225.	Le-1067	4240±60	Krasny Yar	53.55	91.24	2920-2690	3020-2620
226.	Bln-4835	2906±38	Sukhanikha	53.52	91.27	1190-1010	1260-970

227.	Bln-4764	4409±70	Sukhanikha	53.52	91.27	3310-2910	3340-2890
228.	Le-1315	4370±100	Lebyazh'e	54.11	91.33	3310-2880	3400-2700
229.	Le-2093	4820±50	Malinovy Log	53.59	91.34	3660-3520	3710-3380
230.	Le-1316	3880±30	Vostochnoe	54.04	91.38	2460-2300	2470-2230
231.	Le-1612	4410±50	Letnik-6	53.30	91.38	3100-2920	3340-2900
232.	Le-3044	3340±60	Birya	54.09	91.41	1690-1520	1770-1450
233.	Le-3046	3780±40	Birya	54.09	91.41	2290-2130	2340-2030
234.	SOAN-3086	2940±40	Eleneva cave	55.56	92.29	1260-1030	1290-1000
235.	SOAN-3295	4930±55	Eleneva cave	55.56	92.29	3770-3650	3940-3630
236.	Le-3355	5640±140	Badanka-2	52.12	92.56	4680-4340	4850-4100

Iron Age, the Scythian time

During the Scythian time there was a sudden increase of archaeological sites, in both the European and Asian regions. The increase in the amount of the Scythian sites in Asia is more pronounced than in SE Europe (Fig.1, part 3). The oldest Scythian time barrow located in the Asian territory is the Arzhan-1 monument, which was discovered by M. Gryaznov in 1971 in the Uyuk valley (Tuva Republic) (Gryaznov, 1980, 1983). Now more than 2000 monuments and sites belonging to these cultures are known for the Eurasian territory. The economy of these nomads was based on cattle-breeding and one can assume that the natural landscape was favorable for such types of economy. Most Asian Scythian time monuments were radiocarbon dated because they contain wooden remains from the barrow construction. The radiocarbon method could be used for the European Scythian monuments only after the introduction of the AMS dating method. This is because the most famous monuments were discovered in the 19th century and material for dating (small samples) had to be taken from different museum collections. In spite of this complication there is now a rather representative series of ^{14}C dates for these monuments. The list of ^{14}C dates for Eurasian Scythian time monuments have been presented earlier (Alekseev et al. 2001, 2002). The age of most Scythian time monuments is in the period 2500-2300 BP. It is the period of very active migration and interaction of nomads, which probably was caused by favorable environmental conditions (van Geel et al., this volume).

Comparing the distribution maps (Fig.1, A and B) one can see that the increase of the amount of sites belonging to the Scythian period is more pronounced in Southern Siberia and Central Asia than in Europe. The main questions concerning the direction of migration of the ancient nomads and the motives for these migrations are discussed below.

CALIBRATION CURVE AND ENVIRONMENT

Figure1 A and B show that after the Neolithic period an intensive occupation of the Eurasian territory occurred, but during the Bronze Age there was a more dense distribution in the European part than in the Asian part. Towards the Late Bronze Age and the beginning of the Iron Age (Scythian time) a sharp increase of monuments is obvious for the Asian territory. While in the beginning of the Bronze Age there were migrations from Europe to Asia, migrations in an opposite direction occurred during the Scythian time. One of the reasons for migration could be environmental changes. Such changes could trigger migration to areas with more favorable conditions for people with a nomadic economy. It is difficult to compare the peculiarities of the environmental conditions of the European and Asian steppes in these periods but extra information can be obtained by analyzing the character of the radiocarbon calibration curve (Fig. 2). Fluctuations of the calibration curve may reflect global environmental changes connected with fluctuations of solar activity and cosmic rays intensity (van Geel et al. 1996, 1999, 2000; Renssen et al., 2000).

The calibration curve has a complicated character during the time intervals 4700-4200 BP and 2700-2200 BP (Fig. 2, A, B).

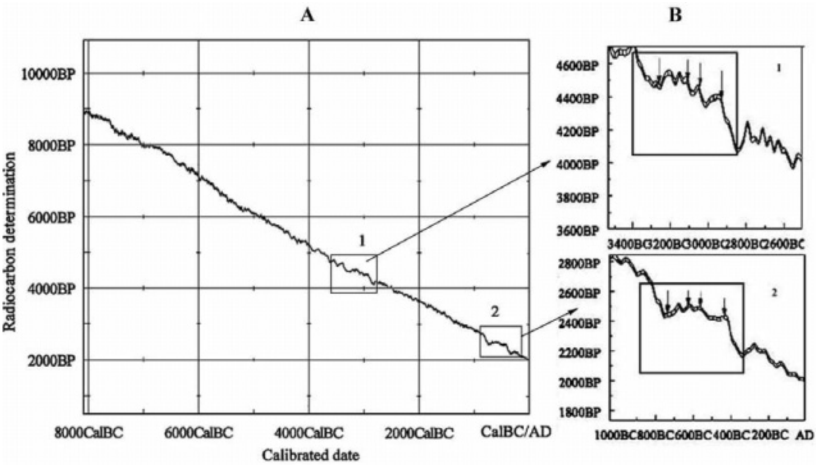

Figure 2. The parts of the calibration curve.
A- all Holocene; B- the separated parts of the Bronze and Iron Age epochs.
☐ 1- the parts with the plateau; 1- around 4600 BP (the Bronze Age epoch)
2- around 2600 BP (the Scythian time).

The fluctuations during these periods are part of a large-scale 2000-2400 years periodicity in the atmospheric ^{14}C record (Dergachev et al. 1993). While abrupt climatic change around 2650 BP is now evident (van Geel et al 1996, 199, 2000), evidence for climate change around 4700 BP is less clear.

Comparing these parts of the calibration curve (Fig.2, A and B) one can observe similarities: a long-lasting plateau between steep parts of the calibration curve for the intervals 4500 - 4400 BP and 2500 - 2400 BP. At the start of both periods the atmospheric ^{14}C concentration had become rather high). Besides, the plateau have characteristics in common: the periodicity of wiggles on these plateau shows a similar pattern (Fig. 2, B).

Changes in solar activity and related fluctuations of cosmic ray intensity might have an effect on cloud formation and thus on the humidity of climate (van Geel et al. 1999; Renssen 2000). Humidity is a major factor for the productivity of steppe zones and thus for the development of the nomadic economy. It may well be that environmental changes occurred during the Earlier Bronze Age (4700-4200 BP), making the territory of Southern Siberia more attractive for immigration. In other words: the penetration of the Aphanasievo culture in Southern Siberia (dated to the 4th- 3rd millennium BC) may have been triggered by a climate shift. After immigration the occupation of the steppe parts of the Minusinsk and Uyuk valleys was continued (Fig.1).

The next remarkable period (2700-2200 BP) encompasses the appearance and development of the Scythian cultures. The Tagar culture is the most significant Scythian time culture and it occupied the Minusinsk hollow. Many burial mounds are present in this territory and only a part of them has been studied. The Uyuk hollow (Tuva) is separated from the Minusinsk hollow by hills of the Sayan. The Uyuk hollow was occupied by the population of the Aldy-Bel culture which has some similarities with the Tagar culture. The oldest monument of the pre-Scythian time is the famous Arzhan-1 barrow discovered in 1980 by Prof. M. Gryaznov (Grayznov 1980). But in the Minusinsk hollow there are barrows of the Tagar culture dated by archaeological evidence in the same period as the Arzhan-1monument. Among them is the Cheremshino barrow. A newly discovered Scythian monument located in the Uyuk hollow is the Arzhan-2 barrow, discovered in 2000 by a Russian-German expedition (Chugunov et al., 2002). Obviously the occupation density of both territories was very high during Scythian time, compared with the European part (Fig.1).

Possibly climatic changes caused the migration of the Earlier Bronze Age population from Europe to Asia and, later, climate change may have triggered the migration of Scythian nomads from Asia to Europe. In the near future detailed environmental investigations based on pollen and other analyses may help to answer the questions concerning the motives and directions of the migration of ancient nomads in Eurasia and to solve the problems of the origin of the Scythian culture.

METHODOLOGICAL PROBLEMS IN THE CHRONOLOGICAL STUDY OF SCYTHIAN MONUMENTS

The plateau of the calibration curve (Fig. 2, A, B, parts 1 and 2) causes uncertainties in the transformation of ^{14}C ages into calendar ages. Time intervals in the calendar age scale can be much wider than the statistical error of the BP value. This plays a role for the archaeological sites belonging to the Middle Bronze Age, dated to 4500- 4200 BP (Fig.2, A). For example: the date of the Riazovskay site 4455 ± 75 BP (OxA-4676) corresponds to the calendar time interval from 3340-3010 calBC (1σ); the date of the Starchiki

4510 ± 40 BP (Le-5032) corresponds to 3350-2890 calBC (1σ), and so on (Table 2).

Very important for determining the calendar time intervals for the Scythian sites is the possibility to compare the radiocarbon chronology of European Scythia with written sources (Alekseev 2003). The part of calibration curve corresponding to this period is presented in Fig. 2, B). At least, one can determine three parts of the calibration curve for Scythian time: 800-750 BC, 750-420 BC and 420-350 BC. Two of them have a rather similar character (inclination of the calibration curve: 800-750 and 420-350 BC). These time periods correspond to the earliest Scythian (Arzhan-1) and the latest Scythian monuments (for example, the Pazyryk groups). The chronology of the Scythian monuments belonging to the development stage of Scythia fall on a very complicated (plateau) part of the calibration curve from 750 up to 420 calBC (Fig.2, B) causing difficulties for the transformation of ^{14}C age into calendar time.

To study the developmental stage of the Eurasian Scythian monuments the characteristics of the calibration curve can be used. There are differences in the chronological studies of the European and Asian Scythian monuments caused by differences of the materials suitable for the ^{14}C determinations.

1. For Scythian time monuments located in Southern Siberia and Central Asia wood samples are available, both for dendrochronology and radiocarbon research. In this case the most suitable approach is the ^{14}C wiggle matching method, allowing us to determine the time of the barrow construction with a precision up to 10-20 years. The wiggle matching method had been used for the chronology of different Scythian monuments with wooden remains located in Kazakhstan, Altai, Khakassia and Tuva regions (Dergachev et al, 1999, 2001; Alekseev et al. 2001, 2002).
2. The European Scythian monuments do not contain sufficient wood material for tree-ring studies and radiocarbon dating. In this case rather good results can be obtained by combining ^{14}C dates and use the OxCal program (Bronk Ramsey 1994, 1998). A good example is the chronological study of the royal Solokha barrow, located in the northern Black Sea region. Based on archaeological data this barrow is dated to 400-375 BC (Alekseev, 1992). Eleven ^{14}C dates have been produced by both AMS and conventional methods, and these point to an age in the interval 2425-2270 BP. The combined ^{14}C date obtained by the OxCal computer program is 2333 ± 15 BP, corresponding to 400-395 calBC (1σ) and to 403-390 calBC (2σ), which fits well with the archaeological date (Alekseev et al., 2002).

The first chronological results have been obtained for the Arzhan-2 tsar monument discovered in 2001 by a Russian-German expedition in Tuva (Chugunov et al., 2002). By using the wiggle matching method on the dating of wood remains from walls and floor of the chamber of the royal grave 5 this monument is dated to the 7th century BC (Chugunov et al., 2004, Zaitseva et al. 2004) and the combined ^{14}C date of different organic materials (leather, textile, seeds and others) obtained by the OxCal computer program points to the same time interval.

In spite of the special problems, the combined research (archaeology; scientific dating methods) of Scythian monuments can lead to a detailed chronology.

CONCLUSIONS

The occupation history of the steppe zones of Eurasia shows some characteristic developments. The steppes located in the Minusinsk and Uyuk hollows of Asia became inhabited only during the Eneolithic epoch, while other parts of the Eurasian steppe had a continuous occupation from the Mesolithic up to the Iron Age. The Minusinsk and Uyuk hollows became more attractive during the Late Bronze Age and especially during Scythian time, and the amount of Scythian sites in Asia was increasing faster than the number of settlements in the European steppes. This may be explained by environmental changes which made the Asian steppes (the Minusinsk and Uyuk hollows) more favourable for the nomadic way of life. Probably environmental changes stimulated migrations of the nomads from Europe to Asia and back. The indirect evidence for a possible cause of such changes can be derived from the character of the calibration curve (around 4600 and 2600 BP). Major changes in the calibration curve were caused by changes of cosmic ray intensity, as a consequence of solar activity changes, which also may have influenced the climate. The effects of such changes may have been different in Europe and Asia. Palaeo-environmental studies may help to understand possible relationships between climate change and archaeological developments in the European and Asian steppes. The complicated character of the calibration curve around 4500 and 2600 BP results in uncertainties when transforming radiocarbon ages into calendar time intervals. This is an important factor for the chronology of the Scythian period and it requires a special approach in the chronological research based on the radiocarbon method.

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Chapter 7

^{14}C DATING OF THE SIBERIAN STEPPE ZONE FROM BRONZE AGE TO SCYTHIAN TIME

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ABSTRACT

New ^{14}C dates from the Minusinsk basin are presented. These dates have been calibrated together with earlier results. Different calibration methods have been used to study the chronology of the cultural developments in this region. Durations and timing of cultural developments in the Minusinsk basin from the Bronze Age to Scythian time are discussed.

Keywords: chronology, radiocarbon dating, calibration.

INTRODUCTION

The chronological problems of the Steppe Zone have been under intensive investigation over the last few years. We present new ^{14}C-dating results for samples from the excavation sites Suchanicha, Bystraja and Chernavoja (Leont'ev, Parzinger and Nagler 1996).

These samples give us new absolute dates for different Bronze Age cultures including Afanas'evo, Okunev, Andronovo and Karasuk (classical Karasuk and Kamennyj Log phase) as well as for the Scythian culture and the early Bainov, Podgornovo and Saragash as well as the late Tes' phase of the Tagar culture, the latter related with the Huns. One date is from the Tashtyk culture. The dates allow a comparison of the development in the Minusinsk basin with other neighbouring regions.

The presented dates form part of a cooperative project with the ^{14}C-laboratory and specialists of the Institute of the History of Material Culture of Russian

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Academy of Sciences (St. Petersburg) to investigate chronological problems of the South Russian and Siberian Steppe Zones.

METHODS

Chemical pretreatment of wood and charcoal samples was done by A-A-A treatment (Mook and Streuerman 1983). The procedure for separating the collagen fraction of bones was essentially according to Longin and Olsson (Longin 1970, Olsson et al. 1974). The dates were made with gas proportional counters of the Houtermans-Oeschger type, using methane at 133.3 kPa pressure as filling gas. Measurement control and data processing were done with the help of computers (Görsdorf 1990; Görsdorf 2000). Modern measurement electronics were used. Preamplifier, pulse amplifier, comparator, pulse shaper and anti-coincidence systems are located in a box (19cm x 10cm x 5cm), which is directly connected with the counter. The detection of variation in environmental radiation and the inspection of the long term stability of the electronics were required in order to achieve the required measurement accuracy. The δ^{13}C-measurements were done by H. Erlenkeuser and colleagues (Leibniz-Labor, University of Kiel) and are reported with respect to PDB-standard.

RESULTS

It was not possible to count the tree-rings of the charcoal and wood samples. So, in the calibration program OxCal v3.8 (Ramsey 1995, 1998, 2001, 2002) we used the decadal calibration curve (Stuiver et al. 1998) as a first approximation for all samples. The calibration intervals are reported with a confidence of 68.2 % in a 10 year rounded form. The following summary in Table 1 shows the results together with locations, ordered by locations, cultures, phases and dating results:

Table 1: Dating results

Suchanicha (53° 52′ 26″N, 91° 28′ 11″E)				
Lab number	description	δ^{13}C	^{14}C age (1 σ)	Calibrated range
Bln 5280	Afanes'evo culture Wood, burial mound 19A, grave 1	-25.7‰	4271 ± 30 BP	2910-2880 cal BC
Bln 5311	Classic Karasuk culture, human bone, feature I, grave 1	-16.3‰	3134±27 BP	1440-1390 cal BC 1330-1320 cal BC
Bln 5318	Classic Karasuk culture, human bone, feature VI/3, grave 1	-15.2‰	3101±26 BP	1420-1370 cal BC 1340-1310 cal BC
Bln 5312	Classic Karasuk culture, human bone, feature VIII, grave 1	-18.0‰	3006±30 BP	1370 - 1360 cal BC 1320 - 1210 cal BC 1200 - 1190 cal BC 1180 - 1170 cal BC 1140 - 1130 cal BC
Bln 5314	Classic Karasuk culture, human bone, feature 8, grave 1	-17.1‰	2987 ±27 BP	1290 - 1280 cal BC 1270 - 1190 cal BC 1180-1160 cal BC 1150 - 1130 cal BC

Bln 5319	Classic Karasuk culture, human bone, feature VIII, grave 3	-17.1‰	2985±26 BP	1290 - 1280 cal BC 1270 - 1190 cal BC 1180 - 1160 cal BC 1150 - 1130 cal BC
Bln 5281	Karasuk culture (Kamennyj Log), wood, burial mound 11, grave 1	-25.9‰	3044± 29 BP	1380 - 1330 cal BC 1320 - 1260 cal BC
Bln 5316	Karasuk culture (Kamennyj Log), human bone, burial mound 11A, grave 1	-15.8‰	2833± 27BP	1010 - 920 cal BC
Bln 5317	Karasuk culture (Kamennyj Log), human bone, burial mound 11, grave 1	-16.5‰	2810± 25 BP	1000-920 cal BC
Bln 5315	Karasuk culture (Kamennyj Log), human bone, burial mound 10, grave 1	-17.7‰	2667± 24 BP	830-800 cal BC
Bln 5313	Tagar culture, Podgornovo phase, human bone, burial mound 14, grave 1	-18.5‰	2651± 26 BP	830-800 cal BC
Bln 5342	Tagar culture, Saragash phase, charcoal, burial mound 88, grave 4	-25.7‰	2563± 24 BP	800-760 cal BC
Bln 5341	Tagar culture, Saragash phase, charcoal, burial mound 82, grave 3	-26.2‰	2543± 26 BP	800 - 760 cal BC 690 - 660 cal BC 630 - 590 cal BC 580 - 560 cal BC
Bln 5343	Tagar culture, Saragash phase, charcoal, burial mound 93, grave 3	-24.8‰	2541± 23 BP	800 - 760 cal BC 690 - 660 cal BC 620 - 590 cal BC 580 - 560 cal BC
Bln 5277	Tagar culture, Saragash phase, human bone, burial mound 82, grave 1	-17.5‰	2519± 27 BP	790 - 750 cal BC 690 - 660 cal BC 640 - 590 cal BC 580 - 540 cal BC
Bln 5276	Tagar culture, Saragash phase, human bone, burial mound 88, grave 3	-16.9‰	2448± 27 BP	760 - 690 cal BC 550 - 480 cal BC 470 - 410 cal BC
Bln 5278	Tagar culture, Saragash phase, human bone, burial mound 93, grave 4	-16.3‰	2425± 30 BP	760 - 720 cal BC 540 - 400 cal BC
Bln 5340	Tagar culture, Saragash phase, human bone, burial mound 82, grave 3	-19.1‰	2389 26 BP	520-390 cal BC
Bystraja (53° 43′ 39″N, 91° 36′ 8″E)				
Bln 5283	Tashtyk culture, charcoal, tomb 1	-23.9‰	1835 29 BP	130-220 cal AD
Chernovaja (53° 54′ 14″N, 91° 33′ 15″E)				
Bln 5279	Okunev culture, human bone, burial mound 1, grave 1	-19.2‰	3487 25 BP	1880 - 1840 cal BC 1830 - 1790 cal BC 1780 - 1740 cal BC

INTERPRETATION

In Figures.1 and 2, earlier published results (Görsdorf, Parzinger and Nagler 1998, 2001; Görsdorf 2001) together with the above results are shown. The dates from Suchanicha, Potroshilovo, Chebaki, Ujbat, Krivaja, Bystraja and Chernovaja can be considered as an important step forward in the absolute dating of South Siberian cultures.

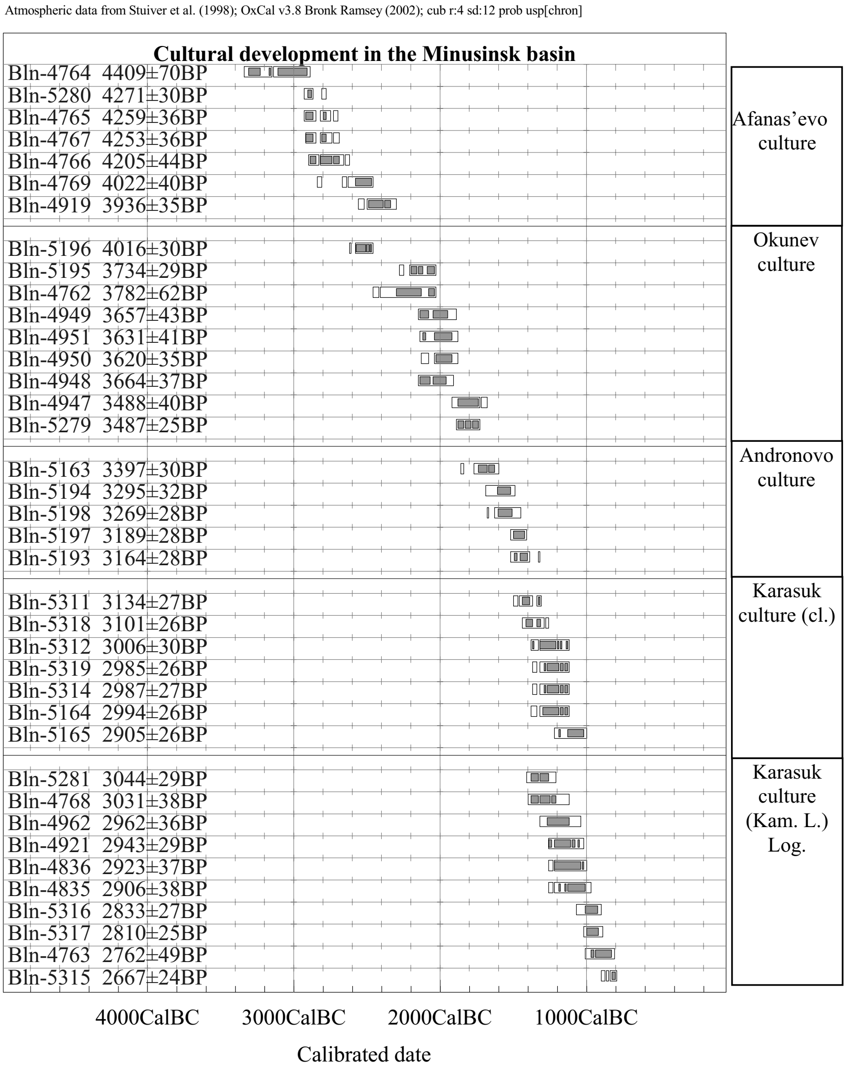

Fig.1 Cultural development in the Minusinsk basin during the Bronze Age.

Atmospheric data from Stuiver et al. (1998); OxCal v3.8 Bronk Ramsey (2002); cub r:4 sd:12 prob usp[chron]

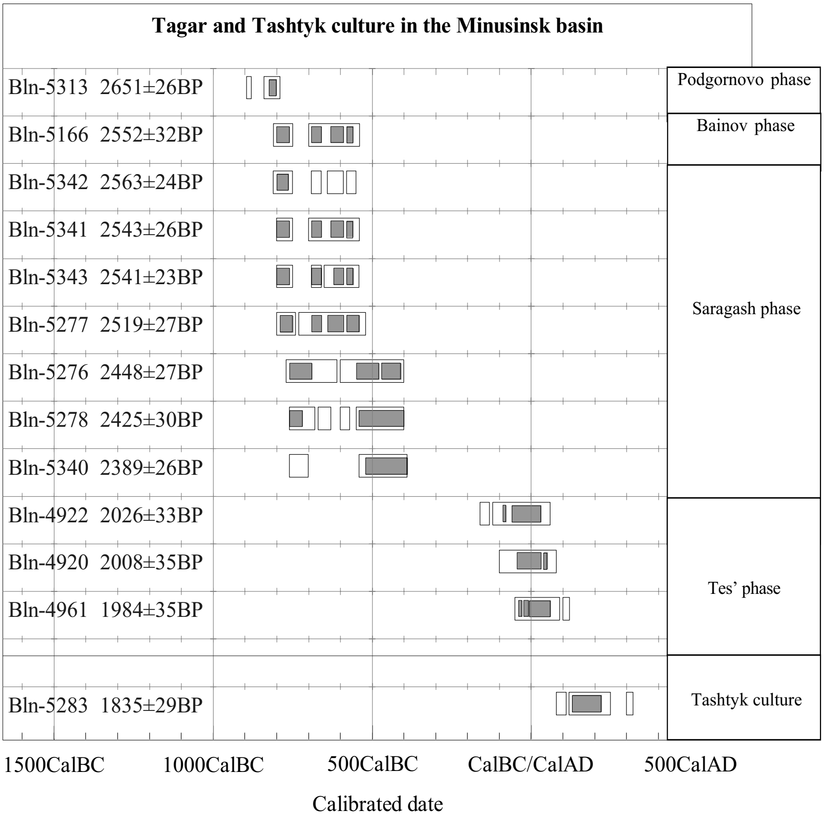

Figure.2 Dating of the Tagar and Tashtyk cultures in the Minusinsk basin

For the small region of the Minusinsk basin we now have 51 dates in a time range of about 3000 years. This means that the dates presented here can only be considered as an important first step, which must be followed by many more dates from South Siberia and neighbouring regions to solve the still existing chronological problems.

Up to now we calibrated the results as single dates. Now we are interested in the calibration of data groups. In the calibration program OxCal v3.8, we used whole ranges. With OxCal v3.8, it is possible to calculate the distributions of the boundaries between the cultures. We used the archaeological information that the cultures Afenas'evo, Okunev, Andronovo, Karasuk and Tagar followed each other without gap. That means the end of one culture has to be identical with the beginning of the next. Only between the 'classical' Karasuk and the Kamennij Log phase we see an overlapping in time. From the archaeological point of view we find a kind of transformation here. The boundaries in the program OxCal v3.8 mark the beginning and the end of the cultures. In Table 2 we present the beginning, end and duration of cultures for a boundary probability of 68,2%.

Table 2: Cultural development in the Minusinsk basin

Culture	Beginning	End	Duration(years)
Afanas'evo culture	3000 ± 90 cal BC	2520 ± 30 cal BC	480 ± 120
Okunev culture	2520 ± 30 cal BC	1715 ± 65 cal BC	805 ± 95
Andronovo culture	1715 ± 65 cal BC	1420 ± 40 cal BC	295 ± 105
Karasuk culture ('classical)	1420 ± 40 cal BC	115 ± 75 cal BC	305 ± 115
Karasuk culture (Kam Log)	1320 ± 60 cal BC	830 ± 25 cal BC	490 ± 85
Tagar culture	830 ± 25 cal BC	70 ± 70 cal AD	900 ± 95

The time ranges are given as ages with symmetric error. We see these results as a first approximation because the beginning of the Afanas'evo culture and the transition between the Afanas'evo and the Okunev culture are especially sensitive and can be changed by further measurements.

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Chapter 8

NORTH-WEST CASPIAN SEA STEPPE: ENVIRONMENT AND MIGRATION CROSSROADS OF PASTORAL CULTURE POPULATION DURING THE THIRD MILLENNIUM BC

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ABSTRACT

The study is focused on the development of Eneolothic cultures on the background of environmental changes. Analyses of the geomorphologic location of the Yamnaya, Early Catacomb, North-Caucasus and Predkavkazskaya Catacomb cultures' kurgans; the topography of burial grounds; climatic characteristics of 3,000 BC; ^{14}C data; analyses of planigraphy of burial grounds and seasonality of graves enable us to develop a model of migration of pastoral culture populations within the study area, i.e. Kumo-Manich depression – the South Ergenui hills.

Gradually the climate deteriorated starting from 2,600-2,500 BC. Newcomers representing different cultures arrived from the South and maybe from the South-West. At first the population of the North Caucasus and Early Catacomb cultures exploited river valleys and watershed areas only during summer. Such a situation could have developed not only due to climatic changes but also thanks to consent of the Yamnaya culture bearers that were the first to use these areas. Appearance of "mixed" (multiritual) graves, multiritual funeral goods found in the graves of both autochthonous populations and newcomers allow us to suppose that this coexistence could be quite peaceful.

Key words: Eneolothic cultures, archaeological study, chronology, environment, migration, interaction

INTRODUCTION

The North-West Caspian coastline steppe is characterized by a mosaic of landscapes. It was occupied by pastoral groups starting from the fifth millenium BC. The history of the third millenium BC was very complicated. Several cultures played a key role in the spread of a pastoral economy

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throughout this period, i.e. Yamnaya, North-Caucasus, Early Catacomb, and Catacomb cultures. The seasonal mobile cycle of grassland use developed among these cultures at the turn of the Early Bronze Age and the Middle Bronze Age during cal.2600-2400 BC and is an indication of a complex process of herding economy evolvement and development.

This paper presents data collected within a pilot area for our research, i.e. the Kuma-Manych depression – the South Yergueni hills (Fig.1,2).

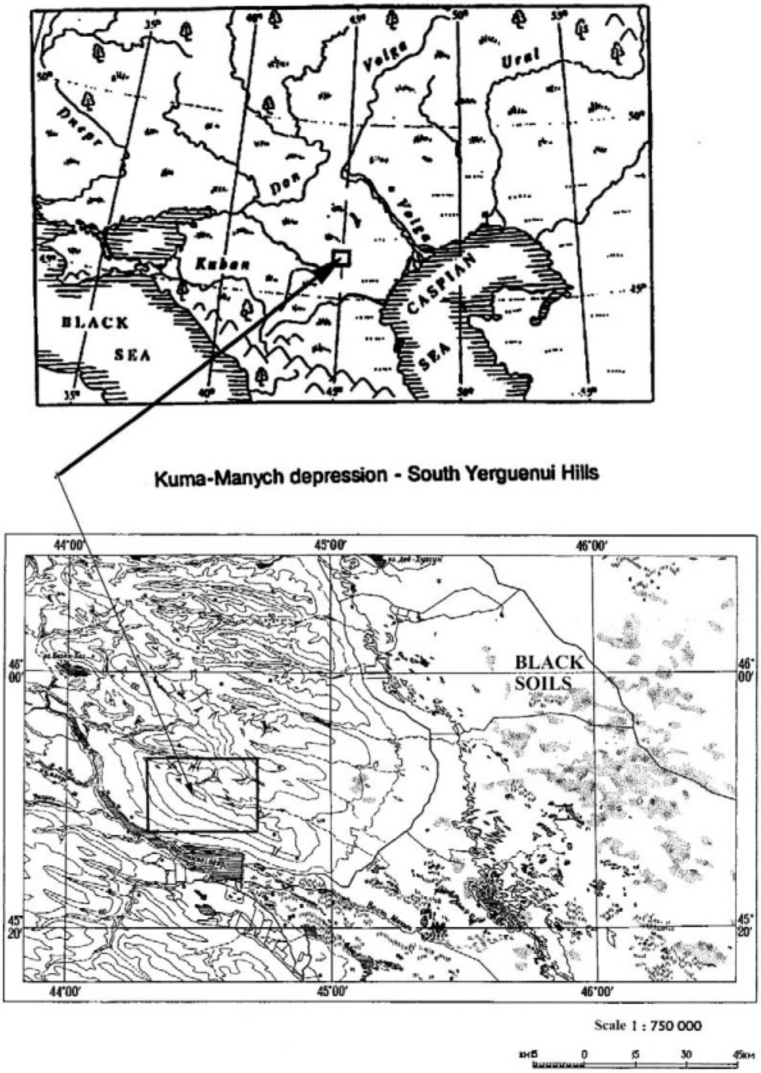

Figure1. Pilot area of the research: Kuma-Manych depression – South Yergeuni Hills

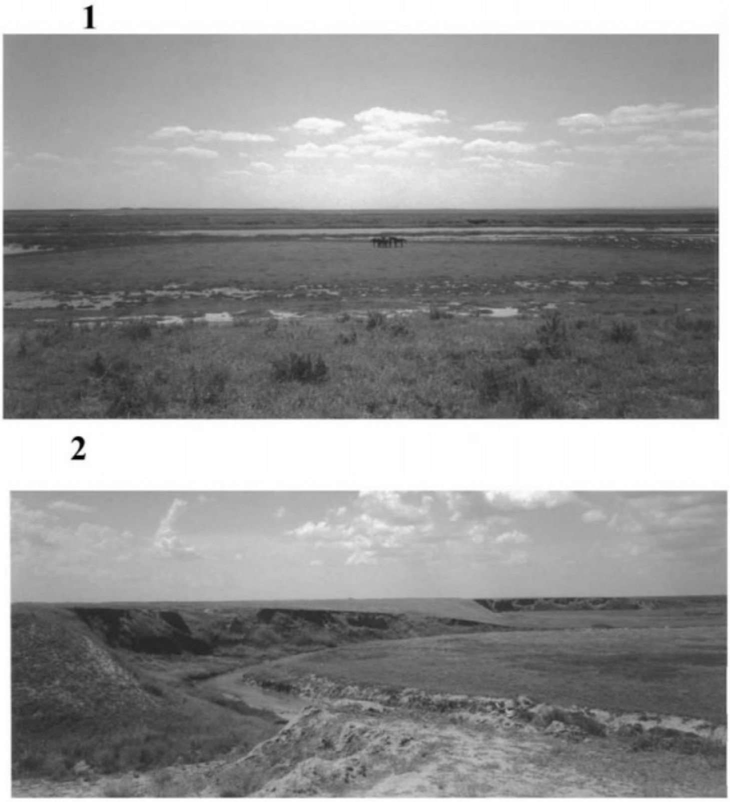

Figure 2. Pilot area of the research: 1- Vostochny Manych river. General view; 2 – South Yergeuni Hills. General view

The data are related to the geomorphologic location of kurgans, the topography of burial grounds, climatic characteristics of third millennium BC, ^{14}C dates, analyses of planigraphy of burial grounds, seasonality of graves. These data enable us to develop models of migration of the pastoral culture population within the pilot area and link migration routes with climatic changes and development of the pastoral economic cycle.

THE KUMA-MANYCH DEPRESSION – THE SOUTH YERGUENI HILLS: 3000 BC

Environment[1]

. At the beginning of the Yamnaya culture Age (cal.3000 BC) local landscapes of the watershed plateau were very similar to the dry steppe environment. They were characterized by the presence of wormwood (*Artemisia*), leguminous plants (*Fabaceae*), grass plants (*Poaceae*), goosefoot (*Chenopodiaeceae*), lily (*Liliaceae*), dicotyledonous mixed grasses (*Silenaceae, Asteraceae, Polygonaceae*), with turf steppe gramineous plants playing a significant role. Therefore, at the beginning of the Yamnaya culture Age the watershed steppe areas were characterized by the presence of mixed grasses steppes and mixed grasses and gramineous steppes.

The modern vegetation pattern of the area under investigation may be characterized by steppe plants as well as by semi-steppe plants: mixed grass steppes or wormwood-fescue-feather grass and wormwood-fescue steppes predominate. The flora includes grass plants (*Poaceae*), *Compositae*, labiate plants (*Lamiaceae*), goosefoot (*Chenopodiaeceae*) (mostly, on saline soils), umbelliferae plants (*Apeacea*), cloves (*Silenaceae*); polidominant plant associations from the fescue-feather grass group predominate (Novikova 2001, 2002). Comparison of the data obtained from the Yamnaya culture burial grounds with the modern geobotanical description enables us to suggest that during that period, cal. 3 000-2 600 BC, dry-steppe landscapes were predominant in the region, while the environment was more humid than nowadays. There were forests in ravines. Pollen from the Khara-Buluk swamp (Kremenetsky 1997) correlates with the identified wood from the Yamnaya culture graves, i.e. oak (*Quercus*), poplar (*Populus*), ash (*Fraxinus*), elm (*Ulmus*)[2] .

Therefore, the analysis of data from the Yamnaya Culture kurgans indicates that the early stage of the Yamnaya culture coincides with the climatic optimum, cal. 3000-2600 BC. This optimum abruptly came to its end by mid-3000 BC, when a gradual change of vegetation occurred: dry steppes gave way to semi-desert steppe landscapes, where wormwood-fescue associations predominated, ravine forests started disappearing (Kremenetsky 1997). Climate began to be more continental. The annual precipitation rate was 50 mm below the current rate, i.e. 300 mm (Kremenetsky 1997, 43). The presence of fish bones of carp, sturgeon and pike-perch in subsequent Catacomb culture graves (Shilov 1975) is indirect evidence that the annual temperature increased as a result of climate aridization[3]. Carp is very particular about the quality of the spawning site, temperature and depth of water, spawns in water, the temperature of which is no less than +18-20°C. Pike-perch is also a heat-loving fish, it spawns in March-April when the water temperature is +10-12°C.

Generally the annual temperature throughout the second half of 3000 BC was very close to the current temperature, i.e. +10°C (Tashninova 2000), but the annual precipitation rate was lower.

Comparison of the soils buried under Yamnaya culture kurgan 3 of burial ground Zunda-Tolga-1 with the buried soils of kurgan 2 (layer 2) dating to the Catacomb culture has identified changes in the vegetation cover of the steppe and replacement of the steppe and mixed grass steppe vegetation by semi-desert vegetation (Alexandrovsky 1995).

The low-lying flood-prone area of the island situated between the Kalaus River and the Vostochny Manych River where the Late Yamnaya culture burials of the Ostrovnoy burial ground were found is characterized by the presence of wormwood (*Artemisia*), goosefoot (*Chenopodiaceae*), gramineous plants (*Poacea*), sedge (*Cyperaceae*), goosefoot (*Atriplex*), white water-lily (*Nymphaeae*), lily (*Liliaceae*), ephemeris (*Tulipa, Holosteum, Ceratocephala* and others.), spores of ground lichens, dicotyledonous mixed grasses (*Silenaceae, Asteraceae, Polygonaceae).* During the Yamnaya Culture period this part of the steppe looked like a semi-desert landscape, with goosefoot (*Chenopodiaceae*) and wormwood (*Artemisia*) predominating. Spore of *Botrychium lunaria* indicates that there were waterless valleys nearby as well as springs, flood-plain lakes with a lot of brushwood of reed (*Phragmites Adans*). The modern vegetation pattern is the same as during the Late Yamnaya culture Age (Shishlina et al. 2002).

Thus, throughout the third quarter of 3000 BC climatic characteristics were almost the same as nowadays, though today the climate is more arid. The annual precipitation rate was 300-350 mm (Demkin et al. 2002). Small forests were growing in ravines. Analyses of the paleosoils which date back to mid-3000 BC show that plant vegetation was changing, dry-steppe landscapes were replaced by semi-desert landscapes with predominance of wormwood-fescue associations. Forests were decreasing.

Cultural Context.

The area of Kuma-Manych depression and the South Yergueni Hills were first exploited by the Yamnaya culture population (Fig.3-1,2) starting from ca.3200-3000 BC. Twenty Yamnaya culture burial grounds (213 Yamnaya culture kurgans and 451 Yamnaya culture graves) were excavated in this area.

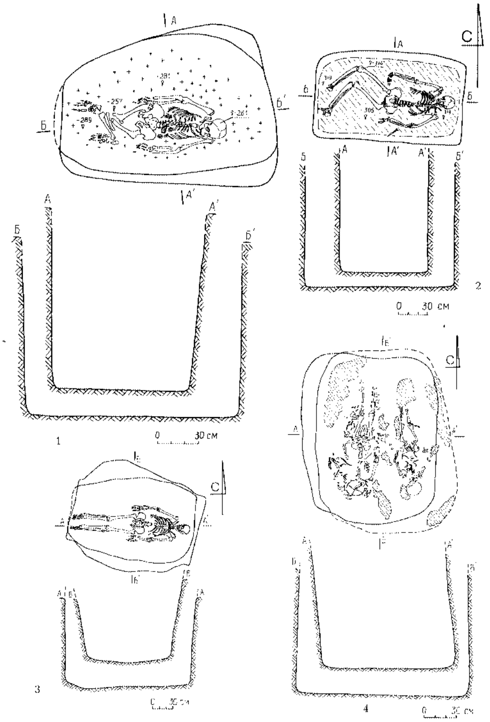

Figure3. Yamnaya culture graves: 1- Mandjikiny-1 kurgan 3 grave 2; 2 – Mandjikiny-2 kurgan 11 grave 3; North Caucasus culture: 3 – Chogray IX kurgan 9 grave 3, 4 – Mu-Sharet-1 kurgan 6 grave 4

Starting from the ca.2600-2500 BC, people representing new cultures, i.e. Early Steppe North Caucasus cultures (Fig.3-3,4) (13 burial grounds yielded 66 kurgans and 81 graves of the North Caucasus culture), the Early Catacomb culture (Fig. 4-1) (15 burial grounds had 77 kurgans, with 98 graves dating to this culture) appeared. Starting from ca.2500-2400 BC the Catacomb culture population (Fig.4-4) began to occupy the pilot area.

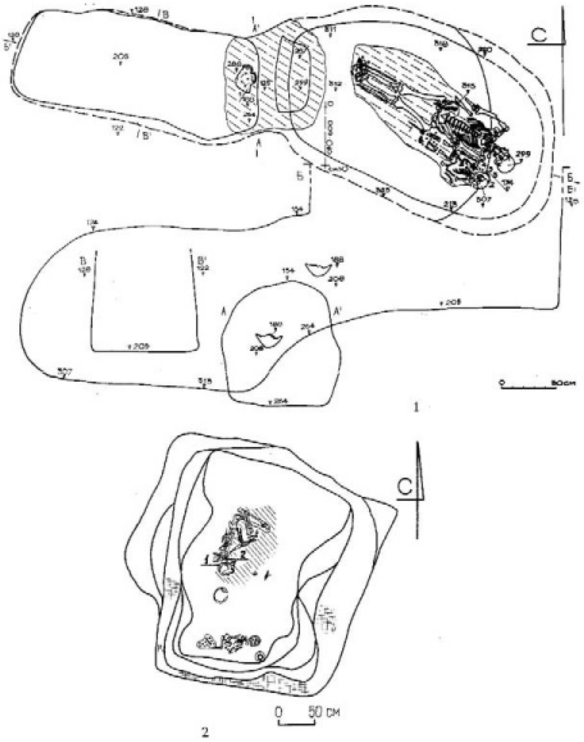

Figure4. 1 – Early Catacomb culture: Mandjikiny-1 kurgan 42 grave 1;
2 – Catacomb culture: Zunda-Tolga-1 kurgan 10 grave 2

Analysis of the burial ground planigraphy.

This analysis of the fully excavated sites has shown that kurgans of one culture form a sort of “cluster” within chains of kurgans that are likely to have been used as family cemeteries of different pastoral groups. For example, we have identified two groups of Yamnaya culture burials in Mandjikiny-1 burial ground that differ both in burial rites and location within the burial ground. We believe these two groups of kurgans to have been left behind by two non-synchronous pastoral groups. When newcomers arrived at the sites of an old necropolis, at first they used ancient kurgans mounds very rarely, probably only under very special circumstances. They built their own mounds very close to the kurgans of their predecessors. Comparison of the total number of graves belonging to different cultural groups indicates that the number of newcomers was very small. That is why, there are so few cases of reverse stratigraphy in the excavated Bronze Age kurgans. Many scholars used the kurgan stratigraphy when they proposed sequences of cultures of the region (Safronov 1974).

Seasonality data of graves and burial mounds of several burial grounds of different cultures are presented in the Table 1.

Table 1. Identified season of Yamnaya, North-Caucasus, Early Catacomb, Catacomb and mixed Yamanaya-Catacomb graves[4]

Kurgan/grave	Sex/age	Calendar time intervals, cal BC	Season
Zunda-Tolga-1			
Yamnaya culture			
Kurgan 3, mound			summer
Catacomb culture			
Kurgan 9, grave 1	male? 40-45 years old	2465-2313 (GrA-10045)	spring
Kurgan 5, grave 1	?	2201-1961 (GrA-10694)	spring
Kurgan 8, grave 1	female > 55 years old	2573-2353 (GrA-10165)	autumn, winter or early spring
Kurgan 1, grave 11	?	***	spring
Kurgan 7, grave 1	cenotaph	2457-2301 (GrA-10051)	summer
Kurgan 4, grave 1	?	***	summer
Kurgan 10, grave 2 (проверить по списку – 51)	female 50-60 years old child of 1,5-2 years old	2871-2508 (IGAN-2421)	second half of the summer
Kurgan 10, grave 3	male ~ 35 years old	***	summer (May-July)
Zunda-Tolga-2			
Early Catacomb culture			
Kurgan 1, grave 1	male adultus	3304-2911(IGAN-2406)	summer
Catacomb culture			
Kurgan 1, grave 4	child	***	end of spring-beginning of summer
Kurgan 1, grave 5	male? maturus-senilis female? adultus-maturus	***	summer
Zunda-Tolga-3			
Yamnaya culture			
Kurgan 1, grave 4	male 18-25 years old	3029-2709 (IGAN-2422)	late spring-early summer
Kurgan 1, grave 8	male >50 years old	***	Summer
North Caucasus culture			
Kurgan 1, grave 11	female? 14-15 years old ? male? 15-17 years old	2837-2461 (ИГАН-2404)	summer
Early Catacomb culture			
Kurgan 1, grave 9	cenotaph	***	second half of spring-early summer
Catacomb culture			
Kurgan 1, grave 1	child 12-14 years old?	***	first half of summer
Kurgan 1, grave 2	male adultus	***	first half of summer
Kurgan 1, grave 3	female? 17-25	***	first half of summer
Kurgan 1, grave 5	?	***	first half of summer

Kurgan 1, grave 6	female?	***	end of spring-begining of summer
Ostrovnoy			
Yamnaya culture			
Kurgan 3, grave 33	? 17-25	2393-1635 (IGAN-2106)	end of spring – beginning of summer
Kurgan 3, grave 34	?	5592-4797 (IGAN-2105)**	winter? summer?
Early Catacomb culture			
Kurgan 3, grave 37, skeleton one*	male 17-25	***	end of spring-beginning of summer
Kurgan 3, grave 37, skeleton two *	female 17-25 years old		February-March
North Caucasus culture			
Kurgan 3, grave 36	?	***	late spring
Catacomb culture			
Kurgan 3, grave 10	?	2399-2147 (IGAN-2130)	winter or early spring
Kurgan 3, grave 24	child 1-2 years old	***	summer
Kurgan 3, grave 28	female 17-25 years old	***	end of winter-very early spring
Kurgan 3, grave 30	?	***	late spring - beginning of summer
Kurgan 6, grave 6	female 40-45 years old	***	spring
Kurgan 6, grave 8	male 80 years old	***	summer
Mandjikiny-1			
Yamnaya culture			
Kurgan 3, grave 2	male 20-30 years old	2464-2313 (IGAN-1891)	winter, early spring
Kurgan 3, grave 1	female ~ 15 years old	***	summer
Kurgan 12, grave 4	male 25-35 years old	***	summer
Kurgan 14, grave 10	male 20-25 years old	2911-2700 (IGAN-2402)	late autumn-winter
Kurgan 14, grave 12	male 17-25 years old ?	2489-2313 (IGAN-2492)	late autumn
Early Catacomb culture			
Kurgan 12, grave 2	male 45-55 years old female 40-55 years old	***	late summer-beginning of autumn
Kurgan 14, grave 5	?	***	second half of spring – summer
Yamnaya Catacomb type of grave			
Kurgan 19, grave 1	female > 55	***	summer
Kurgan 19, grave 2	male 35-40 years old	***	summer

Catacomb culture			
Kurgan 3, grave 3	?	***	summer
Kurgan 14, grave 1	male 30-35 years old	2488-2148 (IGAN-2493)	late summer-beginning of autumn
Kurgan 5, grave 2	female adultus-maturus	***	April-May
Kurgan 9, grave 1	male 35-40 years old	2190-2044 (IGAN-2278)	early spring
Mandjikiny-2			
Yamnaya culture			
Kurgan 11, grave 3	female 45-60 years old	2835-2815, 2665-2645 (GrA-12690); 2615-2485 (IGAN-2056)	winter
Early Catacomb culture			
Kurgan 37, grave 1	child 7-9 years old	***	winter
Kurgan 37, grave 3	male? 15-18	***	very early spring
Kurgan 42, grave 1	female 40-45 years old child 1-1,5 года	1946-1884 (IGAN-2273)	summer
Kurgan 45, grave 2	male 17-20 years old	2451-2206 (IGAN-2272)	late autumn-winter
Kurgan 54, grave 5	child 9-10 years old	***	late summer
Kurgan 54, grave 3	child 11-13 years old	***	May-June
Kurgan 54, grave 6	Female 25-30 years old newborn child	2880-2699 (IGAN-2277)	late spring – early summer
Mu-Sharet-4			
Yamnaya culture			
Kurgan 8, grave 1	male 30-40 years old	***	second half of the summer
Kurgan 11, grave 4	female 25-30 years old	***	late autumn or winter
Kurgan 12, grave 1	male 17-20 years old female? 14-17 years old	3304-2923 (IGAN-2275)	Late autumn-winter
Kurgan 12, grave 2	male 35-45 years old	***	late autumn-winter
Kurgan 12, grave 5	child 6-7 years old	***	late spring – early summer
Catacomb culture			
Kurgan 9, grave 1	male 40-45 years old	***	summer
Kurgan 12, grave 4	male 50-60 years old	***	summer
Mu-Sharet-1			
Yamnaya culture			
Kurgan 1, grave 2	child 5-6 years old	***	late autumn-winter
Kurgan 3, grave 1	?	***	late spring – early summer
Kurgan 2, grave 1	male adultus	***	Summer

North Caucasus culture			
Kurgan 2 grave 3	child child	***	summer
Kurgan 6, grave 4	child 6-8 years old child 4-5 years old		summer (May, June)
Yamnaya-Catacomb culture type			
Kurgan 8, grave 3	male 17-19 years old	2278-2141 (IGAN-2055)	early summer
Early Catacomb culture			
Kurgan 2, grave 3	child 5-6 years old child 2-4 years old	***	end of summer - beginning of September
Catacomb culture			
Kurgan 2, grave 4	?	***	late spring
Kurgan 5, grave 2	female 25-40 years old	***	late spring-early summer
Shupta-1			
Yamnaya culture			
Kurgan 1, grave 5	female 18-20 years old	***	late autumn, winter
Kurgan 1, grave 2	male 20-30 years old	2460-2205 (IGAN-1890)	late autumn, winter

* Analyze of grave planigraphy let us to suppose that both skeletons were not buried at the same

** ^{14}C is so old because the sample had some Quarter soils

*** ^{14}C date was not identified

? no data obtained

So, we can make several observations based on the data from Table 1.

- Yamnaya culture groups of the pilot area (ca.3200-2400/2300 BC) moved predominately along short-distance routes: from the river to the watershed and back to the river again. These data are consistent with a previously advanced model of seasonal migrations of the Yamnaya culture groups (Shishlina at al. 2000). Though we have to note that the season of the Yamnaya culture graves from valleys of the Vostochny Manych River and the Kalaus River is late spring and summer (Zunda-Tolga1, 3; Ostrovnoy). Probably, during the climatic optimum of the Yamnaya culture Age the depth of the winter snow cover was too high and domesticated animals were not able to break the snow with their hooves in search of fodder. Local Yamnaya culture groups must have migrated to the south, i.e. the Stavropol region, or to other places in search of winter pastures.
  In watershed areas of the South Yergueni Hills we have found burials dating to all seasons, from autumn-winter to spring-summer (Mandjikiny-1, Mu-Sharet-4, 1). Local Yamnaya culture groups occupied these areas all year round, moving from pastures located on the top of the watershed plateau in spring and keeping fertile pastures located near river steppe banks intact to be used in

autumn and winter. This cycle allowed them to use family cemeteries all year round.
It is interesting to note that the identified season of “family” Yamnaya culture kurgans from Mandjikiny-2 and Shupta-1 burial mounds is only winter. Perhaps summer pastures of these Yamnaya culture groups were located far from the winter ones and these groups buried their relatives in other burial mounds.

- The season we have determined for the North Caucasus culture in this area (ca.2500-2400 BC) using the data from four burial grounds is late spring-summer. No late summer, autumn-winter, early spring graves have been found. These data have allowed us to advance a proposal that migration of the North Caucasus groups from the south areas to the north, to the steppes, took place only during warm seasons of the year. Spatial analyses of the North Caucasus culture location in the North-West Caspian steppes have shown that graves of these cultures are very seldom found to the north of the pilot area, for example, in the Middle Yergueni Hills, only three North Caucasus culture graves have been found in the area of the Caspian lowlands. There are only two such graves in the Sarpa lowlands in the north and the Volga River valley. Thus, we believe that migrations of the North Caucasus culture groups to the north, to the south part of the Kalmykia steppes were seasonal and occurred in late spring and summer.

- The Early Catacomb culture groups (ca.2500-2400 BC) buried their relatives in low-lying flood-prone areas of the Vostochny Manych and Kalaus Rivers in late spring-early summer; in upper part of the watershed plateau in the second half of spring-summer and early autumn (Mandjikiny-1 burial ground); in winter-early spring, summer-late summer, late spring (Mandjikiny-2 burial ground). Therefore we conclude that some Early Catacomb culture groups must have migrated from the south to the steppe watershed areas going back to the south (for example, to the Stavropol plateau) by the time cold winter weather set in.

  The season of one of the cenotaph of the Early Catacomb culture of Zunda-Tolga-3 burial ground (kurgan 1, grave 9) is second half of spring – early summer. Some Early Catacomb culture groups must have migrated from south to fertile watershed pastures, returning back to south (to the territory of the Stavropol Hills) by winter. In the subsequent period some Early Catacomb culture groups settled down in the South Yergueni Hills area. Our estimates indicate that their migrations coincided with the Yamnaya culture migration: from the river to the watershed and back to the river. The season of synchronous graves of the Yamnaya Catacomb type is summer.

- The earliest graves of the Catacomb culture of the area under investigation date back to ca.2600-2500 BC (Shishlina et.al. 2000), the burials of the last period of its existence date back to cal.2000-1900 BC. These groups migrated along the rivers during the warm period of the year, i.e. during spring-summer. Let us examine the following example: the group that left burials in kurgan 1 from Zunda-Tolga-3 burial ground exploited pastures near the Kalaus River during the first half of summer, then migrated to a different place.

  Catacomb culture burials of the Ostrovnoy burial ground were made at the end of winter, late spring and summer. Apparently this group spent autumn and early winter somewhere else. Watershed pastures of the South Yergueni Hills were used during early spring and summer.

CONCLUSION

Based on the analyses of kurgans and graves of the Yamnaya, North Caucasus, Early Catacomb and Catacomb cultures of the pilot area, we can establish a link between the environment and the evolution, development and spread of the Bronze Age pastoral cultures.

- There are two types of areas singled out in the southern part of the North-West Caspian Sea steppes, which were used during the Yamnaya culture period: river valleys and watershed areas located nearby. Climatic optimum at the beginning of ca.3000 BC was conducive to all year round short-distance migrations of the Yamnaya culture people.

- Gradually the climate deteriorated starting from ca.2600-2500 BC (aridization, higher annual temperature, decrease in the annual precipitation rate, decrease in forests, and replacement of dry steppe landscapes by semi-desert landscapes). Newcomers representing different cultures arrived from the south and maybe from the south-west. At first, the population of the North Caucasus and Early Catacomb cultures exploited river valleys and watershed areas only in summer (a warm season). This historical situation could have developed not only due to climatic changes, but also because of consent of the Yamnaya culture people, who were the first to use those areas. Appearance of “mixed” (multiritual) funeral goods found in the graves of both autochthonous populations and newcomers suggests that this coexistence could have been rather peaceful.

- Colonization (resettlement and settlement) may be linked only to migration (from the North Stavropol region? The Low Don area? Western slopes of the Middle Yergueni Hills?) of several Early

Catacomb culture groups that appear to have ousted the local Yamnaya culture population making them move further to the north and east. It was a gradual process. It was caused by both deteriorating climatic conditions in these areas and a social and economic situation: further development of exchange, increased mobility and changes in the overall seasonal cycle. New pastures were changed more frequently and distance of migrations became much longer because of the lack of water resources and pastures.

- Catacomb culture population was the most mobile, it fully adapted to semi-desert landscape areas. Routes of their migrations (seasonal movements) could extend across hundreds of kilometers.

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[1] Paleosoils under the kurgans of Yamnaya, Early Catacomb and North-Caucasus cultures from the Zunda-Tolga-1,2,3, Mu-Sharet-4 were analyzed as well as pollen and phytolith data.

[2] Wood identification was made by A. Golyeva and V. Filin

[3] Identification of fish bones was done by E.K. Sychevskaya

[4] Seasonality analyses was made on the basis of pollen identification as well as dentin and cementum analyses of animal and human tooth. This work was done by M.Packhomov, G.Klevezal & I.Kirillova.

Chapter 9

CHRONOLOGY OF PAZYRYK 2 AND ULANDRYK 4 KURGANS BASED ON HIGH RESOLUTION RADIOCARBON DATING AND DENDROCHRONOLOGY - A STEP TOWARDS MORE PRECISE DATING OF SCYTHIAN BURIALS

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ABSTRACT

High-resolution radiocarbon dating of tree ring sequences provides a tool to overcome complications of the radiocarbon calibration curve. The time (2500 BP) when the Pazyryk culture thrived in the steppes of Siberia coincides with wiggles on the radiocarbon calibration curve. Results of radiocarbon dating of tree logs from the Pazyryk 2 and Ulandryk 4 tombs allow wiggle matching to the calibration curve and more precise dating of the time the kurgans were constructed. The ages of 300 and 311 BC for Pazyryk 2 and Ulandryk 4, respectively, support historical dating of the finds. Our chronology provides a piece in the puzzle of the expansion and the extension of the Scythian like cultures that dominated the steppes between 800-200 BC.

Keywords: radiocarbon dating, chronology, tree-rings, wiggle matching

INTRODUCTION

There is a general quest for precise chronologies of archaeological finds. Historic data may be very useful and precise however they are not always applicable and may be controversial. Dendrochronology can provide very precise chronologies (annual resolution) wherever well-preserved tree rings are present. This is possible when there is good preservation/condition of the wood and a master chronology of the

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region exists. Another possibility is radiocarbon dating of organic material found at the sites (van der Plicht, this volume). In most cases of archeological excavations such material is present. Though due to the complexity of the dating method, a site and problem specific approach is needed.

The most common problem leading to inaccurate result in dating archeological finds is a false association of material suitable for dating with the artifacts and the cultural deposits. Reworked deposits or contamination might result in odd radiocarbon ages. On the other hand, due to the complicated nature of the radiocarbon time scale, accurate ages might provide imprecise calendar ages. This is due to the presence of the periods characterized by constant radiocarbon ages (plateau) occurring on the calibration curve. In such cases, radiocarbon ages of even the highest precision fall into a wide range of calendar ages when calibrated. Typically, presence of plateau and wiggles on the radiocarbon time scale is viewed as a problem for dating. Environmental studies of peat bogs and lakes showed ways of bypassing the problem (Hajdas, 1993; Hajdas et al., 1995; Kilian et al., 2000). As described by van der Plicht (this volume) the wiggle matching method fits sequences of ^{14}C data to the calibration curve and provides means of more precise calibration. Apart from a wide applicability in dating peat sections, wiggle matching is used to place floating varve or tree ring chronologies on the calibration curve. This method has been used in the records which attempted to extend the calibration curve (Hughen et al., 1998).

SCYTHIAN CULTURES - QUEST FOR UNIFIED CHRONOLOGY

Radiocarbon dating, especially using wiggle matching, has a potential for building a unified chronology and reconstructing a chronological frame of the Scythian culture, which is found in the vast Eurasian steppes. The kurgans, which are found across the steppe-forest belt of Eurasia, preserved parts of the world in which prehistoric nomadic people used to live. The barrows, which have been excavated since the 19th century, yield a wealth of artifacts and everyday goods found with buried bodies. They are rich in organic remains suitable for radiocarbon dating and most important many of those burials include wooden constructions. Well-preserved timbers were found in burials located in the permafrost region. There, the frozen ground prevented decomposition of wood and allowed dendrochronological dating (Seifert and Slusarenko, 1996; Slusarenko, 2000). So good was the condition of the wood that even the last ring of the growth could be found in some of the logs (Seifert and Slusarenko, 1996). The first attempts at dating using the tree rings proved to be difficult due to the lack of a master dendro curve. The first relative chronologies had to be revised and corrected (Slusarenko, 2000). Applying ^{14}C wiggle matching to setting the age of the last ring appears to be a powerful tool, which might help to solve uncertainties in the chronologies of Scythian sites (Bunker et al., 1991; Juliano, 1991).

Altai region: Pazyryk and Ulandryk

Most of the finds of Pazyryk were exceptionally well preserved thanks to the permafrost conditions. The wooden logs (larch) of burial chambers from five kurgans provided relative dendrochronologies for the Pazyryks (Slusarenko, 2000). The final relative chronology published by Slusarenko and Seifert (1996) established that the oldest of all kurgans were Pazyryk 1 and Pazyryk 2 and the youngest, Pazyryk 5, which was built 48-50 years later. Combining results of the ^{14}C wiggle matching of one kurgan (in this case Pazyryk 2) with the relative chronology enables absolute dating of other kurgans (i.e. kurgan 5, 4, 3 and 1). Moreover, the Tuekta 1and Arzhan kurgans can be also dated using the relative chronology.

Ulandryk is located on the border with Mongolia some 150-200 km to the east of the Pazyryk site. Slusarenko and Seifert (1996) obtained a long sequence of 363 tree rings from mound 4. This sequence could not be dated by means of dendrochronology because of a lack of a dendrochronological master curve. Radiocarbon wiggle matching provides a solution to this problem. Our results of dating and the results obtained by the Arizona Laboratory (Slusarenko et al., in press; are consistent and provide a high resolution floating chronology.

Radiocarbon dating

The radiocarbon samples were taken from the same wooden disks that were previously used in establishing the dendrochronology. Every second set of 10 tree rings was selected for measurement starting with the outermost 10 rings. In order to remove contamination with carbonates and humic acid, the wood was pretreated using a modified AAA method i.e. 0.5M HCl (65°C, 12 hrs) followed by 0.1M NaOH (65°C, 12 hrs) and finally with 0.5M HCl (65°C, 1hr). About 8 mg of dried wood was then placed in preheated Vycor tubes with a few grams of CuO and silver powder, which was added to remove traces of sulfur compounds. The tubes were then sealed under vacuum and left in an oven (950°C) for 2 hours to combust. The tubes were then broken under vacuum and the sample was purified of water vapor by passing the sample through a water trap during the transfer to the reaction chamber. While frozen with LN_2 hydrogen was added to allow for the reaction of CO_2 and H_2 over cobalt at 625°C as described by Hajdas (1993). Filamentous graphite formed on the surface of the cobalt powder was pressed onto the pre-roughened surface of a copper disk. Two targets were prepared for each sample in order to minimise statistical error. Each target was measured for 30 min in four runs along with standards and a blank sample (Bonani, 1999; Bonani et al., 1987).

The timber from Pazyryk 2 mound contained 231 rings. Samples for ETH were taken starting at the outermost ring. They consisted of ten rings and were sampled every ten rings. Results are shown in Table 1. The $^{14}C/^{12}C$ content of tree rings from Pazyryk 2 was measured on two targets (in one case, sample ETH-19862 four targets) in order to reduce counting error.

Eighteen samples were taken from the tree log from mound 4 of Ulandryk. Similarly, every other ten rings were sampled starting from the outermost ring (bark boundary). The resulting ages are listed in Table 2. Despite repeated measurements, two of the ages appeared to be younger than the age expected when the whole sequence is considered. These two samples must have been contaminated during sampling because no such problem occurs in the Arizona data set (Slusarenko et al., in press). All the ages listed in Table 2 are weighted means of repeated measurements, which were performed in order to minimise statistical error.

Table 1. Results of AMS ^{14}C dating of tree rings from Pazyryk 2. Sample which was measured four times is marked by star.

Lab. No.	Rings	^{14}C Age BP
ETH-19862*	231-221	2130±40
ETH-19863	211-201	2190±40
ETH-19864	191-181	2205±40
ETH-19865	171-161	2275±50
ETH-19866	151-141	2280±40
ETH-19867	131-121	2355±55
ETH-19868	111-101	2365±55
ETH-19869	91-81	2450±40
ETH-19870	71-61	2420±40
ETH-19871	51-41	2480±40
ETH-19872	31-21	2385±40
ETH-19873	11-1	2540±40

Table 2. Results of AMS ^{14}C dating of tree rings from Ulandryk 4. Samples measured four times are marked by a star.

Lab. No.	Rings	^{14}C Age BP
ETH-19844	363-353	2215±25
ETH-19845	343-333	2170±25
ETH-19846	323-313	2230±35
ETH-19847	303-293	2295±35
ETH-19848	283-273	2330±35
ETH-19849	263-253	2410±35
ETH-19850	243-233	2450±35
ETH-19851	223-213	2465±40
ETH-19852	203-193	2490±35
ETH-19853	183-173	2410±50
ETH-19854	163-153	2450±50
ETH-19855	143-133	2410±45
ETH-19856	123-113	2455±35
ETH-19857	103-93	2515±35
ETH-19858	83-73	2530±35
ETH-19859	63-53	2550±50
ETH-19860*	43-33	2410±25
ETH-19861*	23-13	2345±25

Wiggle matching of Pazyryk 2 and Ulandryk 4 using ^{2}

Variations in the atmospheric ^{14}C content are observed in records dated back to 40 ka BP. The amplitude of these changes might be extremely large (Beck et al., 2001; Hughen et al., 2004) but the Holocene period, which is of interest to this study, shows changes on the level of 50‰ which are well reconstructed by the calibration curve. There are two wiggle matching approaches that can be used to place a floating chronology (tree ring or varves) on the calibration curve. Ramsey et al., (2001) have shown that using a Bayesian approach gives similar results to the χ^2 method.

Both floating ^{14}C chronologies of Pazyryk 2 and Ulandryk 4 were compared to the INTCAL98 calibration curve (Stuiver et al., 1998) in order to obtain absolute ages for the dated timbers. We applied a □^{2} method to find the best fit to the INTCAL98 dendro curve. Figure 1 shows the final fit of the floating chronology of the tree log from Pazyryk 2 barrow. A calendar age of $300^{+25}/_{-28}$ cal BC was obtained for the last ring which dates the felling of the tree.

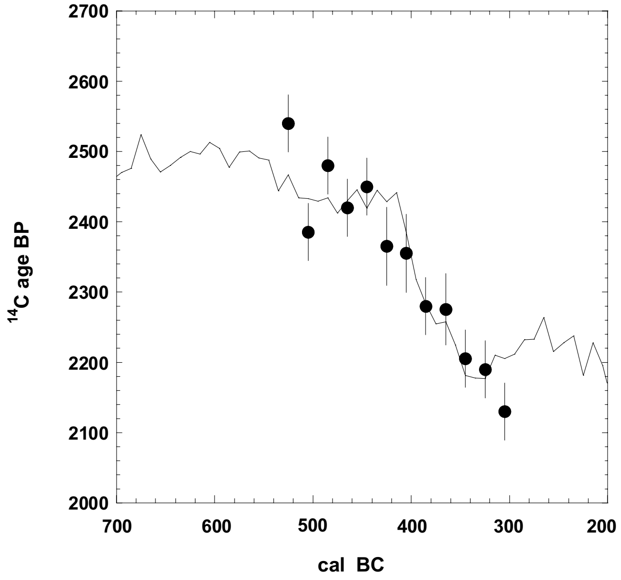

Figure 1. Radiocarbon chronology (ages plotted with one sigma error) and tree ring chronology (interval of 10 rings) of wood from Pazyryk 2 fitted to the INTCAL98 calibration curve. The youngest (outermost) rings are dated to $300^{+25}/_{-28}$ BC.

A very close calendar age of $312^{+13}/_{-21}$ cal BC was found for the last ring of the chronologies of the Ulandryk 4 burial. The two outliers in the Ulandryk 4 data set are not included in the fit procedure. On the other hand, these two points have no impact on the age of the fit, except for the error being larger (Hajdas et al., in press).

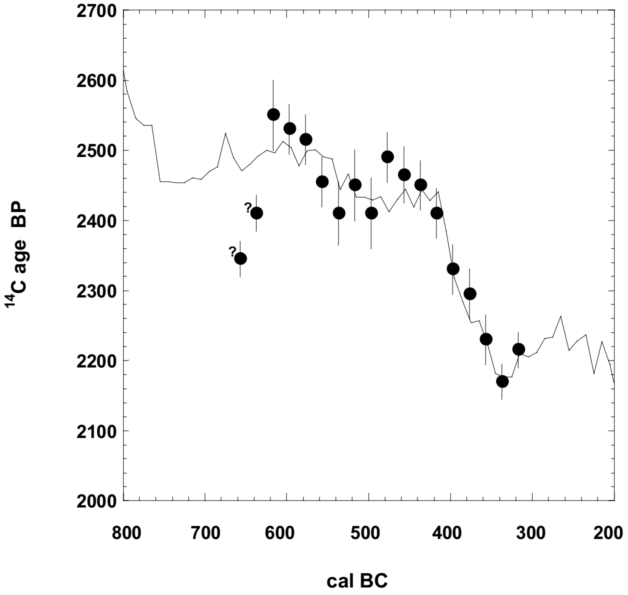

Figure 2. Radiocarbon chronology (ages plotted with one sigma error) and tree ring chronology (interval of 10 rings) of wood from Ulandryk 4 fitted to the INTCAL98 calibration curve. The two outliers (marked with question marks) were not included in the fit. The age of the youngest sample (interval which includes bark boundary) is $312^{+13}/_{-21}$ BC.

Both chronologies obtained in this study corroborate results published by other groups. Comparison of the results from Ulandryk 4 is straightforward. The very same log (#19116) has been sampled for AMS dating at Arizona AMS laboratory in such a way that most of the gaps in the ETH chronology could be filled (Slusarenko 2004). The Bayesian fit of the Arizona data set places the age of the last ring (bark boundary) at 314 cal BC (Slusarenko et al., in press). This is in a very good agreement with the χ^2 fit of our data set. However, a χ^2 fit of the Arizona data set places this sequence at $341^{+26}/_{-34}$ cal BC (χ^2=1.20). Combination of both data sets ETH and AZ results in a long (363), high-resolution record of 51 data points. A χ^2 fit of this combined data set to the calibration curve dates the last ring at $311^{+22}/_{-29}$ cal BC. Although agreement with the previously obtained date for the last ring is striking (Figure 3), the error is larger than the one obtained for the ETH data set.

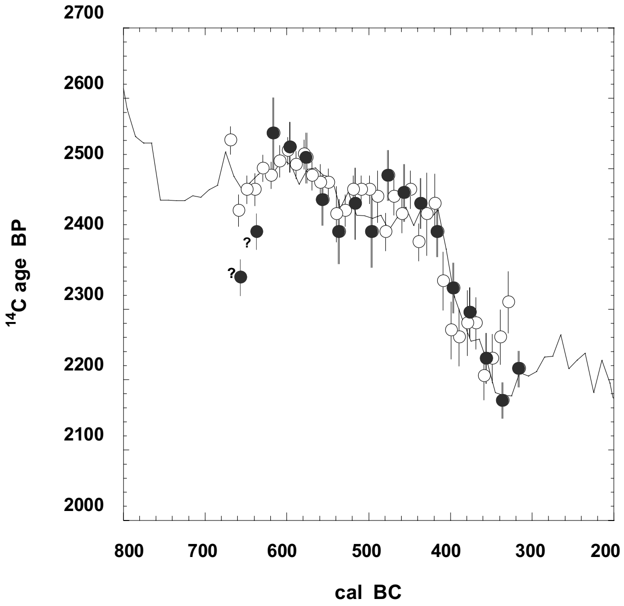

Figure 3. A combined radiocarbon chronology (ages plotted with one sigma error) and tree ring chronology (interval of 10 rings) of wood from Ulandryk 4 obtained by Arizona laboratory (empty circles) and ETH laboratory (filled circles) fitted to the INTCAL98 calibration curve. The age of the youngest sample (interval which includes Bark boundary) is $311^{+22}/_{-29}$ BC. Two outliers in ETH data set are marked with question marks.

Summarizing the results: the wiggle matching of both data sets places the age of the construction between 282 and 333 cal BC. In addition one can conclude that the Bayesian approach provided accurate absolute ages in both cases whereas χ^2 resulted in an older age for the Arizona data set. Nevertheless, both Ulandryk 4 chronologies are close and the age $311^{+22}/_{-29}$ cal BC appears to be a well-established date for the construction of this kurgan.

The result of our dating the last ring from Pazyryk 2 kurgan $300^{+25}/_{-28}$ cal BC can be compared with two other results obtained by wiggle matching. Our chronology is in an excellent agreement with these chronologies. The Belfast group determined a felling date for the larch to be between 301-282 cal BC at 2σ (Mallory et al., 2002). Similarly, (Vasiliev et al., 2001) who used a χ^2 approach in order to match the floating chronology of (Zaitseva et al., 1998), obtained an age of $298^{+10}/_{-10}$ cal BC for this event.

Chronology of Pazyryk culture

All these results indicate that the kurgans of the Pazyryk culture were constructed close to the end of 4th and beginning of the 3rd century BC. This later date is consistent with the chronology proposed by experts specialising in the history of Chinese and Central Asian art who tended to favor later dates in the late 4th or beginning of the 3rd century BC (Bunker, 1991). The narrow range of dates obtained for the Pazyryk 2 kurgan allows setting absolute age on the kurgans dated by relative dendrochronology (Table 3). This chronology can be extended to other kurgans such as Tuekta and Arzhan from the Altai region (Slusarenko, 2000). Such combined dendrochronology and wiggle matching has a potential for reconstructing patterns of migration in the region.

Table 3. Timing of construction of kurgans of Pazyryk culture based on the age of Pazyryk 2 and relative dendrochronology (Slusarenko 2000) as well as the results from literature.

Kurgan	Relative Cal Age	^{14}C wiggle matching Cal BC	Reference
Ulandryk 4		$311^{+22}/_{-29}$	This study
Ulandryk 4		314	Slusarenko et al., in press
Pazyryk 1	-5	295	This study[1]
Pazyryk 2	0	$300^{+25}/_{-28}$	This study
		301-282	Mallory et al., 2002
		298	Vasiliev et al., 2001
Pazyryk 3	-1	299	This study[1]
Pazyryk 4	-6	294	This study[1]
Pazyryk 5	50	250	This study[1]

Moreover, calendar ages obtained by calibration of ^{14}C ages of artifacts found in kurgans of Pazyryks, can now be dated more precisely. The best example is the age of the famous Pazyryk rug. This oldest known pile rug (now at the State museum of St. Petersburg), which was found in kurgan 5, has been dated at ETH AMS facility to 2245±35 BP. Calibrated ranges at 2σ are 383-332 (25.4%) and 328-200 (74.6%) (Bonani, 1999). Knowing that Pazyryk 5 is the youngest in the Pazyryk Valley and was constructed some 48-50 years after Pazyryk 2 (Slusarenko, 2000), a date between 250 and 278 cal BC (using our date for the Pazyryk 2) can be attributed to it or a date between 238 and 295 BC (based on all wiggle matching chronologies of Pazyryk 2). As a consequence the interval of calendar ages is narrowed by some 40 years to 383-332 (25.4%) and 328-238 cal BC (74.6%) at 2σ.

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[1] Age determined using age of $300^{+25}/_{-28}$ BC for Pazyryk 2 and relative dendrochronology of Slusarenko (2000)

CONCLUSIONS

High-resolution radiocarbon chronologies of two tree logs from Pazyryk 2 and Ulandryk 4 helped to establish the time of construction of these two kurgans as well as other kurgans in the Upper Altai region. Dating the kurgans to the late 4th/early 3rd century BC is in good agreement with studies of artifacts from this region. Thanks to the relative dendro dating of kurgans and the ^{14}C wiggle matching of Pazyryk 2, the age of the Pazyryk rug from kurgan 5 can be dated more precisely. We propose that such an approach might reveal more about relative chronologies of kurgans as well as about the purpose and production of artifacts found inside the barrows.

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Chapter 10

PROBLEMS OF CONSTRUCTION OF A RADIOCARBON CHRONOLOGY FOR THE TIME PERIOD 900-300 CAL BC

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ABSTRACT

This paper considers modelling the ^{14}C calibration curve using a variety of mathematical approaches. The main focus was the period of the 1st millennium BC which is characterized by fluctuations of the ^{14}C concentrations in the atmosphere. This results in a non-linear relationship between the radiocarbon age and calendar age. The present study focuses on the influence of the calibration curve on statistical inference concerning time intervals of archaeological cultures and phases. The result shows that for the first millennium BC the time intervals estimated on the basis of calibrated radiocarbon dates differ from the real intervals on the calendar timescale.

Key words: calibration curve, radiocarbon age, calendar age, mathematical statistics.

INTRODUCTION

The time period of the first millennium BC is characterized by large fluctuations in the radiocarbon concentration in the atmosphere. These changes mean that the radiocarbon calibration curve (the relationship between radiocarbon age and calendar age) is complex and for the time interval 400-750 cal BC relatively flat (see Figure 1). Therefore we can expect that time intervals estimated on the basis of calibrated radiocarbon dates may differ from the real time intervals on the calendar timescale. The paper presents a solution to this problem.

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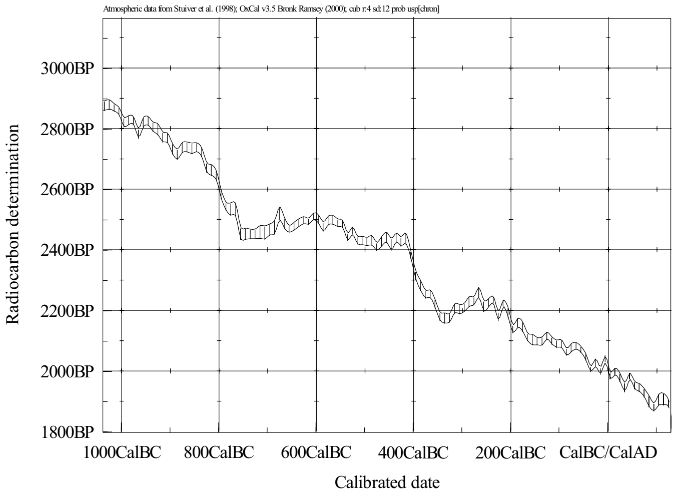

Figure 1. Calibration curve for the first millennium BC (plot produced by OxCal ver3.5).

The time interval of an archaeological phase or other phenomenon may be estimated using a group of radiocarbon dates of artefacts associated with this phenomenon. One of the methods of estimation is to create the cumulative probability density distribution by summing the distributions of the individual calibrated dates. The 50% confidence interval (interquartile range) or highest probability confidence intervals of this distribution are usually interpreted as time limits of the phenomenon. This method was applied for the presented analysis.

METHOD OF ANALYSIS

At the beginning of the analysis the value of the real time span of the phenomenon was assumed known. The analysis was repeated for values of the time span of 200, 500 and 100 calendar years. Because the idea was to concentrate on the influence of calibration curve the following assumptions were made:

- The frequency distribution of artefacts is uniform in the range of the time interval of phenomenon,
- calendar ages of collected samples (artefacts) uniformly cover the whole time interval.

Therefore the calculation steps were as follows

1. We assumed that 11 samples (artefacts) were collected for the analysed time interval. The calendar ages of the samples for the 200 year interval were assumed to be equal in sequence: *the beginning of interval, the beginning of interval+20 years, the beginning of interval+40 years, ..., the end of interval.* For 500 or 100 years intervals the values 20, 40 etc. were replaced with 50, 100 etc. or 10, 20 etc in the above sequence.

2. For each calendar date of the sample, the corresponding radiocarbon age was determined from the calibration curve.
3. Each radiocarbon date was calibrated with the assumption that the error of the radiocarbon date was equal to 25 years.
4. All probability density distributions obtained as a result of calibration were summed in order to calculate a cumulative probability density distribution.
5. On the basis of this cumulative probability density distribution, the following intervals were calculated: interquartile range, the highest probability 50% confidence interval and the highest probability 95% confidence interval.

Calculations were executed using the revised and updated calibration module of Gliwice Radiocarbon Laboratory Calibration Programme GdCALIB (Pazdur, Michczyńska, 1989; Michczyńska et al, 1990).

RESULTS

An example is presented in Figure 2 and shows a number of different types of distortions of the calculated intervals, which may occur.

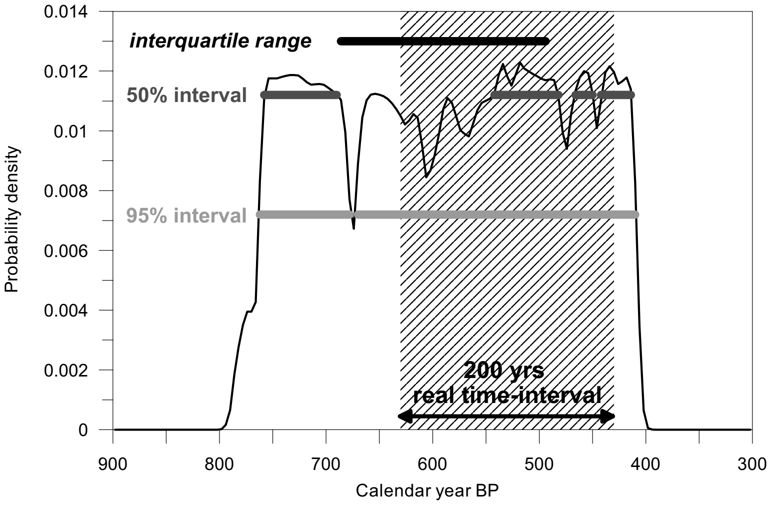

Figure 2. Cumulative probability density function for 11 samples from time interval 630-430 cal BC (dashed area in Figure). The calendar ages of samples uniformly cover the whole 200 years interval i.e. they are equal in sequence: 630 BC, 610 BC, 590 BC, ... , 410 BC, 430 BC. The assumed error of radiocarbon dates = 25 years. Thick horizontal lines show 50% confidence interval (interquartile range) and the highest probability 50% and 95% confidence intervals.

We may notice that:

a) Large parts of each calculated interval lie outside the real time interval,

b) the 95% confidence interval is much wider than the real time interval and c) all calculated intervals are wider than intervals when the influence of the calibration curve is omitted,

The interquartile interval is clearly shifted relative to the real time interval. In order to estimate how important these distortions are for particular time intervals, the following *overlap factors* were defined:

CI Factor which is equal to the length of the common part of the real time interval (Input Interval) and calculated interval (Output Interval) divided by the length of the Input Interval. *CI Factor* describes which part of the real time interval overlaps the calculated interval.

CO Factor which is equal to the length of the common part of the real time interval (Input Interval) and calculated interval (Output Interval) divided by the length of the Output Interval. *CO Factor* describes which part of the calculated interval overlaps the real interval.

If we compare the values of *CI* and *CO Factors* for a particular interval with the values of these factors for the ideal case (when the influence of the calibration curve is omitted) we can draw the following conclusions about the distortion of the calculated interval:

- when *CO Factor* < *CO Factor* $_{ideal\ case}$ then the calculated interval is wider than the real interval or shifted relative to the real one.
- when *CI Factor* > *CI Factor* $_{ideal\ case}$ then the calculated interval is wider than the real interval,
- when *CI Factor* < *CI Factor* $_{ideal\ case}$ then poor agreement between calculated and real interval is apparent – the calculated interval may be shifted in relation to the real one.

Figures 3 and 4 show the results of calculation of *Overlap Factors* for each 200-years time interval from the beginning of the first millennium cal BC (interval 100 AD-100 BC) to the end of the millennium (interval 900 BC-1100 BC).

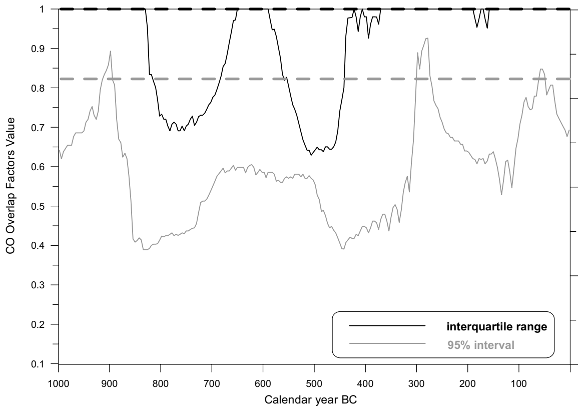

Figure 3. CO Factors for interquartile interval and the highest probability 95% confidence interval calculated for each 200 years time interval from the beginning of the first millennium cal BC to 1000 cal BC. Black and grey dashed lines show the values of *CO Factor* at ideal case respectively for interquartile range and for 95% interval.

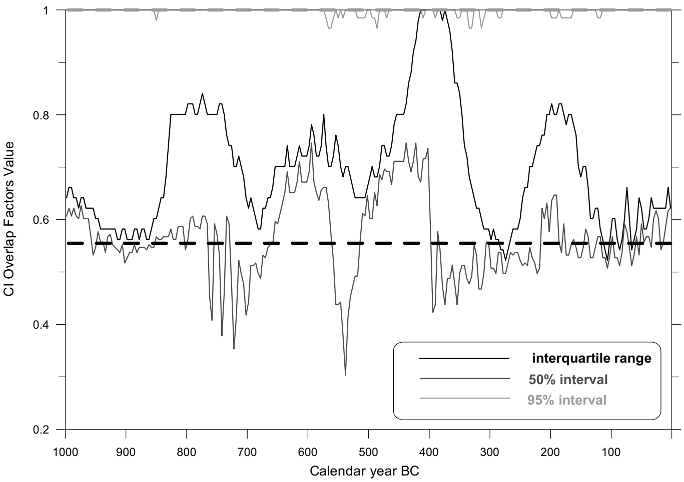

Figure 4. CI Factor for interquartile range, the highest probability 50% and 95% confidence interval calculated for each 200 years time period from the beginning of the first millennium cal BC to 1000 cal BC. Black and grey dashed lines show the values of *CI Factor* at ideal case respectively for interquartile range (and 50% confidence interval) and 95% confidence interval.

The calculated values are assigned to the middle of the considered interval - for example: values of *Overlap Factors* for the interval 400 BC-600 BC are assigned to 500 BC. We see (see Fig.3), that the *CO Factor* value for the 95% confidence interval is almost always lower than in the ideal case. Especially low values are observed for periods 850-750 BC and 480-340 BC. It should be emphasised, that these periods correspond with the periods where the *CO Factor* value for the interquartile interval is low. Figure 4 shows, that the values of *CI Factor* for the interquartile range are almost always greater than the value of this factor in the ideal case. Therefore we may draw the conclusion, that for the 1st millennium BC the calibration curve produces calculated intervals which cover a wider interval than the real time interval. Moreover the calculated intervals for periods 850-750 BC and 480-340 BC are probably shifted in relation to the real time intervals.

Another form of presentation, which clearly shows periods, where the calculated intervals are shifted in relation to the real intervals is presented in Figure 5.

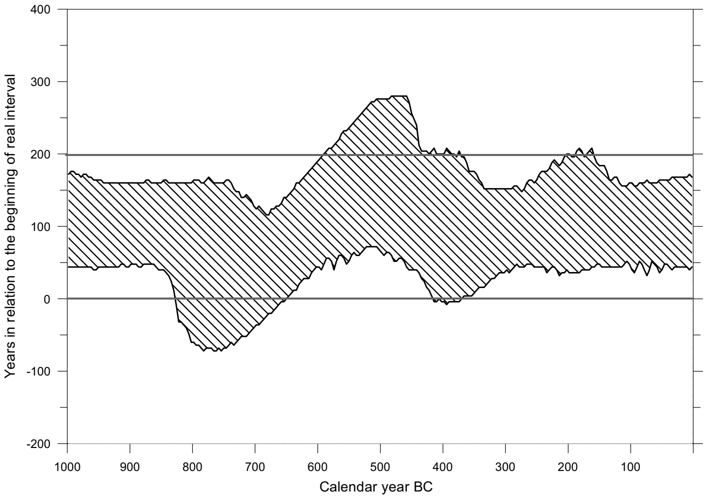

Figure 5. The values of interquartile range shown in relation to the beginning of the real interval calculated for each 200 years time interval from the beginning of the first millennium cal BC to 1000 cal BC . Grey lines show the limits of the real time interval.

This figure presents values of the end and the beginning of the interquartile intervals in relation to the beginning of the corresponding real intervals. We see, that for periods 850-650 BC and 600-350 BC the interquartile intervals are evidently shifted. Figures 6 and 7 show the values of the interquartile intervals in relation to the beginning of the real intervals for each 100-years time interval and 500-years time interval from the beginning of the first millennium cal BC to the end of the millennium. The shift of 100-year intervals occurs for the same periods as the shift for 200-years intervals, but it is much greater than the latter. On the other hand we may notice, that there are no important shift for 500-years intervals.

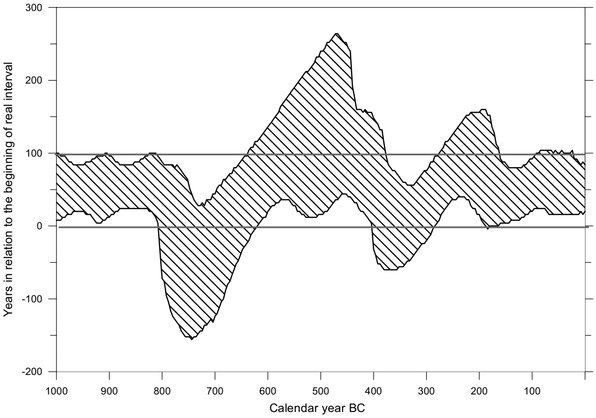

Figure 6. The values of the interquartile range shown in relation to the beginning of real interval calculated for each 500 years time interval from the beginning of the first millennium cal BC to 1000 cal BC . Grey lines show the limits of the real time interval.

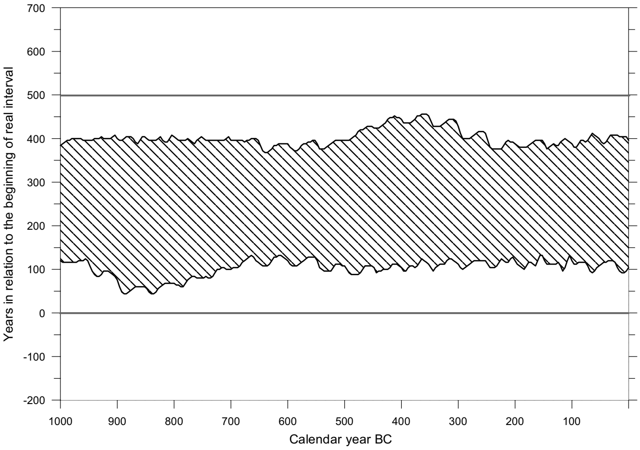

Figure 7. The values of interquartile range shown in relation to the beginning of the real interval calculated for each 500 years time interval from the beginning of the first millennium cal BC to 1000 cal BC . Grey lines show the limits of the real time interval.

CONCLUSIONS

1. The calibration curve almost always results in a cumulative probability density function of a group of radiocarbon dates associated with the phenomenon which covers a wider interval than real time period of this phenomenon. Therefore calculated intervals are often wider than the real intervals.
2. For the first millennium BC the calculated intervals are often clearly shifted in relation to real time intervals – especially for the periods 850-650 BC and 600-400 BC.
3. Differences between calculated intervals and real time intervals are more important for short time intervals.

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Chapter 11

POSSIBILITIES AND LIMITATIONS OF THE USE OF STABLE ISOTOPES ($\delta^{13}C$ AND $\delta^{15}N$) FROM HUMAN BONE COLLAGEN AND CARBONATE AS AN AID IN MIGRATION STUDIES

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ABSTRACT

Stable isotope data (δ ^{13}C and $\delta^{15}N$) from bone collagen are dietary indicators. The isotopic fractionation of the carbon and nitrogen atoms in the amino acid chains from collagen reflects the isotopic fractionation in the food proteins. Stable isotope values make it possible to distinguish herbivores from carnivores, and to further distinguish between marine and terrestrial sources of food.
Keywords: stable isotopes, diet, migration

INTRODUCTION

It is well known that the $\delta^{13}C$ and $\delta^{15}N$ values in the body reflect the diet of an organism, a phenomenon that is now with increasing frequency used for dietary reconstructions within archaeology (see Sealy 2001 for an introduction). Stable isotope values can also be influenced by climatic conditions or by the geological context (see further). This paper reiterates the fact that, based upon these phenomena, isotopic fingerprints can also be used in migration studies. The aim of this contribution is not to present a complete overview of the literature and case studies, but to provide an introduction to the subject, illustrated by some examples and data from the authors' own work.

E.M. Scott et al. (eds.), Impact of the Environment on Human Migration in Eurasia, 125-135.

DIETARY RECONSTRUCTIONS

The basic models

Although the analysis of plant and animal remains from an excavation site can reveal which species were used and consumed, it remains impossible to evaluate the true importance of animal versus plant products in the diet by means of these remains alone. Taphonomic factors such as differential preservation, sampling bias and site type (e.g., ritual versus habitation sites) will bias the palaeo-dietary information obtained from any consumption refuse. However, an alternative approach to dietary reconstruction comprises the analyses of the isotopic fractionation of bone collagen and carbonate from human skeletons, using the same analysis on contemporary animal bones as a comparative test. One of the principal advantages of this method is the fact that the actual food digested by a single individual can be evaluated.

The concept of using bone isotope measurements to obtain dietary information is based on the assumption that the isotopic fractionation of the food is conserved through the food chain. Lee-Torp *et al.* (1989) proposed a simple model for the terrestrial food chain (Table 1), based upon the principle that the carbon isotope fractionation of bone collagen is a function of the isotope ratio of the protein fraction within the food. The difference between the isotope ratios of the food and of the consumer has been termed ‘trophic shift’. This model has been altered and expanded by several authors (including also nitrogen isotopes), and it was concluded that the trophic level shifts within the food chain ideally should be +5‰ for δ^{13}C (Ambrose 1993) and +2 to +4‰ for δ^{15}N (Ambrose 1991).

Table 1. Evolution of the isotopic fractionation of (collagen) carbon along the food chain.

food chain	**δ^{13}C ‰**
A: vegetation	X
B: bone collagen from herbivores eating A	Y = (X + 5)
C: bone collagen from carnivores eating B	Z = (Y + 5)

Evaluation of these theoretical predictions, on the basis of actual measurements on naturally obtained material, often shows widely differing values. In a study by Bocherens (2000), an enrichment of approximately 1‰ in δ^{13}C between herbivores and carnivores was found, and an enrichment of around 4‰ in δ^{15}N. For humans (and other omnivorous animals), the situation is complicated because they utilise a wide variety of foodstuffs, all showing very different isotopic fractionations (see Lanting and van der Plicht 1996: Table 2). In general, it is now clear that the variation in trophic shift measurements is high (see also further). This is again illustrated by Figure 1 in which the isotope values from bone collagen from both prehistoric domestic animals (mostly sheep and goat) and contemporaneous humans from the Balearic Islands are depicted (Van Strydonck *et al.* 2002b; Van Strydonck *et al.* in prep. a). In this case, variation within each group is high and the two clusters almost overlap.

Additional dietary information comes from the analysis of other bone components, other than collagen alone. Whilst collagen reflects the isotope ratios of the protein fraction within the food, the carbonate hydroxylapatite value of the mineral fraction of the bone is considered to reflect the isotope ratios of the whole diet (van Klinken *et al.* 2000). Moreover, the evaluation of the 'spacing' between the $\delta^{13}C$ values of the collagen and the carbonate fractions ($\Delta\ ^{13}C$) gives additional information about the herbivorous or carnivorous nature of the diet, this 'spacing' value being much larger for herbivores than for carnivores. According to Bocherens' study (2000) on animals from arctic and temperate ecosystems, this difference amounts to $\Delta\ ^{13}C = 7.9 \pm 1.1‰$ for herbivores, and $\Delta\ ^{13}C = 4.0 \pm 0.4‰$ for carnivores. However, this measurement also exhibited wide variation between tested populations. A study on domestic animals (mainly sheep and goat) from Bronze and Iron Age sites from the Balearic Islands (Van Strydonck *et al.* in prep. a), for example, yielded an average spacing of $\Delta\ ^{13}C = 11.3 \pm 2.1‰$.

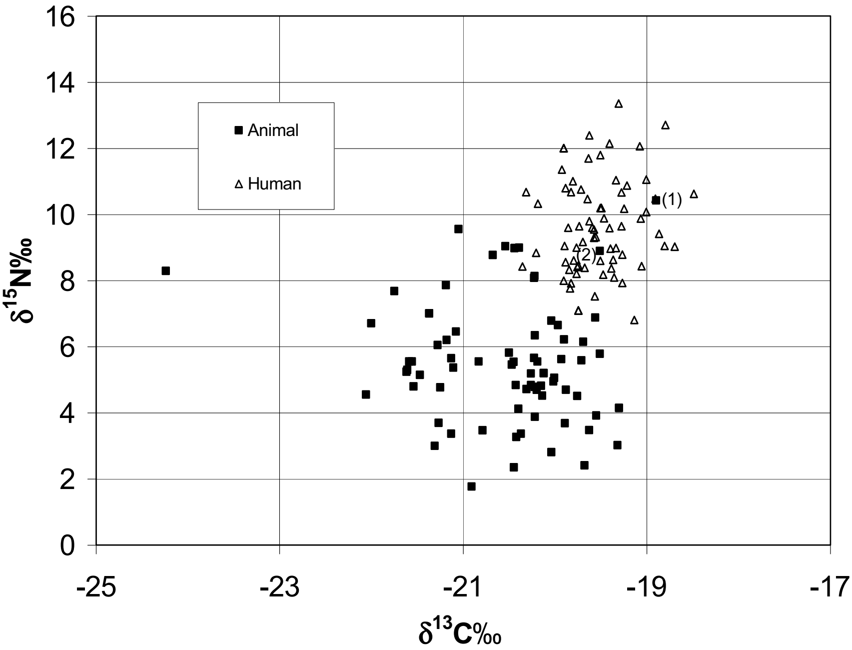

Figure 1. Domestic animals, and humans with a terrestrial omnivore diet from the Balearic Islands (Van Strydonck *et al.* 2002b; Van Strydonck *et al.* in prep. a). The large scatter of the data is observed. Two outliers could be identified: (1) a dog that probably had the same diet as the humans and (2) a goat jaw were probably tooth dentine with a different isotope signature as bone collagen was measured.

Table 2. Isotopic fractionation of carbon and corresponding reservoir age.

bone collagen from animals having a 100% diet of:	**$\delta^{13}C$ ‰**	**$\delta^{15}N$ ‰**	**reservoir effect (years)**
C-3 plants	-21	+5	0
meat C-3 herbivores	-18	+8	0
C-4 plants	-7	+5	0
marine food	-13	+18	400 (Atlantic coast)
river fish	-24	+16	1500-2500
lake fish	-20	+16	500-1500

DIET AND MIGRATION STUDIES: DIFFERENCES BETWEEN INDIVIDUALS

Given the variation demonstrated above, a comparison between the isotopic fractionation of an individual (or of a group) and that of the environment (i.e., an evaluation of the trophic shift), will almost never yield conclusive evidence, linking the human population and the environment. Instead, the comparison between a group and specific individuals can produce clearer results. When, through chemical analysis of the bones, dietary differences are inferred within a large group of humans of comparable date, this could indeed point to the presence of immigrants. When immigrants have consumed a diet comprising different components, compared to that of the residents, or if their diet was similar, but composed of constituents with different chemical characteristics (i.e., derived from a different climate zone or ecosystem), their isotopic signature could be different. Considering variation is always rather high for isotopic measurements, the larger the differences between the diets, the clearer the differences will be between the isotopic signatures. This is especially true between diets dominated by C_3 as opposed to C_4 plants, or between diets rich in fish versus ones merely consisting of meat (see Table 2).

Crucial within this context is how long bones can reflect the diet of the homeland. In 'living' bones, due to different rates of re-modelling through life, the apparent or reservoir ^{14}C age of a bone is estimated between 0 and 30 years, depending on the age of the person (Geyh 2001, Van Strydonck *et al*. 1999). Although the differences are small, the isotopic signature reflects not the situation at death, but the situation in an earlier stage of a person's life, and this not only for ^{14}C but also for ^{13}C and ^{15}N. As a rule of thumb, in human bones, the mean carbon uptake in collagen begins to diminish at an age of 19, the subsequent carbon exchange rate being very slow. Thus, older persons, that have lived the whole of their younger lives at a certain location and have moved at an advanced age, are probably the most useful in providing evidence for migrations. In a new environment, younger individuals will remodel the chemical composition of their skeletons too quickly to reveal any traces of diet from their homeland.

In their study of a large sample of human remains from the Kellis 2 cemetery (*c.* 250 AD) in the Dakleh Oasis, Egypt, Dupras and Schwarcz (2001) were able to identify, on the basis of stable oxygen and nitrogen isotope ratios, at least two persons that could not have lived all their lives in the oasis but must have come from elsewhere, most probably the Nile Valley. Of course, the specific characteristics of the isolated oasis environment have exaggerated the dietary distinction between its inhabitants and the people from other parts of Egypt. In most populations, the recognition of 'outliers' will be hampered by the relative conformity of diets between residents and immigrants, and by the large scatter of the data, caused by differences on the individual level, within the resident population. This implies that a large dataset is always needed and that the observations must be treated statistically. Furthermore, it should always be tested whether there are differences within the population that could be related to sex or age group (see, e.g., the approach taken by Dupras and Schwarcz 2001).

Even when isotopic differences are observed within a population, they do not necessarily have anything to do with migration. Take, for example, a resident population eating the meat of herbivores belonging to flocks that are herded in different environments in the area around the settlement. Variations in isotope fractionation between the flocks could have been caused by differences in the plants they consumed (Tieszen 1991; Tieszen and Boutton 1988) but also by the different parts of the same plants (e.g., roots, leaves) they consume. It has also been noticed that there might be a geographical, probably a climatologic, trend in the $\delta^{13}C$ ‰ values (Nakamura *et al.* 1982; van Klinken *et al.* 1994, 2000). Isotopic shifts can also be caused by differences in altitude, soil acidity (Mariotti *et al.* 1980) and salinity (Karamanos *et al.* 1981), and by the local amount of sunshine, humidity and rainfall (see, e.g., the 'canopy effect': Bada *et al.* 1990). Therefore, the $\delta^{13}C$ of the bone collagen of a herbivore (and of the humans that eat that animal) will thus be significantly determined by its foraging conditions and habits (Heaton 1999).

Beside these natural fluctuations, the data from human bones can also be influenced by cultural differences (Van Strydonck and Wouters, 2001). Within one group of individuals there can be differences depending on personal taste, availability of certain products, status and ideological context. Published and unpublished stable isotope data from bone material from Catholic saints and clerics from the Low Countries (Van Strydonck *et al.* 2001; Van Strydonck *et al.* 2002a) show values that most probably have nothing to do with migration but can be explained by the differences between the almost vegetarian diet of certain monks and a diet with a significant addition of meat, and most probably also of (freshwater or marine) fish, consumed by the remaining monks and by the saints (Figure 2).

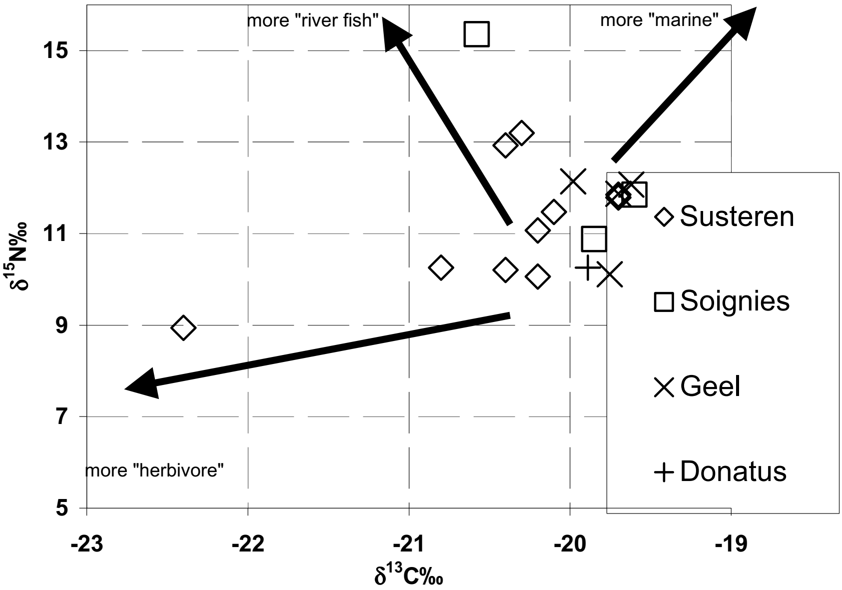

Figure 2. Published and unpublished stable isotope data from Catholic saints (Soignies, Geel, Donatus) and clerical people (Susteren)from the Low Countries (partly after Van Strydonck *et al.* 2001; Van Strydonck *et al.* 2002a).

The archaeological context must also be considered, in respect of differential preservation conditions which can cause differences in the isotopic signatures of elements within a population sample. Archaeological bones will suffer from an additional isotopic fractionation due to degradation processes or contamination of the buried bones (Sullivan and Krueger 1981). This leads in most cases to a lower $\delta^{13}C$ and a higher $\delta^{15}N$ value. The conservation of bones and the preservation of the isotopic signature depends mostly on the characteristics of the soil (humidity, acidity, temperature, presence of oxygen, etc.) and on the stability of these conditions. Deterioration can cause *in situ* humification of the collagen, the absorption of (contamination by) soil derived humic substances and even the complete leaching of the organic substance of the bone. Fortunately, collagen preservation can be checked in various ways, a combination of which gives the best estimation of bone quality. The visual effect of humification of the bone collagen consists of the colour of the collagen-derived gelatine changing from bright white, for an undeteriorated sample, to beige and even brown, for a sample suffering from humification (most methods to extract collagen from bones are based on Longin 1971). The collagen recuperation rate (weight collagen : weight bone), the carbon-nitrogen ratio of the collagen (C:N), and the % of C in the collagen are other parameters for bone quality. Although the collagen content of fresh bone can be up to 20%, most well preserved archaeological bones do not contain more than 10% of collagen-derived gelatine. A very low collagen content, however, is a strong indication of deterioration and possible contamination (Van Strydonck *et al.* in prep. b). Amino acid analyses on archaeological material have indeed shown that, in the case of a low collagen content, the sample contains significant quantities of humic acids. The atomic C:N ratio for well preserved bones is around 3. Van Klinken (1999) reports an average of 3.29 ± 0.27 (n=2146) for the Oxford laboratory. De Niro (1985) states that this ratio should be below 3.6.

DIET AND MIGRATION STUDIES: DIFFERENCES WITHIN AN INDIVIDUAL

Evidence for migration can also be found by comparing the dietary signature of different parts of an individual skeleton. This approach is based upon the observation that certain elements are formed at an early stage in life, and then stay unaltered, while others can be remodelled until rather late in life. In humans, the dentine and enamel of teeth are formed during a short period at a young age. Once the teeth are formed there is no carbon or nitrogen exchange anymore with the environment or with the body. Human bones, however, remain open for remodelling although the mean carbon uptake in the collagen starts to diminish at an age of 19. Consequently, when people have moved at some point in their life, after the teeth had formed, but while the bones were still being remodelled, their dentine can reflect the diet of the homeland, while the collagen of their long bones will mostly reflect the diet at the subsequent place of residence.

Using the analysis of $\delta^{13}C$ and $\delta^{15}N$ ratios in teeth and bones, Sealy *et al.* (1995) have been able to trace the life histories of several South-African individuals. Another good example of this type of inference (albeit based upon other stable isotopes than the ones discussed here), is the analysis of the ‘Iceman’ found in 1991 in the Alps. The isotopes from the teeth revealed that this individual, as a child, must have lived in an area different to that where the remains were found, whilst the adult skeleton reflects an admixture of influence from the area in which the person died. Together, the picture that emerges is of a person born in a lowlying valley settlement, who after reaching adulthood seasonally migrated with his flocks to higher mountain meadows (Müller *et al.* 2003).

CLIMATE AND GEOLOGY

Apparently different isotopic signatures associated with immigrants compared to resident populations, may also have been caused by differences in climate in the immigrants’ homeland, instead of by dietary patterns. Indeed, the $\delta^{13}C$ ratio in living organisms is also temperature dependent (van Klinken *et al.* 1994, 2000), while there is an effect of precipitation on the $\delta^{15}N$ ratio (Heaton *et al.* 1986). However, the stable isotope mostly used for studying the impact of temperature is ^{18}O (Schwarcz *et al.* 1991). It is clear that, when interpreting results related to climatic variation, all biasing factors outlined above for diet composition, must also be taken into account.

Without doubt, human migration studies will benefit in the near future from the development of the analysis of other groups of isotopes. The analysis of strontium isotope ratios has been shown to have potential in this field, revealing migration on the basis of varying geology (Price *et al.* 1994, 2000). In the case of the Iceman, the measurement of argon isotopes has also been used to reconstruct geological characteristics of his origins (Müller *et al.* 2003). Recently, sulphur isotope values have been used to indicate proximity to the maritime coast (Richards *et al.* 2001).

CONCLUSION

It is clear that the analysis of ^{13}C and ^{15}N stable isotopes has a potential within human migration studies but that the many sources of variation will always hamper interpretations. The observation of 'outliers' within a population must always be evaluated against possible biases caused by natural or cultural factors, or by archaeological preservation conditions. Furthermore, the variation on the phenomenon of 'tropic shift' will make it difficult to compare human (or animal) material with its environment. The movement of complete populations (instead of a few immigrants) can thus remain undetectable. In general, it seems that the comparison of the isotopic signatures of teeth and bones form the most promising approach.

Finally, the possibility always remains that food was on the move instead of humans. It must not be forgotten that migration did not always necessarily cause an isotopic shift, since the source area and the new area may have been ecologically similar, thus causing no change in the isotopic composition of foodstuffs. For migration studies, the absence of evidence is thus no evidence of absence.

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Chapter 12

OSL DATING IN ARCHAEOLOGY

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ABSTRACT

The OSL (optically stimulated luminescence) dating method exploits dosimetric properties of grains of minerals naturally occurring in sediments and man-made materials.

In archaeology the OSL method is used to date pottery and other heated materials (e.g., bricks, stones, earth) or sediments related to archaeological finds. The significant improvement of the OSL dating method in recent years makes it applicable to objects ranging in age from 0 to 150 000 years (in some cases to 300 000 or more) with a typical accuracy between 5 and 10%. When compared with the radiocarbon method it makes possible dating objects containing no organic matter or originating in periods for which the radiocarbon method is less accurate due to the shape or lack of the calibration curve.

This paper discusses the details of recent advances in the method and several examples of its application to material from archaeological excavations of Medieval to Palaeolithic sites.

Key words: chronology, luminescence, dating, radioactive dose, archaeology, pottery

INTRODUCTION

The OSL (optically stimulated luminescence) dating method exploits dosimetric properties of grains of minerals naturally occurring in sediments and man-made materials (Huntley et al., 1985; Aitken, 1998). Energy of ionising radiation released by natural radioisotopes is absorbed and stored in the crystal lattice of minerals. It may be released in the form of light (luminescence) upon heating or excitation with visible or infrared light. The amount of luminescence depends on the absorbed dose of radiation and thus enables assessment of the dose. In certain circumstances the dose absorbed per year is stable through time and may be estimated based on spectrometric measurements of radiation emit-

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ted from the dated object and, if necessary, from the soil surrounding it. Thus it is possible to calculate the time during which the absorbed dose was accumulated. The time calculated in this way equals an age of a dated object if mineral grains were reset at the time of the object's origin. The most important factors resetting the crystal lattice of mineral grains, that is zeroing the measured luminescence and absorbed dose, are elevated temperature higher than ca 450 – 500°C, and exposure to sunlight. It practically means that the OSL method dates the last heating or the last light exposure of mineral grains, narrowing the range of datable objects to ceramic (or similarly fired materials) or sediments containing grains that were exposed to light during or prior to sedimentation.

In archaeology the OSL method is used to date pottery and other heated materials (e.g., bricks, stones, earth) or sediments related to archaeological finds. The significant improvement of the OSL dating method in recent years makes it applicable to objects ranging in age from 0 to 150 000 years (in some cases to 300 000 or more) with a typical accuracy between 5 and 10%. When compared with the radiocarbon method it makes possible dating objects containing no organic matter or originating in periods for which the radiocarbon method is less accurate due to the shape or lack of the calibration curve.

PHENOMENON OF LUMINESCENCE

Light emitted by any source is either incandescence or luminescence. This is due to the definition of these physical terms. Incandescence is the emission of light by a hot object. On the contrary, luminescence is the emission of light by sources other than a hot, incandescent body. For this reason it is sometimes referred to as cool light. It is caused by transitions of electrons within a substance from more energetic states to less energetic states. Several types are quite common: chemiluminescence, electroluminescence, and triboluminescence, which are produced, respectively, by chemical reactions, electric discharges, and the rubbing or crushing of crystals.

Incandescence is thermal radiation, and is emitted at the expense of internal (thermal) energy of the hot body, and obeys the general principles of thermodynamics.

Luminescence is radiation emitted through entirely different mechanisms and its spectrum reflects electronic properties of the emitter. For example, spectrum (colour) of light emitted by popular electroluminescence diodes (LED) depends on the semiconductor material and on impurities it was doped with during manufacturing. Energy emitted as luminescence comes from sources other than thermal energy of the emitting body. Depending on the type of energy converted into light we may refer to luminescence under different names. Table 1 gives the most common types of luminescence.

Table 1. Types of luminescence

type of luminescence	type of energy
triboluminescence	mechanical
chemiluminescence	chemical
bioluminescence	chemical (in a biological system)
electroluminescence	electric
sonoluminescence	acoustic
radioluminescence	ionising radiation

Within this division OSL belongs to radioluminescence as the optically stimulated luminescence is emitted at the expense of energy that was deposited in the object by ionising radiation. Radioluminescence is further divided into fluorescence and phosphorescence.

Fluorescence is a phenomenon in which light is emitted from certain substances when irradiated by electromagnetic or corpuscular radiation, especially ultraviolet light. The light is emitted only while the stimulation (irradiation) continues. Depending on the type of incident radiation it may be called: cathodoluminescence, roentgenoluminescence, photoluminescence, etc. For example, the television CRT screen emits mostly cathodoluminescence, while popular fluorescent lamps emit photoluminescence.

In some cases the absorbed energy of incident radiation is stored (in the crystal lattice, for example) and released after a delay in response to other stimulus. The light emitted in this way is called phosphorescence. Phosphorescence is distinguished from fluorescence in that it continues even after the radiation causing it has ceased. The luminescence is caused by electrons that are excited by the radiation and trapped in potential troughs, from which they are freed by the thermal motion within the crystal or by delivering necessary energy in another form. As they fall back to a lower energy level, they emit energy in the form of light. The OSL is thus phosphorescence emitted in response to the visible light stimulus. The closely related IRSL (infrared stimulated luminescence) is phosphorescence emitted due to energy delivered to trapped electrons by infrared light. Thermoluminescence (TL) is a more distant cousin of these two, where trapped electrons are freed by thermal energy upon heating to temperatures of 500°C, that is to the temperature at which incandescence becomes prominent in the visible wavelength region. Phosphorescence, either OSL, IRSL or TL, usually quickly fades as the exposure to the stimulus prolongs (see Fig. 1). It cannot be observed after all the previously stored energy is released by the stimulus. A new dose of ionising radiation is necessary in order to restore the ability to emit luminescence.

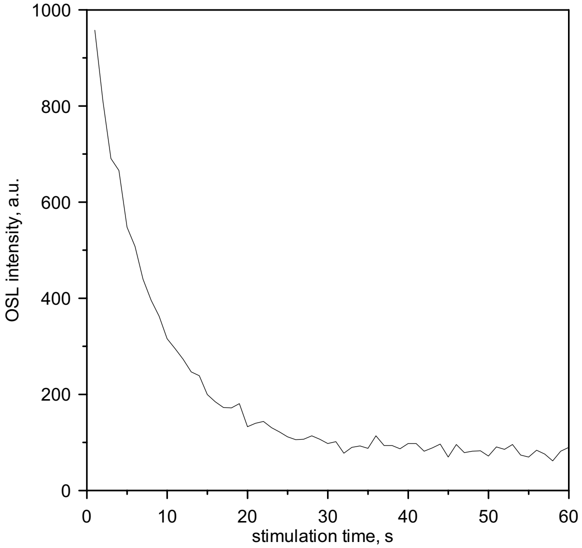

Figure 1. OSL intensity plotted versus stimulation time during the laboratory readout.

The amount of luminescence is a function of the absorbed dose of ionising radiation as shown in Fig. 2.

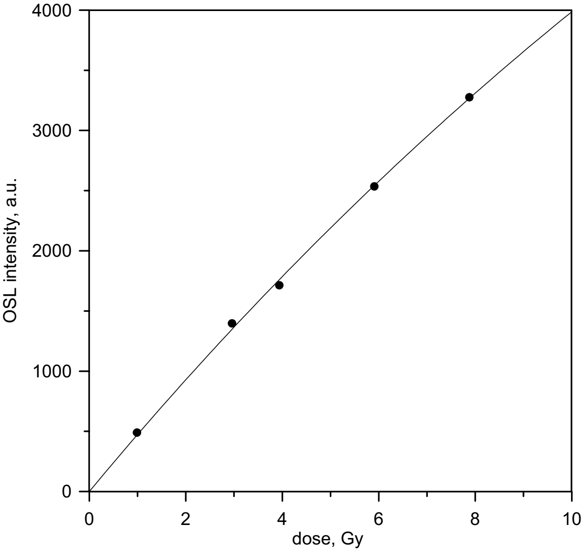

Figure 2. Dependence of OSL intensity (expressed in arbitrary units) on the absorbed dose of radiation. Points are results of OSL measurements on a single aliquot of about 1 mg quartz grains using the regenerative dose procedure.

The OSL growth curve for quartz grains saturates at higher doses around 500 Gy, which imposes a natural upper limit to the absorbed dose that can be assessed based on OSL measurements. This in turn limits the range of the OSL dating method.

LUMINESCENCE DATING

At the present time the most widely used method of luminescence dating employs sand size quartz grains extracted from the dated object (pottery, fired stone, sediment, etc.). Quartz emits OSL when stimulated with visible light, green or blue. Emitted photons of OSL are detected by the photomultiplier (PM) tube, which is a very sensitive light detector. A selection of optical filters suppresses almost totally the stimulation light that could otherwise reach the PM tube and dominate the OSL signal. Because measured intensity of OSL functionally depends on the dose it provides a way for assessing the quantity of radiation dose absorbed by the quartz grains. In the OSL SAR (*Single Aliquot Regenerative dose*) method after measuring the OSL intensity of an aliquot of extracted grains (called natural OSL) the same aliquot is subjected to a series of subsequent laboratory irradiations with a calibrated radiation source and OSL measurements (Duller et al., 1999). Each OSL measurement removes electron charge from the excited levels and the laboratory irradiation regenerates quartz ability to show luminescence.

It is assumed that laboratory regenerated OSL signal grows in the same way as in natural conditions when quartz grains were cut-off from light after being buried in soil or sediment. These laboratory irradiations and OSL measurements form the basis for establishing an individual growth function for the aliquot, which is then used to express the natural OSL in terms of greys of radiation dose absorbed by grains (see Fig. 3). The term ‘regenerative dose’ in the name of the method refers to the way the OSL growth function is regenerated under laboratory conditions.

In fact, the actual measurements are more complicated as additional operations are necessary to normalise the OSL signal after each laboratory dose. This is achieved by introducing irradiation with the same test dose and measuring the OSL generated by it. The test OSL signal is used to normalise the previous OSL signal. Also, additional steps are introduced to check the validity of the method. Table 2 presents the laboratory protocol for OSL SAR measurements (Murray and Wintle, 2000).

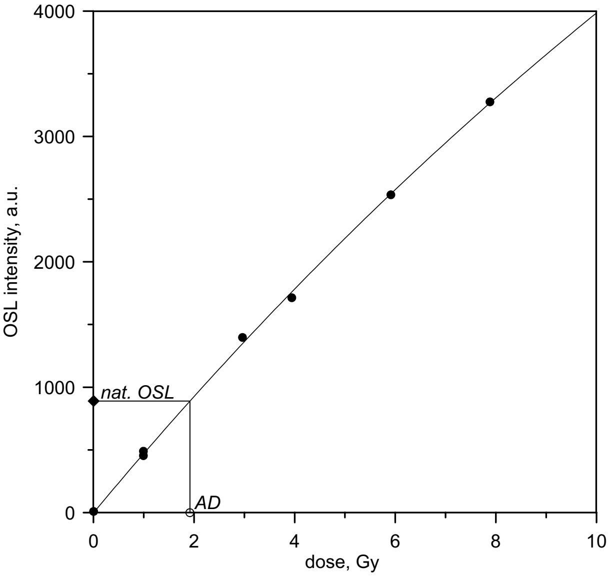

Figure 3. Assessment of dose AD (marked as an empty circle) absorbed in quartz grains by SAR method. Full circles – normalised OSL signal measured after laboratory irradiation, diamond – natural OSL, line – a growth function fitted to the points.

Table 2. Operations within a single step in a measurement protocol for OSL SAR measurements.

Operation	Measured OSL signal
irradiation with laboratory dose D_i	
preheat at temperature T_p for t_p seconds	
OSL measurement at temperature T_{OSL} for t_{OSL} seconds	L_i
irradiation with test dose D_{test}	
cut-heat at temperature T_c	
OSL measurement at temperature T_{OSL} for t_{OSL} seconds	L_{Ti}

Where:
step index $i = 1..n$.
$D_1 = 0$ – natural OSL is measured in step 1.
$D_n = D_2$ – first and last regenerative dose are the same to check if normalisation procedure is valid.
$D_{n\text{-}1} = 0$ – penultimate dose is zero to check for the presence of signal recuperation. No recuperation if $L_{n\text{-}1} \approx 0$.

The normalised value of measured OSL equals $NL_i = L_i \cdot L_{T0} / L_{Ti}$. The method is considered valid for a dated sample if values $NL_n - NL_2$ and NL_{n-1} differ insignificantly from zero. If necessary, the preheat, cut-heat and

OSL measurement parameters may be adjusted for a given sample to make the method valid.

The absorbed dose (*AD*) value is obtained from the first measurement of natural OSL of an aliquot through the individual growth function for this aliquot, which is established based on the remaining measurements (cf. Fig. 3). The precision of the estimate of the *AD* value is typically a few percent, though precision better than 1% is possible for certain samples.

To convert the *AD* value into OSL age one needs information about the accumulation rate of this dose. One of the ways to estimate the value of the absorbed dose rate is to measure the content of radioactive elements (^{40}K, ^{235}U – series, ^{238}U – series, and ^{232}Th – series) in the sample and its surroundings and to calculate the amount of radiation they release per time unit. The calculation takes into account presence of water as it attenuates ionising radiation, and the amount of cosmic radiation that reaches the sample at a given depth below ground surface. The typical value of the dose rate falls between 2 – 4 Gy/ka. There are however environments where the dose rate may be as low as a few tenths of grey per thousand years, or as high as 10 Gy/ka. Typically, the accuracy of the dose rate estimate is a few percent.

If the calculated absorbed dose rate *d* is expressed in terms of Gy/ka (greys per millennium) then OSL age T_{OSL}

$$T_{OSL} = \frac{AD}{d}$$

is expressed in ka (thousand years).

As all measured (or measurement based) quantities values of *AD*, *d*, and T_{OSL} are estimated with uncertainties. The uncertainties, which are the laboratory estimates of measurement errors, are calculated taking into account a number of factors, like uncertainty of calibration of irradiation source, uncertainties in parameters of growth function fitted to measured data, uncertainties in coefficients used in calculations of absorbed dose rate, etc. If not otherwise stated, uncertainty defines the interval where the real value of a measured quantity can be found with a probability of 68.3%.

Taking into account typical accuracies of estimates of both *AD* and *d*, the overall uncertainty of the OSL age value is about 5 – 10%.

EXAMPLES OF OSL DATING IN ARCHAEOLOGICAL APPLICATIONS

While the absorbed dose *AD* in the aliquot of quartz grains and the corresponding OSL age can be estimated quite accurately, there is still a question about how the event that zeroed luminescence of grains is related to the dated artefact or sediment.

OSL dating of heated material

A case of pottery or other fired material is probably the most obvious one. High temperature during baking sets the luminescence to zero level in all grains contained in pottery. They start accumulating dose and luminescence with a rate depending on the ionising radiation intensity. Thus, at the time when a potsherd found during archaeological excavations is examined in the laboratory all extracted quartz grains have the same absorbed dose, and *AD* values assessed by the OSL SAR method should be essentially the same, except for the random measurement error.

Fig. 4 shows a distribution of AD values measured by the OSL SAR method on small aliquots of quartz grains extracted from the burnt stone found in a hearth (Baran, 2002; Baran et al., 2003). Results are plotted here in two different ways. First, as a histogram giving the proportion (or frequency) of results falling into a specified interval. Second, ranked from the minimum to maximum value, where the abscissa (cumulative frequency) equals a ratio of result number to total number of results. Both presentations are related to each other in that cumulative frequency is an integrated frequency histogram.

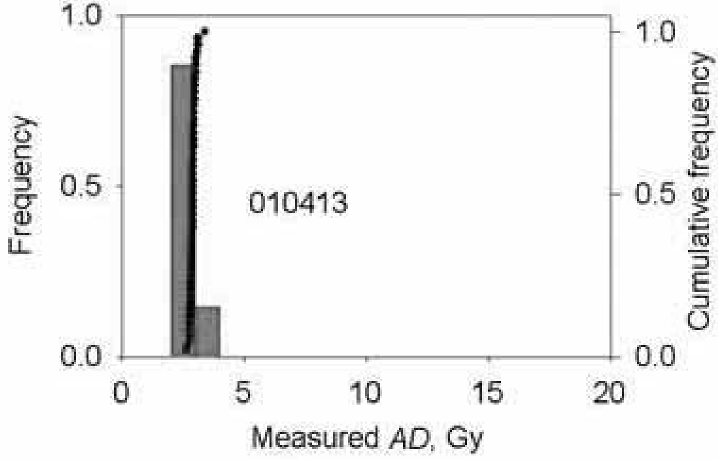

Figure 4. The distribution of AD and the cumulative frequency plot for a heated stone sample from the hearth. The figure shows the results of measuring 48 aliquots. After Baran, 2002.

The distribution of *AD* results is very narrow, giving an average value of 2.919 Gy with an uncertainty of 0.018 Gy. For the sake of brevity it is written in a standard form as 2.919(18) Gy. In this case the average *AD* value corresponds to an OSL age of 2.40(20) ka.

OSL dating of sediments associated with archaeological artefacts

Geological sediments are another matter (Bluszcz, 2000). They were rarely heated to temperatures high enough to erase previous luminescence of mineral grains, but exposure to light, specially direct sunlight, has a similar effect. Exposure to visible and near-UV light very effectively sets OSL to zero; this is also what happens during the laboratory readout of the luminescence signal – a prompt decay of OSL (cf. Fig. 1). It is then necessary that before or during deposition individual grains were exposed to light. Eolian deposits, like loess or dune sand, are the best examples of sediments that contain quartz grains all well bleached by sunlight during the eolian transport. Other types of sediments, depending on their genesis, contain greater or smaller proportion of grains that were well bleached upon sedimentation. The single aliquot method deals with this problem by doing all the OSL measurements on a very small number of grains (even a single grain may be enough to assess the absorbed dose). It enables aliquot (grains) with different absorbed doses to be distinguished. The differences may be either due to incomplete bleaching before, or to mixing after the sedimentation. Thus the resulting distribution of measured absorbed doses in many small aliquots has to be interpreted in the light of other information available for the site, like sedimentology, pedology, archaeology, etc.

Eolian sand covering the above mentioned hearth gave a somewhat broader distribution of results presented in Fig. 5. The greater scatter of *AD* may be attributed to two main factors. The first one is lower OSL intensity, usually observed in unheated material, which results in bigger uncertainties of measured OSL intensity values. The second one is the duration of the process of eolian deposition and mixing of the sediment material by post-depositional processes that additionally give rise to the observed scatter.

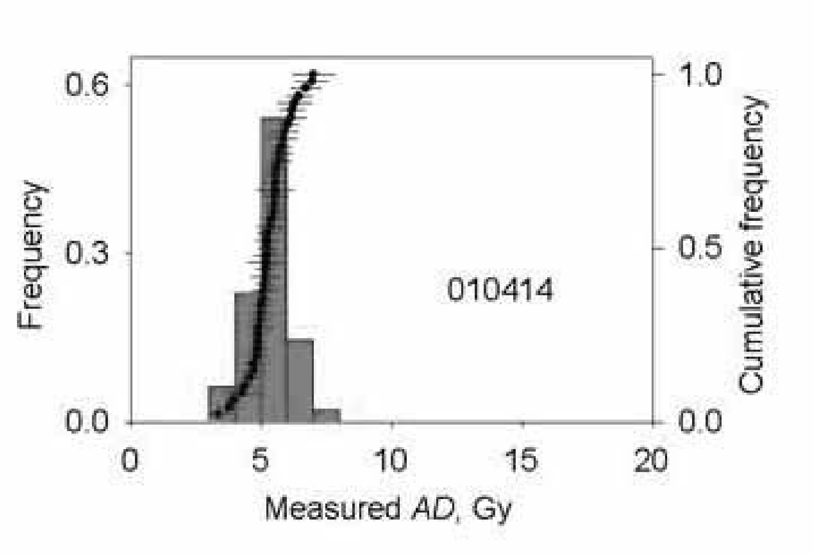

Figure 5. The distribution of AD and the cumulative frequency as a function of AD for the eolian sample. The mean value is 5.32(11) Gy. The figure shows the results of measuring 48 aliquots. After Baran, 2002.

Nevertheless, the OSL age corresponding to the average *AD* is 2.29(13) ka, in accordance with that for the burnt stone.

More often *AD* distributions obtained for sediments found in archaeological context exhibit more complex features. Two such examples are presented in Figs. 6 and 7, where quartz grains were extracted from sediments forming the base of the cultural layers on a Neolithic site and on a Palaeolithic site. Figs. 6 and 7 adopt a different way of presenting the results. The continuous plot of relative frequency is obtained by summing Gaussian functions associated with each result. The mean value and the standard deviation of the Gaussian are equal to the *AD* result and its uncertainty, respectively. Individual *AD* results are plotted against a probability axis. The abscissa values are obtained by transforming the cumulative frequency through the Gaussian cumulative distribution function and expressing it in standard deviations. The advantage of presenting results against the probability axis is that a single Gaussian function transforms into a straight line, and a set of values randomly sampled from a normal (Gaussian) population is transformed into points placed along a straight line. This provides a way to assess whether results form a normally distributed set.

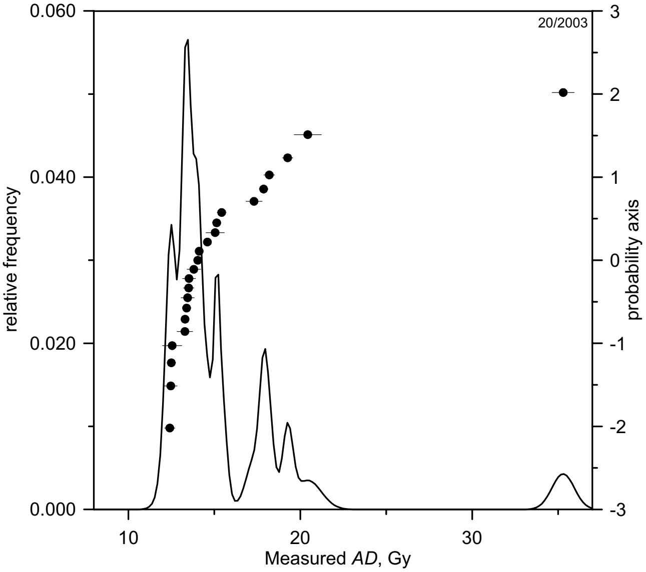

Figure 6. The distribution of AD values measured in 23 aliquots of quartz grains extracted from the sediment in Neolithic cultural context. Points representing AD values are plotted against a right hand probability axis. A continuous line plots relative frequency of a given AD value. The probability axis on the right side is described in the text.

The Neolithic site is situated on playa deposits and dated material was sampled from the layer containing artefacts. The results in Fig. 6 certainly do not come from a single normal population. It may be interpreted as result of mixing older sediment with younger ones due to bioturbation. There are three distinct clusters of results positioned along straight line sections. The averaged *AD* values calculated for these clusters give: 12.483(29) Gy, 13.412(42) Gy, and 18.62(56) Gy. The oldest cluster is probably the age of the sediment substrate on which the Neolithic culture developed. The middle one would be then relevant to sediment that covered the deserted site when climate conditions changed. The OSL ages for these clusters are 12.79(53) ka BP and 9.22(27) ka BP respectively, and 8.59(25) ka BP for the youngest cluster.

The 8 charcoal samples collected at the same site gave ^{14}C results (calibrated) between 12650 – 9550 y BP. The coincidence between the two methods is remarkable.

A similar situation occurs for the Palaeolithic site (see Fig. 7). As in the previous example, OSL ages were obtained by SAR method on small aliquots (ca 0.5 mg) of coarse quartz grains extracted from the alluvial fan deposits forming the base of the cultural layer with Palaeolithic artefacts. There are two clusters distinguished here bracketing the main part of the distribution. Averaged *AD* values are 61.24(41) Gy and 73.44(41) Gy, respectively, which in turn give OSL ages of 120.7(62) ka BP and 144.8(75) ka BP. The older age is probably the age of the sediment substrate of the cultural layer and thus slightly predates the Palaeolithic culture, while the younger one dates the last main phase when bio-processes were actively mixing sediment layers.

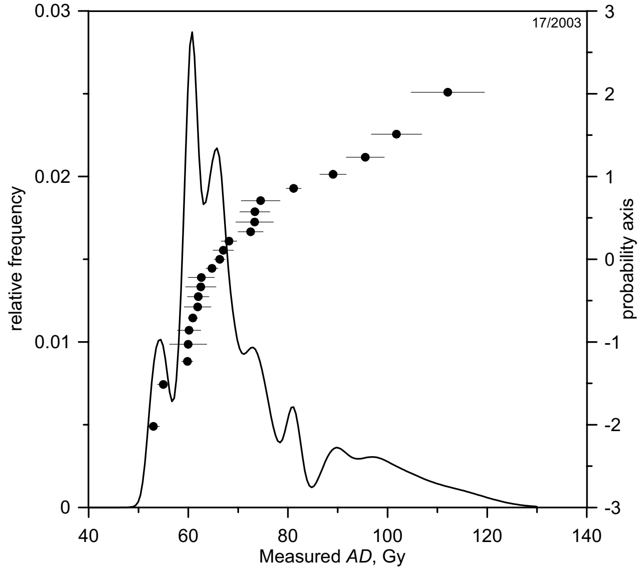

Figure 7. The distribution of AD values measured in 23 aliquots of quartz grains extracted from the sediment in Palaeolithic cultural context. Points representing AD values are plotted against a right hand probability axis. A continuous line plots relative frequency of a given AD value. The probability axis on the right side is described in the text.

CONCLUSIONS

Luminescence dating methods, and especially OSL SAR method, may be successfully applied to date archaeological finds. The age may be obtained either for the artefact itself, providing it was fired at temperatures at least 400-500°C, and contains quartz grains, or for the sediment it was found in. In the latter case the ages bracketing the archaeological event may be estimated by an interpretation of single aliquot results, supported by additional geological, sedimentological, pedological, archaeological, etc., information.

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Chapter 13

THE SUN, CLIMATE CHANGE AND THE EXPANSION OF THE SCYTHIAN CULTURE AFTER 850 BC

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ABSTRACT

The climate shift towards wetter conditions at the transition from Subboreal to Subatlantic in NW-Europe (ca 850 cal. yrs BC; caused by a decline of solar activity), is also evident in South Siberia. Areas that initially were hostile semi-deserts changed into attractive steppe landscapes with a high biomass production, and therefore high carrying capacity. We focus on south-central Siberia where an acceleration of cultural development and an increase in the density of nomadic Scythian populations took place shortly after 850 BC. We hypothesize a causal relationship between the Scythian expansion and migration, and the early Subatlantic shift towards increased humidity.

Keywords: climate change, solar activity

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INTRODUCTION

During the first millennium BC, Scythian cultures occupied areas from northern China to the Danube River which, nowadays, belong to the steppe and forest-steppe zones of Eurasia. Most of the Scythian sites are located between 42° and 55°N and 30° and 100°E. The origin, evolution, and spread of this nomadic culture is an important issue in archaeology. Radiocarbon dating is increasingly important (Alekseev *et al.*, 2001; Dergachev *et al.*, 2001, Görsdorf *et al.*, 2001), but in many cases radiocarbon dates are lacking, and indirect chronologies still play an important role. The Scythian history can be subdivided into three phases: 1) a pre-Scythian and initial Scythian phase from the 9th to the middle of the 7th century BC; 2) An early Scythian phase from the 7th to the 6th century BC; 3) A third phase - the classical Scythian phase - from the 5th to the 3rd century BC.

A wave of pre-Scythian nomads from the eastern Eurasian steppe zone appeared in the northern Black Sea region during the 9th century BC (Klochko *et al.*, 1997). The most ancient known Scythian monument in Europe (Steblev group barrows, grave 15, located on the right bank of the Dnieper River) has been dated to the 8th century BC. Based on data published by Zaitseva *et al.* (1998), van Geel *et al.* (1998) had previously suggested a link between the migration of Scythians to southeast Europe and climate change, but they assumed that the trigger was an episode of 'extreme climate', without a comprehensive understanding of the triggering (negative or positive) environmental factors. Based on new data, we present the hypothesis that the solar-driven climatic change to wetter conditions was of crucial importance for the cultural blooming and expansion of the Scythian culture.

THE CLIMATIC SHIFT AROUND 850 BC

In northwest Europe, the stratigraphic evidence for a sharp climatic shift during the early first millennium BC to cooler, wetter conditions enabled Blytt and Sernander (Sernander, 1910) to distinguish a (warm, dry) Subboreal and a (cool, wet) Subatlantic period. The climate shift is reflected in the degree of decomposition and species composition of raised bog peat, and it was recently radiocarbon dated (using wiggle-match dating) to ca 850 calendar years (cal) BC. Reduced solar activity appeared to be the cause of the change (Bond *et al.*, 2001; van Geel *et al.*, 1996; 1998; Kilian *et al.*, 1995). The climatic shift was also recorded in the raised bog deposits of Central Europe (Speranza *et al.*, 2002) and had pronounced effects in Eastern Europe, with rapid and total flooding of the Upper Volga region (Gracheva, 2002). Kroonenberg *et al.* (personal communication) recorded a pronounced highstand of the Caspian Sea. The climatic shift in the temperate zone was characterized by enhanced strength of the westerly winds, and probably also by a southwards shift of this west-east circulation (van Geel and Renssen, 1998).

Paleoclimatological studies show that the change in the atmospheric circulation pattern around 850 cal BC also affected southern Siberia and Central Asia. Lake Telmen, Mongolia, has terraces dated between 2710 and 1260 BP, indicating a greater than present-day effective moisture balance (Peck *et al.*, 2002). Grunert *et al.* (2000) reconstructed lake-level fluctuations in lakes Uvs Nuur and Bayan Nuur, which are situated just south of the Russian-Mongolian border and only 100 to 200 km southwest of the lowlands in Tuva, an area with an early and rich archaeological evidence for the Scythian cultures (Tagar and Aldy-Bel). A decline of the lake levels of Uvs Nuur and Bayan Nuur occurred from ca 5000 BP onwards, indicating a decrease in precipitation. But a sudden rise of lake levels, combined with glacial readvances, and soliflution started between 3000 and 2000 BP, suggesting enhanced rainfall and lower temperatures. Pollen analysis of a peat deposit showed wetter climatic conditions since ca 2500 BP (Lehmkuhl *et al.*, 1998), and a vegetation transition around Bayan Nuur from steppe to a temporary forest.

The pollen record of Kutuzhekovo Lake (southern Siberia, 53º 36’ N, 91º 56’ E) shows the late-Holocene vegetation history (Dirksen *et al.*, this volume) of the Minusinsk depression, which is surrounded by the Sajan high-mountain system. The pollen record in the lower part of the diagram points to a dry steppe or even a semi-desert, with open soils and low biomass productivity. A clear transition in the pollen diagram, dated at ca 2800 BP, reflects large-scale environmental changes. The xerophytic taxa show a strong decrease, while moist-demanding taxa show a sharp rise, reflecting a change from a dry to a relatively humid climate. The vegetation changes coincide with a sedimentation change from sandy to predominantly organic lake deposits, an additional indication of a dense vegetation cover in the catchment of the lake (less erosion), probably combined with high local organic productivity in the lake. We conclude that a climatic shift at the Subboreal-Subatlantic transition to cooler, wetter (less dry) climatic conditions also occurred in southern Siberia and Central Asia and the increased precipitation changed an east-west belt of semi-deserts into steppe, with an enhanced vegetation biomass production, and thus with an increased carrying capacity, which was of vital importance for nomadic people.

CULTURAL DEVELOPMENTS IN SOUTHERN SIBERIA AND TUVA

The geographical distribution of the Scythian culture, between 42° and 55°N and 30° and 100°E, is (at present) closely linked with an area of a relatively dry, continental climate with steppe vegetation. We focus on central southern Siberia and Tuva (central Asia). The archaeology of the Minusinsk basin, including both Khakassia and the Krasnoyarsk province north of the Sayan Mountains, differs from that in Tuva which is situated to the south of those areas. Therefore the cultural developments of these areas are discussed separately.

Central Southern Siberia (Minusinsk basin, Khakassia)

The Palaeolithic Aphontovo culture is represented by many sites (Vadeckaya, 1986), but the Mesolithic and Neolithic (8th to 4th millennium BC) are poorly represented (Vasiliev, 2001). Mesolithic-Neolithic sites are found in the present-day taiga and mountain zones and not in the steppe zone. Occupation of the steppe started at the end of the Neolithic period. The Afanasievo (4th to 3rd millennium BC) is the first barrow culture of a europeid population and the easternmost one among the stock-breeding cultures of Eurasia. The Bronze Age starts with the Okunevo culture. The beginning of this culture is dated to the end of the 3rd millennium BC (Görsdorf *et al.*, 1998).

The northern part of the Minusinsk depression was the southernmost region where the Andronovo culture occurred (Middle Bronze Age; 18th to 14th century BC). Compared to neighbouring territories such as Kazakhstan and Western Siberia, a relatively low number of Andronovo sites were found in the Minusinsk hollow. It is difficult to explain why the Andronovo population did not move to the southern part of the Minusinsk hollow, but it may well be that environmental conditions were a limiting factor (see below).

The most represented Late Bronze Age culture in the Minusinsk hollow is the Karasuk culture (14th to 10th century BC) (Bokovenko and Legrand, 2000). Thousands of burial mounds as well as some settlements of this culture were discovered in the steppe zone of the Yenisei River Basin. The local variants of the Karasuk artifacts and their influence were fixed on the huge territory from Central Kazakhstan up to Mongolia and China (Chlenova, 1972, Novgorodova, 1970). The archaeological and osteological material demonstrates that horse-riding became important in this period and the transition to a nomadic stock-breeding economy occurred.

The Karasuk culture developed into the early Iron Age Tagar culture, which is contemporary and closely related to the Scythian cultures in other parts of the Eurasian steppe-belt. The change from the latest phase of the Late Bronze Age to the beginning of the Tagar culture does not represent a break in the cultural development (Leont'ev *et al.*, 1996). A long series of radiocarbon dates clearly suggests that the transition from the Late Bronze Age to the Tagar culture should be placed around the 9th century BC (Alekseev *et al.*, 2002; Sementsov *et al.*, 1997, 1998). In the context of the present paper it is important to note that this fits with the period of evidence for climate change at the Subboreal-Subatlantic transition. However, in the region to the North of the Sayan mountains, no cultural developments point to a causal relationship with climatic change.

The Tagar culture was one of the most pure nomadic cultures, with stock-breeding, complicated burial traditions, weapons, and arts. In the earlier Tagar cultural artifacts, one can recognise elements suggesting both connections with the preceding Karasuk culture, and cultural innovations reflecting contacts with the Kazakhstan-Central Asia region.

Central Asia region (Tuva republic)

Compared to the northern sites, the archaeological evidence from the area south of the Sayan Mountains (Tuva) offers a completely different picture. Palaeolithic sites were located on the banks of Yenisey River and its tributaries (Astakhov and Vasiliev, 2001). Neolithic sites were found only in the Sayan canyon of the Yenisey River (Toora-Dash and Ust'-Khemchik III (Semenov, 1992). At the turn of the 3rd/2nd millennium BC most of these settlements were abandoned and an enormous gap in the prehistory of Tuva follows. It is not known if any cultures spread along the Upper Yenisey River during the first half of the 2nd millennium BC, when the Andronovo culture dominated the Minusinsk hollow. In the second half of the 2nd millennium BC, the situation is little different, especially in the northern and central parts of Tuva. Despite intensive archaeological research, the Karasuk culture of the Late Bronze Age has until now only been represented by isolated finds. This almost complete lack of archaeological records in Tuva is significant.

The situation changed completely after the 9th century BC, when the Scythian culture emerged in Tuva, earlier than in the western parts of the Eurasian steppe zone. The Arzhan-1 barrow yielded very early Scythian material dated to the late 9th/early 8th century BC (Gryaznov, 1984). This early date is confirmed by dendrochronology in combination with ^{14}C wiggle-matching, as well as by archaeological arguments. The immigration and strong increase in human population density of Tuva, soon after the middle of the 9th century BC, had an enormous impact in the whole Eurasian steppe zone. In Tuva the Aldy-Bel culture of the Scythian type emerged earlier than in any other part of the steppe. We suggest that climatic change played an important role in the archaeological development. The coincidence of the sudden transition to less dry conditions (mid 9th century BC) and the population density increase and cultural development in Tuva is significant. Prehistoric communities living in marginal areas of food production may be very sensitive to environmental change, because such changes can have an enormous impact on their way of life. We postulate that the emergence and expansion of the nomadic culture of the early Scythians in Tuva was only possible after a climate shift towards higher humidity (increased plant biomass production and thus a higher carrying capacity). The climatic shift changed Tuva from a dry semi-desert area into a steppe, which was attractive for groups with a nomadic way of life. Similar environmental shifts may have taken place in areas east and west of Tuva, and thus a large east-west situated belt of newly formed steppe vegetation could successfully be invaded.

Van Geel *et al*. (submitted) and Zaitseva (submitted) used the St. Petersburg Radiocarbon Database to compare the geographical distribution and age of the different monuments (2200 14C dates from about 650 sites) in the territory of the Eurasian steppe between 42° and 55° N, and compared the separate dates from southern Siberia (Khakassia) and Central Asia (Tuva) with the complete dataset. Like the archaeological record, the ^{14}C record shows an 'empty' Tuva during the Bronze Age and a sharp increase of its occupation shortly after 3000 BP.

CONCLUSION

A climatic shift towards wetter (less dry) climatic conditions around 850 calendar years BC was responsible for a suddenly increased carrying capacity (higher biomass production) of the Tuva area. We suppose that Tuva was part of a vast, east-west situated belt (the southern part of the temperate climate zone) which - as a consequence of the climate shift - suddenly became available as an attractive living area. The climatic change around 850 cal BC was triggered by a temporary decline of solar activity, and thus we hypothesize that the sun was a major factor, indirectly influencing the cultural blooming and expansion of the Scythian culture.

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Chapter 14

LARGE-SCALE PERIODICITY OF CLIMATE CHANGE DURING THE HOLOCENE

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ABSTRACT

Numerous natural events documented in instrumental, historical and palaeoclimate records clearly indicate that large regions of the Earth have experienced occurrences of both slow and rapid climate change in the past. Various proxy records of long duration demonstrate distinct cyclicities from eleven years to hundreds of thousands years that have been attributed to external forcing. Until quite recently, palaeoclimatic research has tended to focus on evidence for longer-term climatic change, especially on glacial to interglacial timescales. The duration of these oscillations are varied with approximately a 1500-year periodicity and therefore not related to the Earth's orbital variations around the Sun. After a number of cooling/warming episodes (Dansgaard-Oeschger cycles) there are terminal dramatic coolings called Heinrich events with temperature drops up to about 5°C before a major warming event. Such a cycle of warming and cooling is known as a Bond cycle with a mean duration of 2500 years. Both marine and continental sediment records confirm these rapid shifts.

The Holocene climate has also been a time of major climatic and environmental change, although in the current interglacial the Earth has remained at a rather steady climatic phase over the last 10,000 years in comparison with the preceding climatic phases of the last glacial cycle. From more recent studies on ice cores and marine sediments, there is evidence that the Holocene climate closely parallels that in the preceding last glacial cycle.

Key words: climate, Pleistocene, Holocene, cyclic, natural events.

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INTRODUCTION

Numerous natural events documented in instrumental, historical and palaeoclimatic records clearly indicate that large regions of the Earth have repeatedly experienced the impacts of both slow and rapid climate change in the past. During the last few decades many scientists and politicians have associated a rapid rise in globally averaged surface temperature with increases in anthropogenic greenhouse gases. Systematic global temperature records have only been available since AD 1860. However, even these temperature records are incomplete and contain significant uncertainties and inconsistencies. Prior to AD 1900 there were no reliable temperature data for more than 50% of the Earth's surface. Interpretation of these climatic data is complicated by instrumentation errors at weather stations, and the urban heat island effect. From these data we cannot indicate future changes. Studies of earlier climates are based on indirect evidence.

A wide variety of records of past climate history indicate that during glacial periods the Earth's climate was significantly different from that of the present. The palaeoclimatic data that can be extracted from ice cores, can importantly be used to study and compare in detail climatic events both at the two poles of the Earth and in mountain areas of the globe. Various proxy records of long duration demonstrate distinct cycles ranging from eleven years to hundreds of thousands years that have been attributed to external forcing. Until quite recently, palaeoclimatic research has tended to focus on evidence of longer-term climatic change, especially on glacial to interglacial time scales.

From the detailed study of Greenland ice cores it was established that during the last glacial cycle between approximately 100 thousand years and 11 thousand years ago, the climate indicators in the ice cores clearly indicate repeated sharp millennial-scale temperature oscillations of extremely abrupt warming with large amplitude (e.g. Dansgaard et al. 1993). These episodes of warming called Dansgaard-Oeschger (D-O) cycles reflect temperature changes over Greenland of up to about 10°C magnitude. The duration of these oscillations are irregular and varied, with approximately a 1500-year periodicity (e.g. Bond et al., 1997). At the end of a series of cooling/warming episodes (D-O cycles), there are dramatic cold shifts called Heinrich events with temperature drops up to about 5°C before a major warming event. Such a cycle of warming and cooling is known as a Bond cycle. Each Bond cycle includes several D-O cycles. (McCabe and Clark, 1998). These rapid climatic shifts are reflected in both marine and continental sediment records.

From an analysis of a deep-sea sediment core retrieved from an intensively studied ice-rafted debris belt in the northeast Atlantic Ocean, Helmke et al. (2002) detected and quantified three distinct levels of late Pleistocene climate variability. During glacial maxima, <u>medium</u> climate variability occurred; during times of either ice sheet growth or ice sheet decay <u>maximum</u> climate variability occurred; and during periods of greatest warms (such as the Holocene epoch) minimum climate variability was observed.

During the ice ages, global temperatures fell by 5°C and the ice-sheets advanced over much of Europe and North America. Ice ages are separated by warmer interglacial periods. Since the end of the last ice age, approximately 14,000 – 10,000 years ago, globally averaged surface temperatures have fluctuated up to 2°C on time scales of centuries or more. The factors influencing these changes probably included fluctuations in the radiation output from the Sun, and changes in the circulation and overturning in the oceans. The magnitude and rapidity of past climatic changes extend far beyond human experience. We are still far from understanding these changes, and therefore the climate system. Past climatic changes produced major physical and biological changes, including effects on human development.

Holocene climate has been remarkably stable in the context of Quaternary climate change. The Holocene epoch of warmth over the past 11,500 years appears to be a unique period during the past 100,000 years. However, the Holocene climate has also been a time of major climatic and environmental change, although in the current interglacial the Earth has remained at a rather steady climatic phase over the last 10,000 years in comparison with the preceding climatic phases of the last glacial cycle. From more recent studies on ice cores and marine sediments, there is evidence that the Holocene climate closely parallels that of the preceding glacial cycle. The Holocene is characterized by a long-term trend of warming, and centennial and millennial-scale variability of cold and warm periods superimposed on this trend. However, the amplitude of the variability is small compared with the climatic oscillations of the last Ice Age. Changes in climate during the Holocene have been at higher frequency and lower magnitude than the glacial-interglacial cycles. Proxy climate data related to changes in the size of glaciers, the altitude of the alpine tree-limit, and the width of tree rings allow us to derive the history of summer temperatures in the Northern Hemisphere over the last 11,500 years. The results revealed a number of long- and short-term temperature fluctuations in the order of 1°C and less. The most recent extremes in average temperatures in Europe occurred in the warmest period of the Medieval Optimum from AD 950 to 1045, and in the coldest part of the Little Ice Age from about AD 1645 to 1715. Many records indicate a millennial-scale oscillation in Holocene climate in Europe, with the warm and cold extremes which are similar to what we know as the Medieval Warm Period and Little Ice Age.

The Holocene is the most important phase of human development and landscape evolution. Its study provides an historical perspective on modern problems such as climate change, deforestation and soil erosion. Consequently, using a variety of methods, many scientists are investigating the climatic changes that occurred over the past 11,500 years.

Long-term changes of weather, or climate impact humans, animals and all other life forms. A great body of data has now been accumulated from palaeoecological, archaeological, and palaeontological research concerning the environmental and human history of different parts of the world. Pollen, phytolith, and diatom data from lakes and peat deposits record the changes in vegetation resulting from climatic oscillations and human-induced factors. Archaeological data provide cultural records of human exploitation of the flora and fauna, and land use. Unlike many earlier climate oscillations, the Little Ice Age has been widely documented by human observers. Records include the first readings from meteorological instruments. Based on the information obtained from the proxy data, scenarios of environmental conditions during the period of the Little Ice Age have been developed.

Cold climate and glacier expansion during the Little Ice Age are documented from almost all continents (Grove, 1988, 2001). The most extensive and reliable historical evidence comes from Western Europe, which experienced a general cooling in climate between AD 1150 and AD 1460, and a very cold climate between AD 1560 and AD 1850 that brought heavy consequences for its peoples. The colder weather impacted on agriculture, health, economics, emigration, and even art and literature. Increased glaciation and storms also had a detrimental effect on people that lived in the proximity to glaciers and the sea. In Europe and North America, phases of glacier expansion were delimited by milder intervals. Advances of glaciers during the Little Ice Age resulted in unfavorable conditions for farms and villages located in mountain valleys below the glaciers. Many farms and some villages were destroyed by glacier advance, melt-water floods, landslides and related accidents. Population in the affected mountain regions declined significantly, due to emigration and death.

The Medieval Warm Period was a time of extremely favorable climate in northern Europe (e.g., Hughes and Diaz, 1994). Harvests were successful, fish stocks were abundant, sea ice remained far to the north, vineyards existed 500 km north of their present limits, and famine was rare. This was the period of extensive Viking expansion from Scandinavia. In addition to their warlike image, Vikings were also colonists. Their settlements were based on cereal grains (wheat and barley) and dairy herds (goats, sheep, and cattle).

Various studies suggest that the collapse of many ancient societies coincided with unfavorable climatic events such as droughts or floods. Hoddell et al. (2001) studied an ancient lake bottom located on the Yucatan peninsula and found that from AD 800 to AD 1000 (the Medieval Warm Period) the lake was exceptionally dry. The scientists suggested that the recorded periodic droughts coincided with a 206-year solar cycle. The droughts coincided with Mayan troubles, and eventually with the final days of Mayan civilization. Verschuren et al. (2000) reconstructed rainfall and drought from the level and salinity fluctuations of a lake in equatorial east Africa, and established that over the past millennium, equatorial east Africa has alternated between contrasting climate conditions. Three Ages of Prosperities of cultural history coinciding with a relatively wet climate during the Little Ice Age (~AD 1270-1850) were interrupted by three prolonged dry episodes. There are strong chronological links between the reconstructed history of natural long-term rainfall variation and the pre-colonial cultural history of east Africa, highlighting the importance of a detailed knowledge of natural long-term rainfall fluctuations for sustainable socio-economic development. Van Geel et al. (in press, and this volume) hypothesized a causal relationship between a solar forced climate shift to less dry conditions around 850 cal BC and the fast expansion of the Scythian culture in the Eurasian steppe zone.

Additions to the archaeological record seem to indicate that there have also been social changes concerned with climate changes in the previous epochs. The Little Ice Age provides a bridge from historical observations to the more distant past and validates the use of many natural archival records in the reconstruction of more ancient climate change. It is of interest to establish the characteristic properties of climate shifts during the Holocene.

An important component of this paper will be devoted to tracing the periodicity and timing of large-scale climate changes in various regions of the globe, in order to improve understanding of the variability of the Earth's natural climate. An understanding of how the climate system varied both in the past and how it varies at present is required to reconstruct the history of interaction of ancient man and nature, and more accurately identify and predict the potential effects of global warming due to human activity. The ultimate goal of this paper is to discuss the physical mechanisms connecting climate variability and natural forcing on it, and primarily to evaluate the role of the Sun in climate variability.

MILLENNIAL-SCALE CLIMATE VARIABILITY FROM PALAEOENVIRONMENTAL ARCHIVES

Of the numerous natural archives, glaciers are one of most responsive to climate change. Glacial features in the long-term record provide essential information about the past behavior of climate. Histories of Pleistocene and Holocene climate, and the forcing factors of climatic variability can be derived from a variety of terrestrial and marine archives. It is important to note that the ratio of oxygen isotopes in ice cores and sediments yields information about temperature and precipitation in the cloud from which the snow or rain fell. Proxy climate data related to changes in the size of glaciers, the altitude of the alpine tree-limit, the width of tree rings and so on provides us with the valuable information about the changes of temperature in the Northern Hemisphere over the last 11,500 years. Oxygen isotope records from central Greenland ice cores (Grootes and Stuiver, 1997) indicate essentially no significant Holocene variability (Figure 1, bottom panel), and no significant trend. The results revealed a number of temperature fluctuations of up to 1°C magnitude.

However, the synthesis of proxy records, as prepared by the Intergovernmental Panel on Climate Change (Houghton et al., 1990), indicates that temperatures during the Holocene maximum were warmer than those of the past few decades for a period of time of the order of several thousand years (Figure 1, top panel). The results revealed a number of temperature fluctuations, the warmer periods of which were about 2°C warmer than at present. Moreover, the global climate has been generally cooling after the Holocene optimum.

The Last Glacial Maximum, about 21,000 years ago (Broecker, 1997), extended from the North Pole down to the Ohio River Valley in North America and to the Valdai Heights in Russia. Relatively long-term cycles, of the order of 1-2000 years apparently played a major role in the many advances and retreats of the Pleistocene ice sheets.

The core evidence for Holocene climate variations came from the study of alpine glacier advances and retreats, and peat stratigraphy. It is important to note that records of glacier advances and retreats indicate relative summer temperature. The maximum size of a glacier will occur some time after a minimum in summer temperature, that is, glaciers grow during years with cool summers. Therefore, studying the historical record of glacier advances and retreats provides a record of general temperature variations. Denton and Karlen (1973) and Rothlisberger (1986) found evidence of glacier fluctuations throughout middle and high latitudes (in the vicinity of

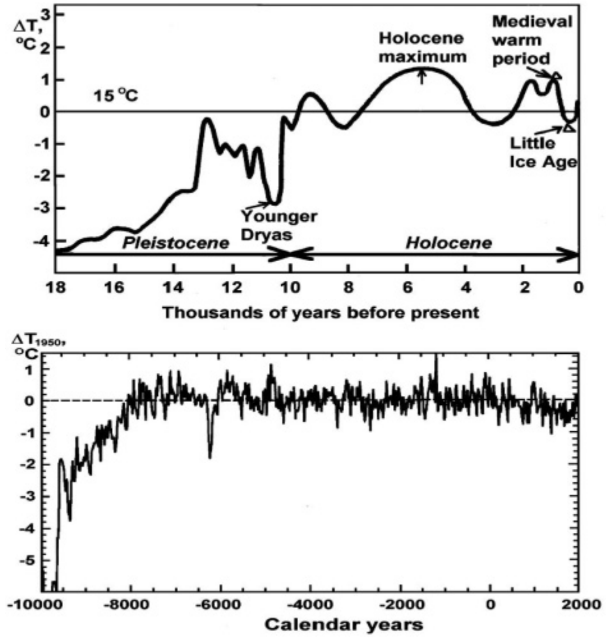


Fig. 1. Temperature changes inferred from values of the oxygen-18 concentration in Greenland ice core (bottom panel) and other proxy records (top panel).

450, 2700, 5000, 7200 and 9500 cal years BP). Rothlisberger (1986) demonstrated a record of glacier fluctuations in both the northern and southern hemispheres, from 12 regions for the past 10 kyr. Recently developed Holocene palaeoclimate records from ice cores and marine sediments show that the Holocene climate was also unstable, having been punctuated by several significant, millennial scale cooling events.

Glaciochemical time series developed from Summit in Central Greenland indicate that the chemical composition of the Earth's atmosphere considerably changed during the Holocene epoch. From detailed analyses of dissolved sea salt and non-sea salt ion concentration variations recorded in ice cores, O'Brien et al. (1995) established that concentrations of sea salt and terrestrial dusts were relatively higher in Summit snow during the period 11300-12900, 7800-8800, 5000-6100, 2400-3100 and 50-700 years ago. The terrestrial dust and sea-salt record reveals extended periods dominated by winter-like circulation patterns and storm conditions that recurred throughout the Holocene approximately every 2400 years. The similarities between the glacier data from different latitudes and Greenland ice core records are evidence that fluctuations in climate occurred simultaneously across large areas. Apparently, the near-synchronous world-wide glacial patterns have been suggested to represent global climatic change.

Pollen data are the main source of climatic information (estimates of precipitation and temperature changes) in vegetated areas. Any pollen diagram contains the integrated information of local character as well as regional vegetation changes in vast territories. Numerous data indicate that some significant changes on millennial and centennial scales are superimposed on the long-term fluctuation of climate. Klimanov and Klimenko (1995) have reconstructed the temperature and precipitation rate in a number of regions of Northern Eurasia during the Holocene, on the basis of data from lake and bog sediments. They deduced four warming maxima during the intervals: 6700-5700, 4500-3200, 2300-1600 BP, and during the 12th-13th centuries (the Medieval Climatic Optimum). These warm periods are separated by cold stages. Comparison with series of generalized palaeoclimatic curves for the Holocene from Karelia (Klimanov and Klimenko, 1995), and the temperature curve from the center of the Russian Plain (Velichko, 1989), reveals that the warming periods generally correspond to the minima of the ~2400-year cycle in the tree-ring radiocarbon content. Large-scale climatic variations during the last 11,500 years have also been demonstrated in records of soil formation, flora, fauna and landscapes in sands of the northern Near-Caspian Lowland (Ivanov and Vasiliev, 1995). The authors established a cyclic character of climate moisture changes, and showed significant shifts in ecological conditions from black-soil steppe to desert landscapes.

Prominent cycles with an average period of about 2,500 years were recorded by Kirkland et al. (2000) over 200,000 annual laminations (varves) from the Castile Formation in the Delaware Basin of West Texas and New Mexico. Hormes et. al. (2001) determined the ages of sub-fossil wood and peat samples from six glacier forelands in the Central Swiss Alps. Radiocarbon dates of a large number of these samples cluster in three major groups centered at 8700, 6600, and 4300 calendar years BP with a c. 2200-year periodicity. However, the most pronounced cold events follow a ~2000-year period.

The climatic history of Africa and the Near East during the Holocene remains one of the major challenges for palaeoclimate research. Sedimentary records from lakes are among the most valuable sources of information for this region. Gasse and Van Campo (1994) used lake sediments to reconstruct the hydrological balance of lake Abyata (Ethiopia) and lake Bosumtwi (Ghana). A large-scale cycle was observed in the palaeohydrological history of these lakes. Minimum lake levels shifts to a more arid climate occur at approximately 10,000, 7500, 5800, 3000, and 400 BP. In addition, the same workers found evidence from lakes in Tibet and Rajasthan of major dry phases at c. 8000 and 7000 BP. This study suggested that dramatic abrupt shifts in the hydrological balance may have had an impact on ancient human populations. Similar millennial fluctuations between cold, dry conditions and warm, moist conditions are also evident during the Holocene in other areas of the world. Abrupt shifts of up to 18 per mil in the oxygen isotope ratio of diatom silica have been found by Barker et al. (2001) in a 14,000-year record from two alpine lakes on Mt. Kenya. Authors argue that Holocene variations in $\partial^{18}O$ are better explained by lake moisture balance than by temperature-induced fractionation. Episodes of heavy convective precipitation dated c. 11,100 to 8600, 6700 to 5600, 2900 to 1900, and 1300 years before the present were linked to enhanced soil erosion, neoglacial ice advances and forest expansion on Mt. Kenya.

Another indication that glacial activity occurred in different source areas simultaneously has been derived from ice-rafted debris (IRD), transported by floating icebergs in times of glacial activity (Bond et al., 1997, 2001; Elliot et al., 1998). IRD has a complex geographical distribution with the varied lithologies reflecting multiple sources. Comparison of IRD peaks (Bond et al., 2001) with the oxygen isotope concentration recorded in Greenland (Grootes and Stuiver, 1997) in Figure 2 shows a similar pattern before the Holocene period. Fine grains of IRD detrital material show the same cyclic character both during the Holocene and late Pleistocene. However, this cyclic character does not occur in the Holocene oxygen isotope record. Additionally, coarse lithic grains and the oxygen isotope concentration exhibit a similar pattern during the Holocene, characterized by sharp oscillations. Cyclic character can be traced in the fine lithic grains, as they are occurred with fine grains of IRD detrital material. The behavior of these grains may be due to oceanic processes.

The proxy data used to reconstruct climate history in the study of Bond et al. (1997, 2001) is the composition of North Atlantic sea-floor sediments. During cold periods, glaciers in Canada and Greenland advanced significantly, producing large numbers of icebergs that floated across the northern Atlantic, shedding rocky debris onto the sea floor as they melt. Spectral analysis of IRD changes in the North Atlantic from both late Pleistocene and Holocene carried out by Bond et al. (1997) shows an IRD maximum every 1470 ± 500 years. Several authors have reconstructed Holocene temperature peaks and found that they recur approximately every 1500 years.

Bianchi and McCave (1999) studied the grain size records of North Atlantic deep-sea sediment cores. These records appeared to be related to the flow rate of the thermohaline circulation of the ocean. These data showed several warm/cool oscillations with a periodicity of c. 1500 years during the Holocene. These oscillations were suggested to be comparable to the Little Ice Age and the Medieval Warm Period, and testify to a "recurrent feature" of Holocene climatic history. McDermott et al. (2001) derived a high resolution Holocene ∂^{18}O record from a speleothem in southwestern Ireland

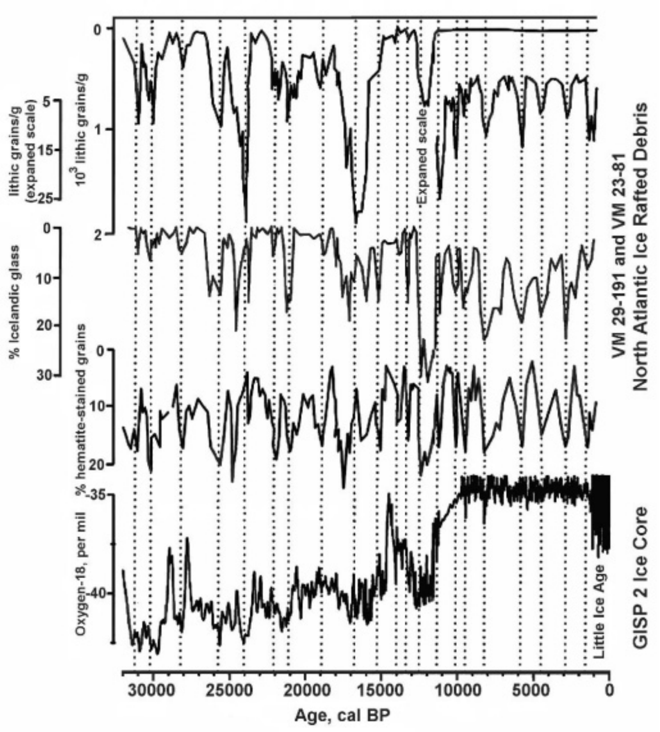


Figure 2. Comparison of hematite-stained grains, icelandic glass, and small lithic grains from the ice-rafted debris concentrations in the North Atlantic (Bond et al., 2001), and the changes of the oxygen isotope record from Greenland ice cores (Grootes and Stuiver, 1997) during late Pleistocene and Holocene.

and found that centennial scale variations correlate with $\partial^{18}O$ changes in Greenland ice cores. Evidence of 1500-year climate variability in North America during the past 14,000 years was derived by Viau et al. (2002) from the terrestrial pollen record. Results of the statistical analyses established nine millennial-scale oscillations during the past 14,000 years in which continent-wide synchronous vegetation changes with a periodicity of approximately1650 years were demonstrated.

There are reliable indications for distinct large-scale periodicities of climatic variability in the Holocene, and forcing factors of this variability have been indicated from ^{14}C concentrations in tree-rings (Figure 3).

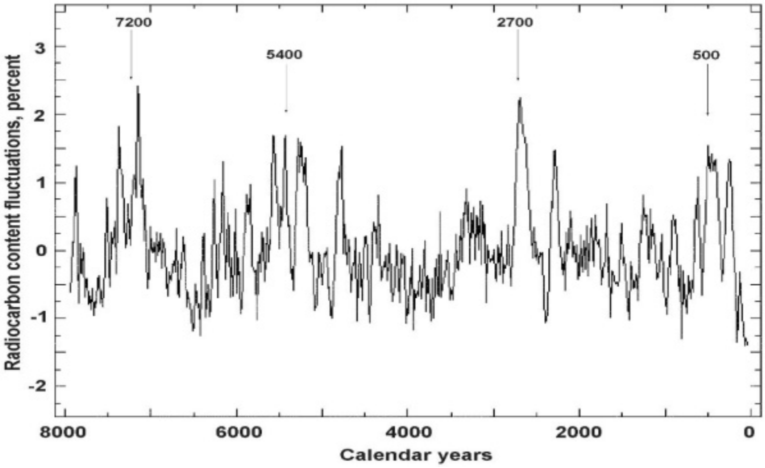


Figure 3. Reconstruction of the radiocarbon concentration (after subtraction of the long-term trend) derived from tree-rings. The arrows show the vicinity of high amplitudes of ^{14}C concentration variations.

Upon subtraction from the initial radiocarbon time series of the long-term trend, the residual time series clearly shows centennial and millennial changes. The major oscillations are in the vicinity of 7200, 5400, 2700 and 500 cal yr BP, with ~2400-year periodicity between them. This reconstruction shows that ^{14}C production was higher during the Little Ice Age, when solar activity was extremely low. Large-scale cyclic oscillations of the ^{14}C concentration with ~2400-year cycle have been suggested to correspond to phases of cold climate (Dergachev and Chistyakov, 1995).

Investigations of mountain glaciers during the Little Ice Age (~500 years ago) show a few periods of glacial growth associated with several low temperature oscillations, and some of them correspond to high amplitude oscillations in the ^{14}C concentration record.

Shifts in climatic conditions of British Columbia, Canada, over the past 5500 years have been based on estimates of changes in lake depth and salinity inferred from diatom assemblages of a well-dated sediment core from Big Lake (Cumming et al. 2002), which oscillate between periods of wet and drier climatic conditions (Figure 4). The most pronounced abrupt shifts in climatic conditions (numbers 0, 2 and 4) are repeated with an approximate 2400-year period. Accounting for the changes in climatic conditions with lower amplitude (numbers 1 and 3), climatic oscillations occur approximately every 1500 years. It is important to stress that the periods of lower lake depth correspond closely to the timing of worldwide Holocene glacier expansions, such as the expansions in the Little Ice Age from AD 1300 to 1920 and 3300 to 2400 cal years BP.

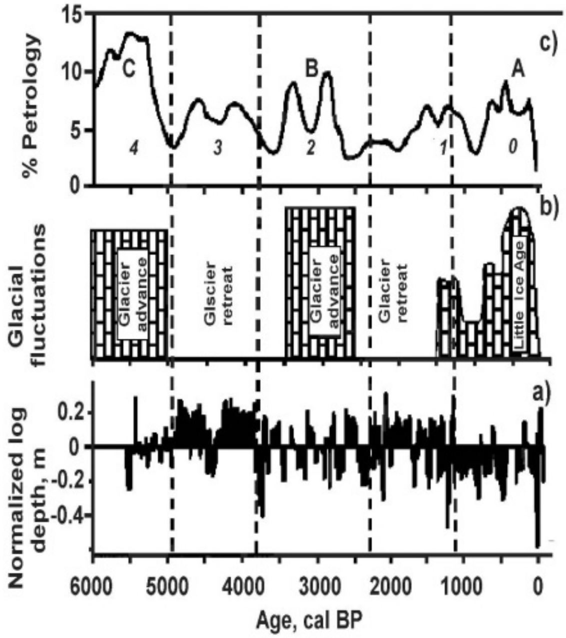


Figure 4. The relationship inferred by Cumming et al. (2002) between changes in depth from the Big Lake core (a) with a summary of worldwide fluctuations in glaciers (b); and a composite diagram of IRD from various marine cores from the North Atlantic (c). Letters A, B, C designate the ~2400-year cycle from glacier fluctuations (Denton and Karlen, 1973). Numbers 0–4 designate the ~1500-year cycles from IRD fluxes in the North Atlantic (Bond et al., 2001).

Bond et al. (2001) have shown that the changes of ^{10}Be concentration in deep sediments or ^{14}C concentration in tree-rings and the ice-rafted debris events during the Holocene are correlated. As shown in Figure 5ab there is good correlation between the ice rafted debris events and galactic cosmic ray intensity (represented by the radiocarbon record in tree rings). This compelling evidence suggests that external forcing has caused the long-term climatic cycle during the Holocene. The most pronounced maxima of glacier advance (Maisch et al., 1999) were synchronous with high amplitudes of long-term variations in radiocarbon rate production (Figure 5c). Magny et al. (2003) and Magny (2004) reconstructed the history of lake-levels in the French Jura Mountains. Holocene lake level fluctuations correlate (Fig. 5d) with the changing galactic cosmic ray intensity (radiocarbon record). This implies that the Jura lake levels also correlate with the periods of increased ice-rafted debris in the North Atlantic (Renssen et al., 2000).

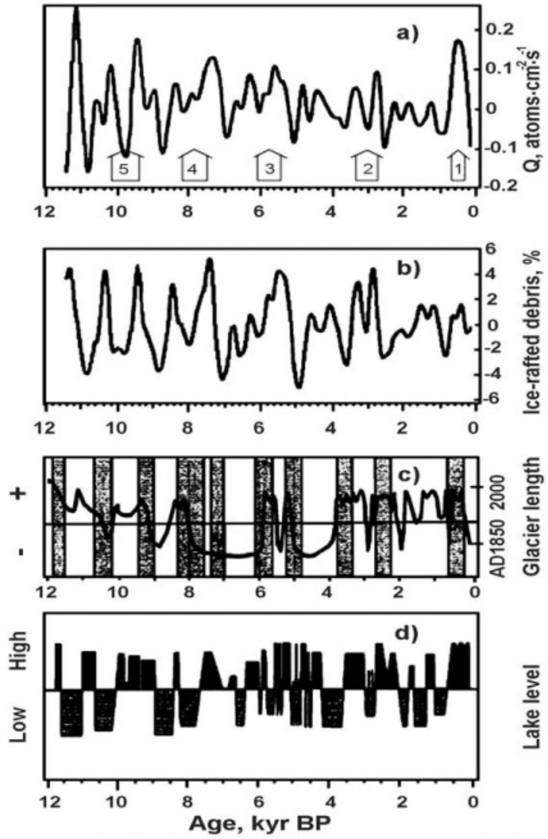


Figure 5. Comparison of: (a) cosmic ray variability (Q is smoothed ^{14}C production rate from the radiocarbon record of Stuiver et al. (1993); (b) combined ice-rafted debris in the North Atlantic (Bond et al., 2001); (c) estimated length variation of Swiss glaciers Maisch et al. (1999), cold intervals are indicated by the shaded areas; (d) lake-level fluctuations in the French Jura Mountains (Magny, 2004). The arrows show the extremes of the long-term changes of processes considered.

SPECTRAL ANALYSIS OF PROXY DATA

Mathematical methods of spectral analysis can give important information on the presence of a cyclicity in a time series of natural processes. Spectral analysis of the available long-term series of the radiocarbon concentration of tree-rings, using the classical harmonic methods of time series analysis, showed spectral lines at a number of periods. However, the same harmonic features are not independent. The dynamics of variations in the ^{14}C concentration in dendrochronologically dated samples has been studied through the utilization of various methods of Fourier spectral analysis by Sonett (1984), and by Damon and Sonett (1991). The first detection of 2200-2400-year quasi-periodicity in the long ^{14}C concentration record of tree rings was made by Suess (1980).

Let us consider the results of some recent spectral analyses of variability in long-term data, mainly the ~ 2400- and ~ 1500- year periodicities. Vasiliev and Dergachev (2002) conducted a spectral analysis of the non-stationary behavior of high-precision radiocarbon concentration data observed in tree-rings (Stuiver and Becker, 1993), over the past 8000 years. Several methods of spectral analysis were utilized: power spectrum, time-spectrum, band-pass filtering and bi-spectrum. It was demonstrated that the amplitude of large-scale fluctuations varied periodically. The period of this change is approximately 2400 years. The bi-spectrum analysis of data demonstrates the existence of amplitude modulation.

The power spectrum in Figure 6 shows a very strong line with the period of c. 2400 years, with an amplitude significantly exceeding the amplitudes of other lines in the spectrum, i.e. the component with period of ~2400 years is the principle component of long-term changes in the radiocarbon time series.

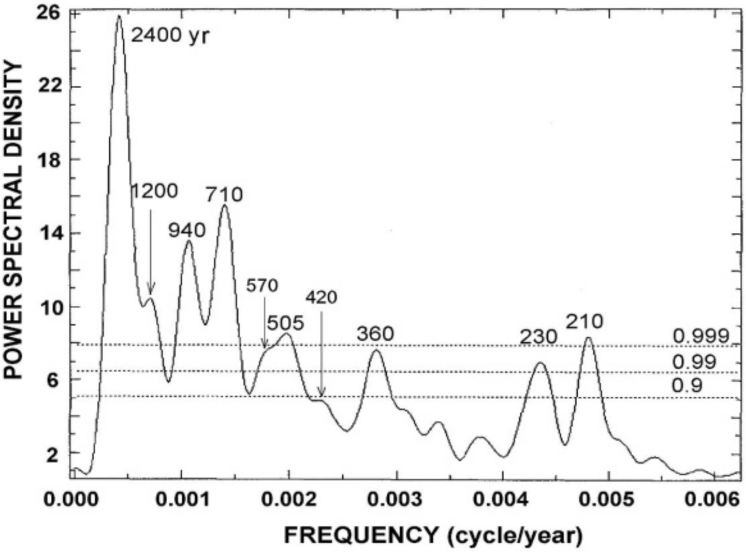


Fig. 6. The normalized power spectrum of radiocarbon time series for the last 8000 years obtained by the Blackman-Tukey method after removal of the long-term trend in the raw data series. The dotted lines are the confidence levels. The numbers near the peaks are periods in years.

We examined the dynamics of long-term periodicity in radiocarbon time series (Stuiver et al., 1998) on the separate intervals of this series. As can be seen from Figure 7, the spectrum indicates a well-pronounced and stable line corresponding to c. 2400 year for all the time spans under study. It can also be seen that the peak in the vicinity of the 1500-year period is less pronounced and stable and is even absent during the time span of 0-11,785 years BP (Fig. 7bcd).

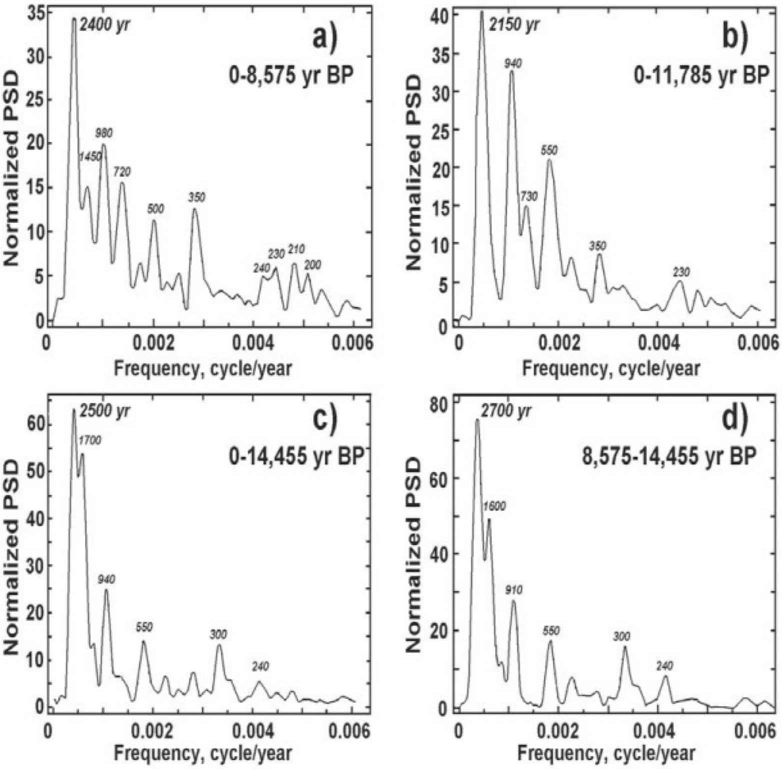


Figure 7. The normalized power spectrum of detrended radiocarbon time series for the different time spans: a) 0 - 8575 years, b) 0 – 11,785 years, c) 0 – 14, 455 years, d) 8575 – 14,455 years.

A detailed study of the dynamics of variations in the radiocarbon time series on the time span of the last 12 kyr (Stuiver et al., 1998) was carried out by Peristykh and Damon (2003). The Discrete Fourier Transformation (DFT) was used to evaluate the contribution of various periodic components by the height of their corresponding peaks. Prior to this, the raw data series were detrended through subtraction of the long-term variation component, by performing low-pass filtering using a smoothing spline method. The whole Fourier spectrum of the detrended time series is depicted in Figure 8a. This spectrum displays all so far known features as in Figures 6 and 7, with a pronounced peak at 2304 years, but little or no peak at about 1500 years. In Figure 8b, the peak of 1433 years is too insignificant to be counted as real.

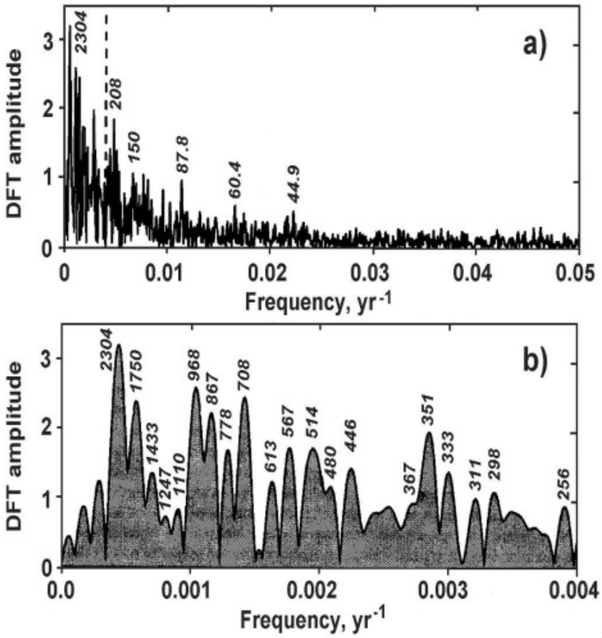
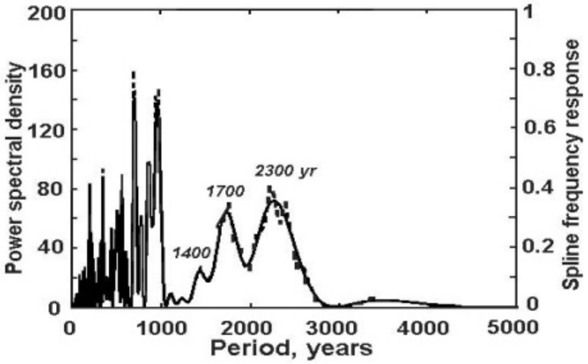


Figure 8. Fourier spectrum of detrended time variation in INTCAL98 record: a) the whole frequency range up to the Nyquist limit; b) bandpass filtered long-term frequency range.

A new Bayesian model using a random walk noise to take care of the trend in the data was developed by Palonen and Tikkanen (2003) to find periodicities in the IntCal98 calibration curve (Stuiver et al., 1998). The Bayesian analysis was constrained to periods of 20-5000 years by prior probability. Power spectral densities from the discrete Fourier transform (DFT - solid curve) and the maximum entropy method (MEM - dashed curve) analyses (Figure 9), show several peaks with long periodicity, c. 1400, 1700 and a most pronounced periodicity at c. 2300 years. Smoothing splines were used to clean up the DFT and MEM spectra by subtracting the spline from real data before DFT and MEM analyses. The Bayesian analysis yields a lower "background", particularly for longer periods.



Fiugure. 9. Power spectral densities of the INTCAL98 radiocarbon data obtained by DFT (solid curve) and MEM (dashed curve) analysis.

It must be emphasized that the millennial-scale periodicity is most noticeable in cosmogenic ^{10}Be concentration. Figure 10 shows a dominant quasi-periodicity of 2600 years and a peak at 1450 years. In all instances discussed above the amplitude of the c. 2400-year periodicity is high in comparison with the amplitude of the c. 1500-year cycle.

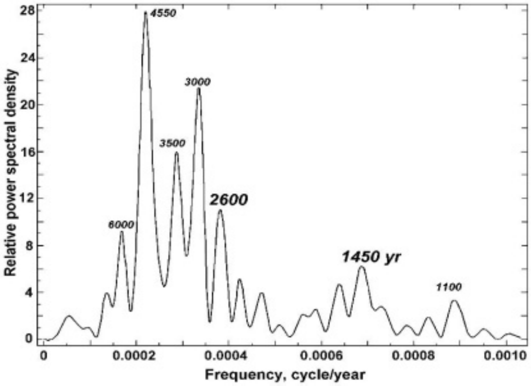


Figure 10. The power spectrum of ^{10}Be time series from GISP2 ice cores during the period 9376 -38500 yr BP (Finkel and Nishisumi, 1997).

Let us consider two examples of the spectral analysis of stable isotope series. The results of spectral analysis of ^{18}O concentration in Greenland ice (Grootes and Stuiver, 1997) is depicted in Figure 11. We emphasize that the spectral analysis of oxygen-18 series shows a resistant spectral power on frequencies close or identical to frequencies that are observed in cosmogenic isotope data. However, the amplitude of c. 2400-year periodicity in ^{18}O concentration is smaller in comparison to the amplitude of the c. 1500-year period.

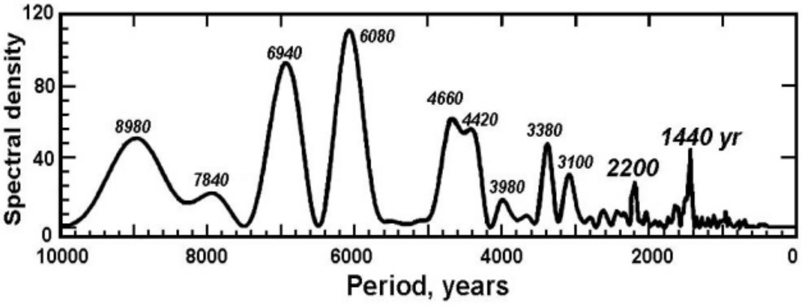


Figure 11. The normalized spectral density of ^{18}O concentration in ice cores from Greenland (without removal of the long-term trend).

Using the SPECTRUM analysis technique of Schulz and Stattegger (1997), Campbell et al. (1998) found a millennial scale periodicity in the rate of change of atmospheric carbon dioxide concentration measured in air bubbles in ice cores from Taylor Dome, Antarctica (Figure 12). It was suggested that this millennial-scale periodicity influences the global carbon cycle. As evident from Figure 12, the amplitude of the c. 2400-year periodicity is smaller in comparison to the amplitude of about 1500-year period, i.e. the amplitude of millennial-scale periodicity varies in the same manner as for the ^{18}O concentration. The opposite is true for such periodicities in the cosmogenic isotopes.

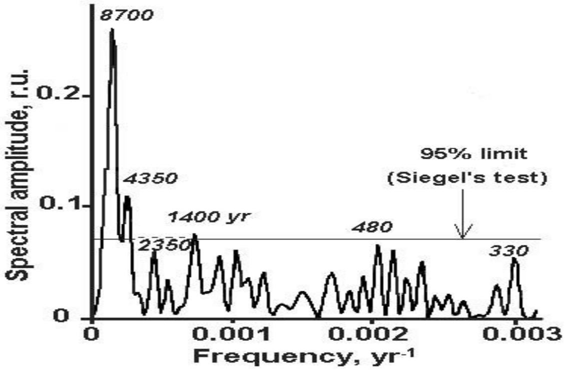


Figure 12. Spectral analysis of Taylor Dome CO_2 record (Indermühle et al., 1999) obtained by Campbell et al. (2000) using SPECTRUM analysis (Schulz and Stattegger, 1997).

DISCUSSION AND CONCLUSION

Powerful evidence for a persistent global millennial-scale cycle of climate occurs throughout both glacial and interglacial periods (e.g., Raymo et al., 1998; de Garidel-Thoron and Beaufort, 2001).

The studies presented in this paper suggest that millennial-scale fluctuations in natural processes occurring during the Holocene are well established. Global Holocene 2400- and 1500-year periodicities are evident in a variety of natural archives. Power spectra of cosmogenic isotopes have a dominant period in the frequency domain of c. 2400-year, and are less stable in the vicinity of the c. 1500-year period. Comparison of the changes of ^{10}Be with $^{18}\partial$O concentration in GISP-2 demonstrates that only the c. 2400-year cycle is in phase with cooling episodes (also of c. 2400-year periodicity).

A review of observations suggests that there is a common origin for the millennial-scale cycles in the climate of both high and low latitudes. These periodicities may have been responsible for millennial-scale climatic events such as the Little Ice Age, and cooling around 800 BC, 4700-4500 BP among other episodes. However, the mechanisms of these abrupt millennial-scale shifts during the Holocene remain poorly understood. Both ice sheets and mountain glaciers show a synchronous response of glacial systems to climate change, reflecting changes in global atmospheric conditions. Numerous studies of proxy climate data have demonstrated that glacial oscillations through the Holocene occurred with a period c. 2400 years. From measurements of soluble impurities in Greenland ice, O'Brien et al. (1995) demonstrated that Holocene atmospheric circulation above the ice caps was punctuated by c. 2400-year climate shifts that appeared to correlate with Denton and Karlen's (1973) glacial advances. Noren et al. (2002) studied sediment cores from lakes in the northeastern Unites States and established four major peaks of storm-related floods during the past 13,000 years; approximately 2600, 5800, 9100 and 11,900 years ago, with the most recent upswing in storminess beginning at about 600 yr BP. Comparison of these results with other climate records, including European glacier fluctuations, shows that intense storms have tended to occur more frequently during the cooler periods (e.g., O'Brien et al., 1995).

Factors influencing these changes probably included fluctuations in solar activity, changes in the galactic cosmic ray intensity and variations in the circulation and overturning of the oceans. Karlen (1998) examined proxy climate data, including changes in the sizes of glaciers, changes in the altitude of the alpine tree-line, and variations in tree-ring widths, in addition to data obtained from Greenland ice cores over the last 10,000 years, and concluded that the similarity between solar irradiation changes and climate change indicates a solar influence on the Scandinavian and Greenland climates.

Van Geel et al. (1999), using as indicators of solar activity the abundances of the cosmogenic isotopes ^{14}C and ^{10}Be, suggested that the relationship between variations in their abundances and millennial-scale climate oscillations during the Holocene was evidence that variations in solar activity have been a cause for millennial scale climate change. They concluded that the climate system is far more sensitive to small variations in solar activity than had been generally believed.

The recent observation of correlations between the galactic cosmic ray intensity and the surface of the Earth covered by low clouds (Svensmark and Friis-Christensen 1997) may provide an important clue to the mechanism for solar-climate variability. An increase in the global cloud cover may be a cause of cooling of the Earth during periods of low solar activity.

Many records of climatic and environmental change based on various proxy data exhibit distinct periodicities that have been attributed to extra-terrestrial forcing such as changes in solar activity. Solar activity modulates the level of galactic cosmic ray intensity, and therefore atmospheric levels of the cosmogenic isotope radiocarbon. A reconstruction of the ^{14}C concentration of tree-rings shows that ^{14}C production was higher during the Little Ice Age, when solar activity was extremely low. After subtraction from the initial radiocarbon time series of the long trend the residual time series clearly shows centennial and millennial changes. The major oscillations are at 8500-7800 cal year BP, 5400-4700 cal year BP, 2680-2200 cal year BP and 1100-400 cal year BP with c. 2400-year periodicity between them. These oscillations of the ^{14}C concentration with a c. 2400-year cycle correspond to cold climate phases. It should be noted that power spectra of cosmogenic isotopes show a millennial periodicity of c. 2400 year and c. 1500 year. The correlation of ^{14}C and ^{10}Be production rates with climate change points to a direct influence of changing solar activity and galactic cosmic rays upon the climate, suggesting that these factors are the prime candidate for the c. 2400-year climate cyclicity.

Examination of the causes of c. 1500-year climate cyclicity has been mainly focused on data from the Atlantic Ocean. Using a combination of palaeodata from other sources, we can improve our understanding of the input of other processes of such changes. It is known that peatlands are sensitive to hydrological fluctuations. Campbell (1998) demonstrated in late Holocene peat deposits of continental western Canada that wet and dry cycles varied with a c. 1450-year periodicity. On the basis of observed changes in patterns of the floristic composition of diatoms in western Canada during the past 5500 years, Cumming et al. (2003) distinguished alternating millennial-scale periods of high and low moisture availability, with sharp transitions in diatom communities occurring 4960, 3770, 2300 and 1140 cal years BP. Significant climate deteriorations, which are associated with cold and humid conditions, were established by Dapples et al. (2003) from records of Holocene landslide activity in the Western and Eastern Swiss

Alps. As result of their investigations, the three most recent and best documented periods of landslide activity were determined to be 3500-2100, 1700-1150 and 750-300 years BP.

The c. 1500-year period is consistent with the average oscillation frequency of thermohaline circulation in the World's oceans (Dansgaard et al., 1993). This oscillation was responsible for a series of abrupt warming episodes during the last glacial period and may also be responsible for Holocene climate oscillations such as the Medieval Warm Period (de Menocal et al., 2000).

Bond et al. (1997) suggested that c. 1500-year climate variations during the Holocene may be due to ocean-atmosphere interactions. In the following work, Bond et al. (2001) demonstrated that this periodicity may be driven by solar variability, amplified through oceanic and atmospheric dynamics. A scenario was described whereby solar-induced changes high in the stratosphere are propagated downward through the atmosphere to the Earth's surface, where changes in North Atlantic Deep Water formation are initiated, altering the global thermohaline circulation. They suggested that the solar signals may have been transmitted through the deep ocean as well as through the atmosphere.

Therefore, the long-term quasi-periodic components of climatic records point to possible forcing mechanisms of climate changes connected with the direct influence of solar activity (c. 2400-year period), and by internally forced oscillations of the ocean-atmosphere system (c. 1500-year period).

At present, particular attention has been given to the abrupt climate change centered at around 2650 BP, which corresponds to one of a number of Holocene cold and wet events (Dergachev et al., 2004, in press). In Europe the most marked climatic change appears from 3150 to 2650 BP. Glacier advance in Europe occurred from 2900 to 2400 BP. Major cold/wet periods occurred in the next time intervals: 2300-3000, 5000-5500 and 7400-8100 cal ^{14}C BP. Cold/wet periods of minor extension occurred from 3250 to 3450, from 5700 to 6100 and from 9000 to 9100 cal BP. Both the major recession phases of glaciers and cold/wet phases demonstrate a c. 2400-year periodicity, and taking into consideration minor episodes, an average period close to 1500 year seems reasonable. Alpine warm phases and the warm phases of Bond's North Atlantic ice-rafting record show a plausible correlation.

Climatic data during the Holocene vary on centennial-millennial scales, producing information about possible forcing mechanisms: 1) external - astronomically induced variations, changes in solar activity and cosmic rays and; 2) internal - oscillations of the ocean-atmosphere system. At present there is the possibility to reconstruct the timing, periodicity, and abruptness of climate changes on different time and spatial scales in various regions of the world. The Holocene period began more than 11,000 years ago and we are at a point on the palaeoclimatic timetable where the onset of a new 100,000-year ice age is expected, and this process may even be already in progress. It is possible that climatic changes in the future will be abrupt, as extreme climate changes often just 10 -20 years duration are strongly evident in proxy climate records. Climate is changing at all time scales and at varying amplitudes, and we cannot control global climate. Hence, the climate research community is bound to help the human community to learn to adapt to the natural variability of climate.

A more complete understanding of natural climatic fluctuations since the last Ice Age may help us to better identify and predict the potential effects of human-induced global warming. Further investigations are urgently needed to improve understanding of spatial patterns and mechanisms behind the millennial-scale variability in climatic conditions, as well as the implications of these changes on human societies.

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Chapter 15

ARCHAEOLOGICAL AND ETHNOGRAPHIC TOXINS IN MUSEUM COLLECTIONS

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ABSTRACT

The analysis of amorphous organic residues from archaeological and ethnographic collections provides direct evidence for the use of natural materials, which can help enrich interpretations of past societies. The value of this approach is increasing, driven by advances in extraction and analytical techniques that permit the analysis of an ever-wider range of compounds. However these approaches have not yet been targeted towards toxins based upon natural plant based poisons and narcotics. This paper will present the outline of a chemical analysis based approach to identifying trace residues associated with hunting poisons and sacred hallucinogens as well as poisons of a purely harmful nature. The successful exploitation of potentially lethal natural toxins can be taken as representative of the great ingenuity shown in man's adaptation to the environment.

Key words: archaeology, toxins, poisons, narcotic, environment, adaptation.

INTRODUCTION: ORGANIC RESIDUES

Environmental archaeologists successfully use organic ecofacts to identify past environments and the capacity of ancient societies to adapt to their surroundings, the data being derived from the diverse range of materials that are capable of surviving. Seeds, wood, plant and animal fibres, tanned leathers are examples of a wide range of materials are all capable of maintaining there physical form over millennia. Provided that suitably distinctive structural physical characteristics are present within the original material, then given good survival conditions archaeological ecofacts can be identified.

E.M. Scott et al. (eds.), Impact of the Environment on Human Migration in Eurasia, 185-197.

There is however also a wide range of natural resources that have been and continue to be exploited that lack physical features that may be visually identified even under high resolution microscopes. The most obvious examples of these amorphous resources are food residues in cooking pots and also wine and olive oil. These are resources of great archaeological significance and yet leave no identifiable physical remains behind. Other examples are the gums and essential oils extracted from herbs and shrubs, resins from trees and even fossil resins such as amber (Heron and Pollard, 1996). The absence of any visible physical characteristics even within modern reference samples means that they can only really be identified from the actual chemical composition of the material. It is within the various chemical components of these materials that one must attempt to identify distinctive compounds that may correlate a non-descript organic sample with a specific oil or resin.

Several case studies exist of the application of organic residue analysis to systematically investigating archaeological problems. The origins of dairy farming has been investigated by Craig *et al*. (in press) The archaeological question was to identify at what point domestic animals started to be reared for there secondary products e.g. milk. On a Late Bronze Age site at Cladh Hallan in the Hebrides, in the Scottish Islands, large ceramic jars appeared to contain amorphous concretions, which after extraction and analysis turned out to be milk proteins (casein) and the distinctive milk based fatty acids.

Another example is from the Mary Rose, a British warship that sunk off the English coast in 1545. Within the wide range of artefacts that were preserved by the cold, water-logged and anaerobic conditions was a medical chest belonging to the ship's surgeon. Within the ceramic and wooden jars were residues of a range of amorphous materials. The archaeological question was whether the residues could be used to investigate the types of medicines used by a Renaissance surgeon. Analysis of the residues demonstrated that significant use had been made of resin tapped from Pinus/Picea, pine or spruce trees. These could be identified by the presence of abietic and pimaric acids also present was boswellic acid, a distinctive compound found only in frankincense (Derham 2000).

In terms of organic residue analysis and adaptations to the Steppe environment, horse fat has recently been identified in an extensive collection of cooking pottery from the Eneolithic site at Botai in Kazakhstan. The cooking residues and the butchered horse bones present on the site combine to demonstrate the immense importance of horses as a food resource (Dudd *et al*. 2003).

PHARMACOLOGICALLY ACTIVE ORGANIC RESIDUES

For centuries various plant extracts have acted as a source of medicines. In particular from the Renaissance onwards specific pharmacologically active plant extracts have been extracted and refined and used to treat specific illnesses and symptoms; quinine from Cinchona bark to treat malaria; foxglove from digitalis to treat congestive heart failure and during the Industrial Revolution the ready availability to the urban masses of cheap laudanum, opium in alcohol, enabled the symptoms of cholera and TB to be alleviated.

The effectiveness of these specifics could be tied to the fact that they contained a specific compound that can be isolated and identified produces a specific physical response. In the case of opium extracts, the natural alkaloids morphine and codeine.

As well as medicines however, archaeological residues may also serve to demonstrate a specific and real threat to man. In damp summers a parasitic mould, *Claviceps purpurea*, the source of ergot alkaloids may become established on rye crops. Under famine conditions the infected material may not be removed from healthy grain and therefore the ergot alkaloids may become incorporated within foodstuffs.

The major physical impact of ergot poisoning is vasoconstriction and the cutting off of the blood supply to the internal organs (liver etc) and also the extremities such as hands and toes, resulting in hallucinations, gangrene and ultimately death. The late Dr Johs Andersen had a theory that many of the large number of archaeological skeletons identified as victims of leprosy had in fact been suffering from ergostism (M.Lewis, *pers comm.*).

Archaeological evidence regarding the death and burial of Iron Age bog bodies, from many sites across Northern Europe seems to suggest that they were actually ritual killings or sacrifices. In several cases it has been possible to analyse their stomach contents, which in most cases consisted of cereal with a few wild fruits. With the Danish bodies however, the last meal at least appears to have been of very poor quality, containing a large percentage of weed seeds such as corn spurrey (*Spergula arvensis*) with the Tollund man also containing the remains of ergot (Holden 2001).

The presence of ergot may therefore, possibly, be used as an indicator of the problems of crop failures at the time of burial, and therefore provide information about environmental conditions at the time. Whether the actual composition of last meal is of any ritual significance is a much contested issue.

In contrast several highly dangerous poisons have found more constructive roles. During the 19th century Liverpool was one of the richest and largest trading cities in Europe with its merchants maintaining strong trade links with South America. Many merchants donated extensive collections of artefacts collected from South American Indians to Liverpool Museum resulting in an extensive archive of ethnographic material, in particular poison darts.

A major source of arrow poisons in South America, are those derived from several species of frog, in particular the Poison Dart Frogs of the *Dendrobates*, *Atropophrynus* and *Colostethus* spp. The frogs secreting a toxic alkaloid histrionicotoxin from their skin when agitated (Albuquerque *et al*., 1977). The *Phyllobates terribilis* frogs exude four steroid toxins from their skin, one of them being, batrachotoxin (Mensah-Dwumah, 1997).

The most common poisons used in South America are those based on the cuarare family of alkaloids, originally identified in the 1920s from a sample deposited at the British Museum (Bisset 1989,1992). Strips of bark are extracted in boiling water and evaporated down to a thick resin that can be applied to fine bamboo darts for use with blowpipes. The main sources of curare are the Mensipermaceae; *Chondrodendron tomentosum* and *Sciadotenia toxifera*. Two species of the Loganiaceae are also used; *Strychnos toxifera* and *Strychnos guianensis*, however these two also produce caracurine alkaloids, structurally much more similar to strychnine. The poisons from the Mensipermaceae are muscle relaxants and produce asphyxia whilst the alkaloids from the Loganiaceae are nerve stimulants and produces muscular convulsions. This explains why historically cases of poisoning attributed to curare have frequently been so inconsistent in terms of symptoms. Related species *S.tieute*, *S.wallichiana* and *S. maingayi* in conjunction with *Antiaris toxicara* are used in SE Asia to produce an arrow poison termed ipoh (Scott 1921)

The arrow poisons in Africa tend to be based upon a class of compounds termed cardiac glycosides extracted from the dry seeds of members of the Strophanthus family (East Africa). Injection of the poison into the blood stream results in heart arrhythmia, loss of blood pressure and unconsciousness (Scott 1921).

Strophanthin G (Ouabain);	*S. gratus* and *Acokanthera* sp.	East/West Africa
	Euphorbia candelabrium	South/East Africa
	Euphorbia virosa	South/East Africa
Strophanthin K;	*S. kombe*	Central Africa
Strophanthin H;	*S. hispidus*	West and Central Africa
Adenium	*A.boehmianum*	S.W Africa
	A.Somalense	Somalia

There are suggestions that the major poison to have been used in Eurasia, is Aconite derived from several species of Aconitum (Mann, 1992).

ARCHAEOLOGY OF CANNABIS

As well as the deliberate use of diverse compounds for their therapeutic or toxic effects, many natural products have also been used for their hallucinogenic or narcotic effects. Indeed Andrew Sherratt at the Ashmolean Museum in Oxford has argued that many of the ritual artefacts recovered from Neolithic and Bronze Age tombs across Eurasia are designed specifically for the ritual consumption of narcotics. Cannabis consumption constituting an intrinsic part of East European mysticism, whilst opium was consumed in Western Europe and the Mediterranean regions (where the plant actually originated) and fermented alcohol in the Fertile Crescent (Sherratt (1997).

Cannabis sativa produces a resin composed of a series of compounds based on isomers of cannabinol. The main hallucinogenic compound in cannabis resin is delta-9-Tetrahydrocannabinol (THC). The resin however, is predominantly composed of cannabinol and cannabidiol. Neither of the most abundant compounds are actually hallucinogenic. The presence of THC or its degradation products is therefore essential to demonstrate use of the resin for its hallucinogenic properties. The actual use of *Cannabis sativa* by past societies is not surprising as it is a source of 3 useful products; hemp fibres and seeds as well as the resin itself and it can also grow wild requiring very little attention (Fleming and Clarke, 1998).

Hemp fibres have been reported from a wide range of archaeological sites, and traditionally it has been use to make cheap textiles and paper as well as rope and cordage. The potential use of hemp fibres therefore to produce fishing lines or nets should not be underestimated. Stable isotope analysis of human bones from 4 sites across the steppes implies that fish was a major food resource (O'Connell *et al*. 2003). Most of the early evidence (anything BC) of what has been described as hemp fibres is frequently based on a very limited analysis, "it is a plant fibre therefore it must be hemp."

Pollen records are frequently unreliable, due to the difficulty of distinguishing between hemp and hop pollen. Analysis of pollen cores have however been used to demonstrate the extensive cultivation of hemp during the Middle Ages even to the point of damaging the local environment (Willis *et al*. 1998).

Cannabis seeds are reported as having been a major grain crop and a source of oil in ancient China, although whether for cooking or burning in oil lamps or both is not clear (Li 1974).

The question remains however whether cannabis was originally cultivated as a hallucinogen. The archaeological use of cannabis as a hallucinogen has only occasionally been reported, associated with religious rites associated with shamanism and ritual purification surrounding death and burial. One of the most reliable examples is the ash found in a tomb dated to 315-392 AD at Beit Shamesh near Jerusalem, with chemical analysis of the ash demonstrating the presence of THC. From Gurbanesti in Rumania cannabis seeds attached to incense burners have been reported, and also in vessels from early Bronze Age tombs in the Caucasus (Ecsedy, 1979). At several Bactrian-Margiana Archaeological Complex temple sites large ceramic bowls containing extensive remains of cannabis, poppy also possibly ephedra pollen have been excavated. The interpretation being that these temple rooms were specifically for the preparation of haoma/soma, a ritual hallucinogenic libation that subsequently became adapted into the rites practised in the Zoroastrian fire temples and is also mentioned in the Rig Vedas the Hindu sacred texts (Sarianidi, 1994).

PAZYRYK TOMBS

The best preserved and recorded example is at Pazyryk in the Altai mountains in a series of Scythian tombs. The Altai tombs were originally reported by Radloff in 1865, excavations were undertaken by the Hermitage in 1925-29 and Pazyryk No1 excavated in 1929. Four major barrows were excavated by Rudenko during the period 1947-49. Tomb No2 was excavated in 1947, and as with the other tombs it consisted of a stone cairn covering an earthen mound constructed over a funerary pit dug in the ground (Rudenko, 1970).

Whilst the area around Pazyryk is not within the region of permafrost, the actual tomb was stabilised in lens of ice beneath the cairn. The stones enhance heat loss during the long winter and act to shade the ground during the short summer. The barrow raises the tomb above the ground and again enhances heat loss. Whilst the gap the between the two layers of timber enhanced the convection of heat out of the burial chamber. The thermal stability of the frozen tombs led to the excellent preservation of an extensive range of artefacts including organic material.

Amongst the artefacts recovered were a set of hexapod props positioned in the centre of the tomb, possibly with a felt covering as large pieces of it were found in the vicinity. The props were associated with a cauldron-shaped incense burner and one had a small leather flask attached containing hemp seeds (*Cannabis sativa*). A second set of hexapod props and also the remains of a leather covering, constituting a tent type structures and a rectangular incense burner where also excavated in the corner of the burial pit. The hexapod stands were present in all of the Pazyryk tombs, but only in tomb 2 did the other items of the set survive (Fig.1).

62 Apparatus for burning hemp, from barrow 2. A, copper censer on feet; B, copper censer with pedestal (1/3); C, rods of hexapod cover-stand.

Figure 1. The apparatus for burning hemp from the Pzyryk group barrows, the Pazyryk-2 barrow

The excellent preservation conditions resulted in the survival of hemp seeds within the incense burners associated with stones. It is presumed that stones were heated in a fire and then transferred to the incensor and the hemp thrown on. It may be concluded that these tents and burners constituted the saunas or sweat lodges of the Scythians that Herodotus described. Although Herodotus never actually travelled to the steppes and so his description may not be as reliable as it seems. The exact circumstances of the use of the incensors therefore remain something of a mystery. The presence of 2 incense burners in tomb 2, built for a man and woman, implies that no gender bias existed in the use of cannabis. Although why are 2 burners present when neither tent is big enough for either person? Are the actual burners designed to go inside another structure be it a larger tent style sauna/sweat lodge or wooden cabin as reflected in the style of the tomb itself. Or are the incense burners simply votive offerings, not actually designed to be functional?

The explicit inclusion of these artefacts in all of the tombs implies that cannabis consumption was not considered to be an anti-social or socio-pathic activity. The questions remains however; did the use of *cannabis sativa* constitute an occasional ritual associated with death and burial or did it actually constitute a more extensive part of the normal social and cultural functioning of Scythian society. In terms of consumption patterns it may be possible to identify regular or intermittent drug use by an individual. In modern forensic medicine it is possible to determine patterns of drug use by analysing sections along hair braids or toe or finger nails. The question remains as to whether the analytical procedures can be adapted to archaeological samples.

ACCELERATED AGEING EXPERIMENTS

Theoretically it should be possible to identify evidence of the presence of pharmacologically active plant products by identifying the actual chemicals or their degradation products in organic residues. The major question however, is do the actual toxins and hallucinogens survive over archaeological time spans or are they rapidly degraded beyond recognition even under favourable conditions? The issues that surround research into the archaeological significance of these compounds are based on the chemically complex nature of the plant extracts. There is also a general lack of research into their stability over archaeological time frames, modern medical research being geared mainly towards proving chemical purity over very short time frames.

In order to tackle the basic analytical issues surrounding the analysis of these compounds. The work so far has been based on establishing an extensive programme of accelerated ageing experiments. The aim being

To gain information regarding the actual decay rates

To generate samples of the actual decay products

To develop analytical procedure that could effectively extract the amorphous residues into solution and to provide unambiguous analytical data.

In terms of investigating the stability of organic residues, the best preserved samples to date have been from cold anaerobic environments, as one would expect for any organic archaeological find. It has been demonstrated that organic residues can survive in fairly unfavourable conditions, when absorbed into inert porous matrices, in particular pottery. The uneven and pitted nature of the surface of most pottery shows the hollows within which organic residues may become absorbed. The pores providing a physically more protected context within which the residue may survive. A wide range of archaeological lipids, fatty acids, waxes and plant resins have all been recovered successfully from pottery recovered from archaeological sites (Heron and Pollard 1996).

Therefore, in order to test the actual potential for survival of the toxins and narcotics, a series of accelerated ageing experiments were set up in which standardised pottery pieces used. The pottery was constructed from modern commercial potters clay although formulated to mimic the type of clay used historically. The advantage of using modern clay is that it is highly blended and homogenous. The individual pottery pieces will therefore be identical, which should rule out any differences in preservation due to differing interactions between the organic and mineral phases. After firing at 750^0 C the pieces are approximately 2cm square, weigh 4.5 grams and have a 100uL hollow in top into which is dropped 100uL of a standard solution made from analytical grade material.

The range of poisons and narcotics examined has been kept fairly wide. The problem being that the active chemicals that have been used around the planet over the millennia are themselves fairly diverse. The morphine in opium differs significantly in chemical structure from the cannabinols in cannabis which again differs from the kava used in the South Sea Islands. These all differ significantly from the arrow poisons discussed earlier. The actual chemical stability of all the various compounds will differ. Therefore over 600 ceramic sherds were spiked with a range of compounds;

Hallucinogens; Atropine, Codeine, Tetrahydrocannabinol, 5-methoxytryptamine, Harmine and Kava

Poisons; Ouabain, strychnine, tubocurarine and coniine (hemlock)

Common commodities; abietic acid (pine resin), olive and cod liver oils and samples of caffeine, nicotine, beer and wine were also included.

Individual sherds were then coarsely ground and placed in individual vials. The vials were acclimatised under controlled environment either in a desiccated environment under air or under nitrogen but with elevated humidity. The vials were then sealed up. Individual racks with a set of samples were then placed in thermostatically controlled ovens at 60 and 90°C. Individual sets being taken out at fixed times over the coming few years.

A second set of samples were exposed to the degradative effects of UV light. A series of open glass dishes are placed on a board 25 cm underneath a UV-A lamp.The light peaks at 340nm but actually runs from 290 to 420nm with minor peaks in the visible light section up to 500nm. The spectrum chosen is that which passes through the ozone layer but is of sufficient energy to initiate degradative reactions in terrestrial samples.

A third set of samples, intact pottery pieces where buried in the sub-soil at an experimental agricultural farm run by Newcastle University. The advantage of this site is that the environmental conditions of the field have been closely monitored for the past 100 years.

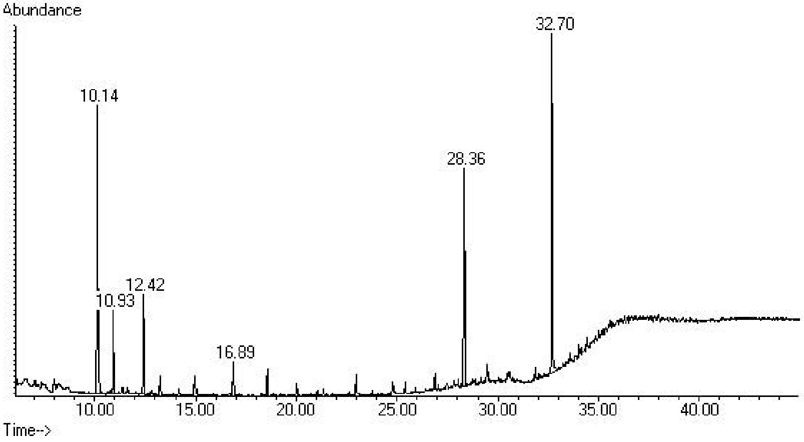
Measuring the loss of organic material in the pottery over time, will enable decay rates of various compounds under differing conditions to be determined. It should be possible to determine which compounds are decay quickly and are therefore unlikely to survive archaeological time spans. And those that decay at rates comparable with lipids such as fatty acids and waxes, compounds which are known to survive in archaeological sites.

The second purpose of the accelerated ageing experiments is to generate pottery sherds that known to contain specific pure compounds that have degraded under known conditions. From these sherds it is then possible to optimise an extraction protocol to extract all the organic components and develop an analytical procedure that can isolate and identify both the intact material and its degradation products.

SAMPLE ANALYSIS

The major analytical problem with plant extracts is that they frequently contain large numbers of compounds, very few of which are the actual subject of interest. For this reason the analyses are being done by gas and liquid chromatography. The sample is injected at one end of a long thin column and slowly washed along the column by a mobile phase, of either gas or liquid respectively. This process fractionates the sample into its individual components.

Hence a plot is produced which shows the increasing time taken for each compound to pass down the column. The individual pure components may then be quantified or structurally identified (Fig.2).



Figur.e 2. Chromatography of the compounds extracted from thehemp fragments by methanol/dichloromethane.

One of the samples analysed to date is a 19th century sample of Indian Hemp from the ethnographic collection at Liverpool Museum. The largest peak at 32.7 minutes is just an internal standard to help quantify the peaks. The peak in the middle area are low levels of fatty acids and the very early peaks volatile essential oils and fumigant.

The identification of the individual components may be determined by passing the compounds isolated by the chromatography stage directly into a mass spectrometer. Here the compounds are ionized and accelerated and then fractionated by an electromagnet according to ratio of charge of mass or *m/z* ratio. The fractionation pattern of the individual molecules is determined by the actual molecular structure and therefore the identity of the compound may be reconstructed from the fragmentation pattern recorded.

The main peaks of interest are at the 25-30 minutes area; 28.36 which is cannabinol, and low level peaks at 25.4 minutes, which is cannabidiol and 27.5 minutes which is tetrahydrocannabinol the main hallucinogenic compound (Fig.3). The same compound that was detected in a tomb at Beit Shemesh near Jerusalem.

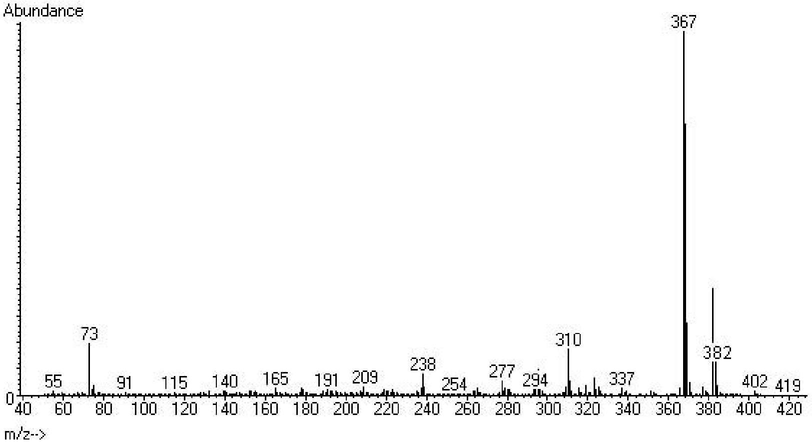


Figure 3. Identification of the individual components by mass spectral analyses.

The mass spectrum of the cannabinol peak at 28.36 min could be identified from the fact that fact that the molecule has a molecular weight of 382, a major peak at 367 and a distinctive sequence of smaller ions formed as the molecule unwraps. The molecule that is actually identified is a TMS or trimethylsilyl derivative of cannabinol. This is a capping group added prior to chromatography to seal any reactive functional groups in the molecule.

The importance of the accelerated ageing experiments is demonstrated by these results in that the main hallucinogenic compound (THC) is unstable and therefore is only just visible as a peak, despite the fact that the sample is hemp! That the sample is dried and powdered and therefore has a very large surface area my actually explain the rapid degradation of the THC.

CONCLUSION

Hopefully the project outlined will establish an effective procedure for identifying residues of toxins, even heavily degraded ones. Gaining an understanding of the capacity of past societies to successfully exploit potentially lethal resources will serve to demonstrate the immense subtlety of the resource management practised by archaeological and ethnographic peoples and help construct an understanding of the role such materials had within past societies. The actual application of the research to archaeological cases is still very much in the early stages and can only really be driven by potential issues raised by archaeologists and museum curators.

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Chapter 16

CHANGES IN PALAEOENVIRONMENT AND HUMAN MIGRATIONS IN THE CENTRE OF THE RUSSIAN PLAIN

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ABSTRACT

The age and genesis of palaeosols buried under barrows and within floodplain sediments in the centre of the Russian Plain have been studied. Palaeosols formed in the time interval from 10000 to 3500 BP are represented by steppe Chernozems attesting to less humid climate, whereas palaeosols dating back to the past 3500 years are represented by Podzolic and Grey Forest soils (Luvisols) attesting to humid climate. The periods of northward migration of steppe tribes into the forest and forest-steppe zone took place in the Middle Bronze Age and in the epochs of Cimmerian and Sarmatian culture (4000–3500, 3000–2700 and 2000–1700 BP, respectively) corresponding to phases with dry climate and the development of steppe Chernozems. Several intervals with active alluviation and soil burial on the floodplains have been identified: 10500, 8000, 4500 and 500 BP, as well as about 6500 and 2500 BP. These intervals correspond to the periods with colder climate.

Key words: Buried soils, Bronze Age, Cimmerian epoch, climatic period, steppe, forest zone

INTRODUCTION

The palaeopedological method is widely used to reconstruct Holocene changes in environmental conditions of the steppe zone (Ivanov, 1992; Demkin, 1997). For this purpose, modern surface soils are compared with palaeosols buried under barrows and hillforts. They can also be reconstructed on the basis of studying buried soils of floodplains (Alexandrovskiy et al., 1987), because alternation of soils and alluvial layers is often conditioned by climatic fluctuations.

E.M. Scott et al. (eds.), Impact of the Environment on Human Migration in Eurasia, 199-208.

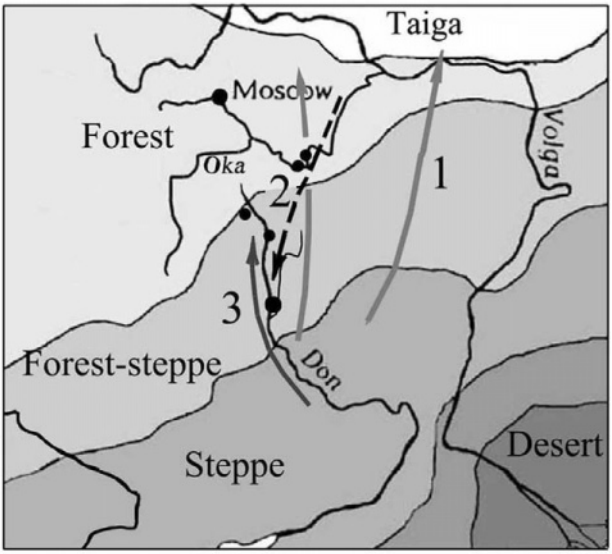

Figure 1. Location of sites and pathways of Human Migrations: (1) migrations of the tribes of Abashevskaya, Fat'yanovskaya, and other steppe cultures to the north; (2) migration of the tribes of Gorodetskay culture to the south; (3) migration of Sarmatian tribes to the north.

Soils of the forest-steppe zone are of particular interest for the study of palaeoenvironment (Fig. 1).

Chernozems developing under steppe communities and Luvisols forming under forest vegetation have distinctly different profiles. Therefore, the presence of buried Chernozems and Luvisols dating back to different time intervals makes it possible to reconstruct unambiguously the conditions of steppe or forest vegetation and judge the character of palaeoenvironmental changes. Palaeosols can be found in the layers of natural sediments and under burial mounds, hillforts and other archaeological monuments (Duchaufour, 1991; Limbrey, 1975). The study of chronosequences of palaeosols buried under barrows and hillforts within the forest-steppe zone of eastern Europe in the past 5000 years attests to considerable fluctuations of the climate and vegetation in the Middle and Late Holocene (Alexandrovskiy, 1996).

Palaeoenvironmental reconstructions can be based not only on the analysis of the genesis of buried palaeosols; in fact, the mere presence of a buried soil within the thickness of sediments attests to changes in sedimentation processes that are often related to climatic changes. In particular, such soils are often found in the thickness of alluvial sediments on floodplains (Holliday, 1992; Sycheva, 2000).

The aim of this paper is to discuss the role of palaeosols for palaeoenvironmental reconstructions and to characterise Holocene changes in the climate and vegetation on the basis of the study of buried palaeosols in the forest-steppe zone. As shown below, these changes are correlated with archaeological data on the migration of ancient tribes of the Bronze and Iron ages.

MATERIALS AND METHODS

Soil is a medium that records environmental conditions and their changes with time in the morphology and chemical properties of its profile (Ivanov, Aleksandrovskiy, 1987). Thus, the reconstruction of climatic moisture and the character of vegetation in the past is possible on the basis of studying palaeosols dating back to different time periods. Various soil features and properties can be used for this purpose, such as the thickness of the humus horizon and the organic carbon (C_{org}) content, the depth of leaching of carbonates, the presence of podzolization features, microfabric of the soil mass and other morphological and analytical soil characteristics. Soils are characterised by moderate rates of development; the record of environmental conditions in the soil profile is usually averaged for relatively large time spans (hundreds and thousands of years). However, if a chronosequence of buried soils is available, a more detailed record of environmental changes can be obtained.

Chronosequences of palaeosols buried under barrows and hillforts in the basins of the Middle Oka and Upper Don rivers were studied (Fig. 2). Along with them, soils buried within the sequence of alluvial layers of floodplains were analysed. Soils of these two groups of study objects have different mechanisms of recording changes in the climate and environment. Therefore, it is of particular interest to compare the results of their interpretation. Buried palaeosols of floodplains compose soil chronosequences oriented in the vertical direction, whereas palaeosols buried under barrows and hillforts are often oriented in the horizontal direction (palaeosols of different ages are found under spatially separated objects). For example, in the area of the Chertovitskii-3 hillfort, the following horizontal chronosequence of palaeosols has been studied: Chernozem under the barrow of the Bronze Age (3700 BP), degraded Chernozem and Luvisol under two ramparts (2400 and 2000 BP), Chernozem under the barrow of Sarmatian age (1700 BP), Luvisol under the barrow dating back to the medieval epoch (1000 BP) and the background surface soil.

The age of studied palaeosols was determined with the use of radiocarbon dating and on the basis of archaeological data. Calibration of dates was carried out with the Groningen calibration program (van der Plicht, 1993), updated with the recommended Intcal98 dataset (Stuiver et al., 1998).

RESULTS

Palaeosols buried under barrows and hillforts.

In the middle reaches of the Oka River (near the settlement of Izhevskoe) and in the Don River basin (near the town of Zadonsk) steppe Chernozems buried under barrows of the Bronze Age have been studied. These soils differ markedly from the background surface Grey Forest soils (Luvisols). The age of humus in the buried Chernozem (according to ^{14}C dating of humic acids) reaches 5900 BP; the age of burying is estimated at 3800–3500 BP (3500±100 BP). Grey Forest soils buried under the ramparts of hillforts dating back to the Iron Age (2320±50 and 2070±60 BP, Ki-5434, 1562) and located in the upper reaches of Don do not differ much from background surface soils.

The soil chronosequence from the area of Chertovitskii III hillfort is of particular interest for the study of environmental changes and peoples' migrations (Fig. 2).

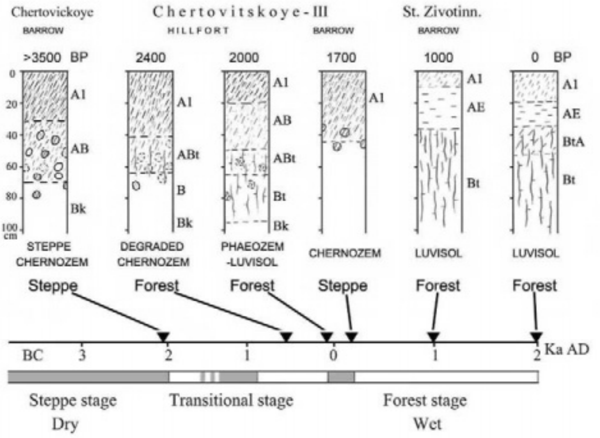

Figure 2. Horizontal chronosequence of soils and stages of soil and environment evolution in the centre of the Russian Plain (Chertovitskaya-3 and Starozhivotinnaya sites).

Under the barrow of the Bronze Age (3700 BP), the steppe Chernozem is buried. Its profile is not differentiated by clay and contains tracks of steppe burrowing animals.

Under the ramparts of the ancient settlement, soils of the forest stage are buried: degraded Chernozem with some features of textural differentiation (2400 BP) and Dark Grey Forest soils with distinct textural differentiation (2000 BP). The eluvial–illuvial differentiation of the soil profiles by the clay fraction content (textural differentiation) increases with time, which attests to the duration of soil development under forest vegetation. Thus, in the soil buried 2400 years ago, the coefficient of textural differentiation K_d is 1.6; in the soil buried 2000 years ago, it is substantially higher (K_d 2.4); in the background surface soil, it rise up to K_d 3.4 (Akhtyrtsev, 1992). On the basis of these data, we can assume that nondifferentiated Chernozems (K_d 1.0) existed in this place 300–400 year before the construction of the first rampart.

The soil buried under the Sarmatian barrow (1700 BP) has evident features of chernozemic pedogenesis. Its profile contains numerous tracks of steppe rodents; textural differentiation is absent (Chendev & Alexandrovskii, 2001). Similar soils were described by us under Sarmatian barrows far to the north of this site, in the upper reaches of the Don River.

The soil buried under the barrow of Borshevskaya culture (1000 BP) is classified as a strongly differentiated Luvisol that does not differ much from the background surface Luvisol. Similar Luvisols were described under a barrow of the same age in the nearby area (Akhtyrtsev, 1992).

Floodplain palaeosols.

Sequences of floodplain palaeosols attest to repeated changes in the environment. On the floodplain of the Oka River near the town of Staraya Ryazan, two palaeosols in the bottom of the section of floodplain sediments date back to 5910±260–4880±120 and 3780±90 BP (radiocarbon dates of humic acids) and are classified as Chernozem-like soils (Phaeozems). Two overlying soils (2280±110 и 1500±90 BP) are classified as Grey Forest soils (Luvisols). Hence, we deal with the same sequence of different stages in the development of soils and landscapes: meadow steppes with Luvisols existing on the floodplain in the Atlantic and Subboreal period; in the Subatlantic period, they were replaced by forests. Besides, the sequence of buried soils on the floodplain attests to the alternation of periods of active pedogenesis and alluviation (Fig. 3).

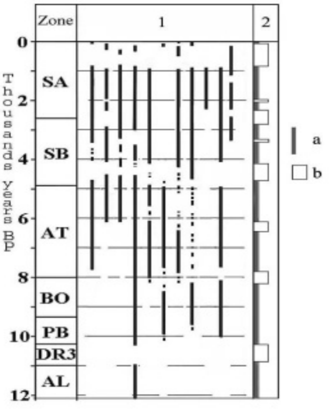

Figure 3. Alternation of the periods of pedogenesis and alluviation in the floodplains of the Russian Plain: (1) intervals of predominant pedogenesis; (2) periods of (a) soil formation and (b) alluviation.

These periods were more or less synchronous not only in the Middle Oka basin but also on the floodplains of other rivers of the Russian Plain (Alexandrovskiy et al., 1987; Sycheva, 2000), which attests to the influence of climatic factors on changes in the intensity of alluviation and pedogenesis on the floodplains.

DISCUSSION

Gradual and abrupt changes in the environment.

The following assumptions were laid in the basis of our interpretation of the data obtained: alternation of soil and alluvial layers in the sequence of floodplain deposits attests, first of all, to changes in the temperature, whereas soil changes on higher geomorphic positions attest to changes in the humidity of the climate (Fig. 4).

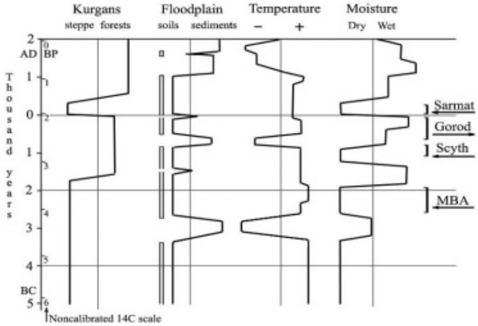

Figure 4. Changes in biomes as seen from data on palaeosols buried under barrows and hillforts, alternation of pedogenesis and alluviation on floodplains, climatic fluctuations and migrations of ancient tribes (Sarmat—migration of Sarmatians to the north; Gorod—migration of the tribes of Gorodetskaya culture to the south; Scyth—migration of Cimmerian tribes to the north; MBA—northward migration of tribes in the Middle Bronze Age).

In general, temporal changes in the character of palaeosols are conditioned by corresponding changes in the climate. The impact of human activity on the environment and pedogenesis in that time was not very pronounced. For instance, though the people of the Gorodetskaya culture cut down the forests around their settlements, this could not stop the development of Luvisols conditioned by the humidity of the climate at that time. The features attesting to some aridization of the climate can be found in the soils buried under barrows. As a rule, these barrows were constructed in the areas lying beyond permanent settlements, where anthropogenic loads on the environment were minimised. Besides, the population density in the Middle Bronze Age and in the Sarmatian epoch was low. Therefore, the development of Chernozems during these periods was conditioned by natural rather than anthropogenic factors. This is also seen from the comparison of buried Chernozems with background surface soils under cropland. Despite a much more intense anthropogenic impact and substitution of cropland for forest vegetation, the latter preserve their Luvisolic nature attributable to a more humid climate than the modern epoch.

The study of soil chronosequences under barrows and in floodplain deposits makes it possible to distinguish between two main stages in the development of the environment in the second half of the Holocene. During the first stage (Middle Holocene, 5000–1800 BC), steppes extended far to the north of their modern boundary; the climate was generally drier than at the present time. The second stage (Late Holocene, 1800 BC–2000 AD) has been marked by the general humidization of the climate followed by an advance of forest vegetation on the steppe. During this stage, soils in the steppe zone have been subjected to the leaching of carbonates and the accumulation of humus, whereas soils in the forest and forest-steppe zones have been podzolized (Ivanov & Demkin, 1999; Alexandrovskiy, 1996). The advance of forest vegetation on the steppe has been also proved by palynological data (Serebraynnaya, 1992).

Along with the general tendency toward an increase in climatic humidity and the degree of soil podzolization, considerable fluctuations of the climate took place in the period from 1800 BC to 400 AD. Archaeological data suggest a considerable decrease in climatic humidity about 1000 BC (Makhortnykh & Ievlev, 1993). However, available paleosol data are insufficient to prove this conclusion for the centre of the Russian Plain. There are only indirect indications of the possibility of climatic aridization in that period. For example, the results obtained during the study of the Chertovitskii-3 hillfort suggest that the transition from Chernozemic to Luvisolic pedogenesis took place about 2700–2800 BP (900 BC[1]). At the same time, some features of climatic aridization and xerophytization of the biomes of the Early Scythian epoch have been established by us in the North-Western Caucasus (Alexandrovskiy, 2003).

The new stage of humidization and cooling of the climate followed by an advance of forests on the steppe took place about 2700–2000 BP. The soils buried under the ramparts of hillforts of the Iron Age attest to a gradual transformation of steppe Chernozems into Luvisols. The soils buried in the fifth–first centuries BC (2320±50 and 2070±60 BP) are characterised by strong podzolization (the Perekhval archaeological site).

Very distinct features attesting to a short-term (first–third centuries AD) stage of climatic aridization are seen in the soils of the Upper Don and Middle Oka basins. This stage was marked by considerable northward migration of steppe vegetation and the development of Chernozemic soils buried under the barrows of Sarmatian epoch in the vicinities of Voronezh, Dankov, and some other areas in the forest-steppe zone. These soils differ markedly from background surface Luvisols that have been developing in the forest-steppe during the larger part of the Subatlantic period. The features of climatic aridization at the beginning of our era have been also established in the steppe zone (Ivanov & Demkin, 1999).

The study of palaeosols buried in the sequence of floodplain sediments makes it possible to identify the main stages of alluviation that, according to our hypothesis, are mainly connected with the periods of climatic cooling. These stages correspond to the following time intervals: 4700–4200, 2700–2500, 800–100 BP and, probably, about 3300 and 2100 BP. It can be supposed that these periods were also marked by an increased climatic humidity.

Climatic changes and migration of ancient people.

The results of palaeosol studies agree well with available data on ancient human migrations within the centre of the Russian Plain (Figs. 1, 4). The use of pedo-archaeological method on particular archaeological monuments (barrows or hillforts) makes it possible to obtain information on palaeoenvironmental changes and on the migration of ancient people. Thus, the periods of northward migration from the steppe and forest-steppe into the forest zone (marked by the presence of barrows typical of steppe cultures in the modern forest zone) coincide with the periods of aridization of the climate and northward migration of steppe vegetation. The reverse tendency can be revealed on the basis of studying hillforts in the forest-steppe zone: both environmental zones and ancient peoples migrated southward during the periods of climatic humidization.

CONCLUSIONS

The following stages of palaeoenvironmental changes and related migrations of ancient tribes can be distinguished in the centre of the Russian Plain within the last 5000 years. In the Middle Holocene (up to 2000 BC), steppe Chernozems occupied much larger territories than at present. The climate was generally drier than the modern climate. In the Late Bronze epoch, some humidization of the climate took place. Forests advanced to the south. This period, with some minor fluctuations, lasted up to the middle of the second millennium AD (Alexandrovskiy, 1996, 2003). After the stage of climatic cooling (3500–2700 BC), during the period of some warming and aridization (2700–2000 BC), tribes of the Middle Bronze Age (the Abashevskaya, Fat'yanovskaya, and some other steppe cultures) penetrated far to the north of the modern steppe and forest-steppe zones, within the forest zone. This migration is marked by barrows in the forest zone. The soils buried under these barrows are similar to typical forest-steppe soils. Later, they were transformed into typical forest soils (Albeluvisols). During the Late Bronze epoch, the climate became wetter and the propagation of forest vegetation into the steppe zone began.

The next stage of climatic aridization dates back to about 1000 BC according to archaeological data. This aridization worsened environmental conditions in the steppe zone and caused the migration of Cimmerian and Early Scythian tribes from the steppe into the forest-steppe and even forest zones (Makhortykh & Ievlev, 1991).

Then, about 800 BC, the climate became cooler and wetter again. This stage is marked by the development of Luvisols and forest biomes in the forest-steppe zone and by the burying of soils under alluvial layers on the floodplains. As forests advanced to the south, the tribes of Gorodetskaya culture (typical "forest" culture) migrated in the same direction (from the Oka basin into the Upper Don basin) (Medvedev, 1993).

In the first–third centuries AD, the climate became more arid once again. This aridization was marked by the northward migration of Sarmatian tribes from the typical steppe to the northern boundary of the modern forest-steppe. The soils buried under Sarmatian barrows are identified as Chernozems or prograded Luvisols, which attests to a considerable drying of the climate in that time.

During the next centuries, the climate was generally humid. Palaeosols buried in the Medieval epoch (1000 BP) are relatively similar to modern surface soils. The propagation of Slavic people to the north and north-east took place during the Little Climatic Optimum in the 9th–12th centuries AD. The maximum cooling and humidization of the climate with the corresponding maximum extent of forest vegetation in the Upper Don and Middle Oka basins took place about 800–200 BP, during the Little Ice Age.

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Chapter 17

ENVIRONMENTAL CHANGES OF THE NORTHEASTERN BLACK SEA'S COASTAL REGION DURING THE MIDDLE AND LATE HOLOCENE.

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ABSTRACT

This paper deals with questions of paleogeography of the Black sea's coast in the late Holocene on the basis of new data that include the lithology, palynology and geochronology of coastal marine, lagoon and deltaic sediments. The palynological results have shown that the warmest and dry conditions prevailed in the intervals 4100-3950, 3500-3300/3200, 2800-2400, 1650-1300 and 1000-900/800 yrs BP. The maxima of humidity for the studied period correspond with the chronological intervals 4500-4300 and 3950-3500 yrs BP, coinciding with the spread of forest communities. During an interval from 2500 up to 1500 BP (V centuries BC - V centuries AD) the dominance of the steppes formation was interrupted by phases of wetter climate which caused at first expansion of the wood-steppe vegetation, and then wide circulation of broad-leaved woods in the landscape. The palynological data have revealed a peculiarity that is connected to the economic activity of the local population.

The study of the coastal morphology and sediment structure have revealed traces of two transgressive phases in relative sea level change for the time under consideration the first relates to the interval 4.2-3.7 ka BP, the second - covers last 1.5 ka. Complex litho-facial, archaeological and geochronological data testify to the existence of a period of downturn in sea level, which covers an interval from the end of the 2nd millenium BP up to the middle of the 1st millenium AD.

Key words: environment, Sea level, palynology, archaeology, chronology, humidity, aridity

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INTRODUCTION

The environmental dynamics of the Black sea's coastal region in the Middle and Late Holocene continue to attract attention in connection with the study of regional features of global climatic cycles and their reflection in changes of coastal environment, and also for elaboration of paleogeographical substantiation of the existing concept of ethno-cultural dynamics in the Southern part of the steppe zone and northern coasts of Black sea in the Bronze - Early Iron Ages.

Paleoenvironmental changes that had taken place during the Middle and Late Holocene in the territory of the Taman peninsula and the influence of paleo-landscape on the activity of ancient Greeks are certified by written sources and also archaeological materials. However the lack of palaeogeographical data about the site-specific environmental conditions of the coastal region of the north-eastern part of Black Sea did not allow confirmation of the climatic reconstruction of this region in the Bronze – Early Iron Ages.

The main peculiarity of the Taman peninsula and adjacent area of the Kuban deltaic plain in pre- and early historical time is related with their role as an ecological "enclave" for three interconnected subsystems: settled potesterian inhabitants, ancient classical states and nomads of the steppe (Vinigradov, Marchenko, 1991). Since the late bronze time several waves of nomadic invasions from the steppe zone have been known that have drastically influenced the pattern of existing ethno-cultural settlement (Vinogradov, 1996; Kuzminskay, 1997). The evaluation of environmental changes and their possible impact on ethno-cultural migration and activity in the region represent one of the main purposes of the conducted research.

The representation of palynological and geochronological data for detailed and reliable climato-stratigraphical subdivision of the Holocene deposits and reconstruction of environmental changes occurring during the last 10 thousand years in the South Russian Plain are extremely scarce (Bolikhovskaya, 1990; Kremenetsky, 1991; Spiridonova, 1991; Gerasimenko, 1995, 1997). Absence or insufficient quantity of absolute dates prevented the use of pollen data for detailed paleoclimatic and phytocoenotic reconstructions. Therefore on the basis of the results of pollen analysis of the Azov and Black sea's bottom sediments (Vronsky, 1976, 1988) and more than 30 sections of East Priazovye (Mishchenko, 1991, 2002; Chebanov et al., 1992) it was possible to describe only generalized characteristics of such a ong stage in a history of vegetation and climate of coastal areas in the Ancient, Early, Middle and Late Holocene.

The multidisciplinary research that was carried out in the Taman regional archeological project have permitted us to obtain new paleogeographical data to reconstruct the paleoenvironmental changes in the Holocene time of this region. On the basis of results of archaeological research and lithological, palynological, malacofaunistic analyses and radiocarbon dating the evolution of the Azov-Black Sea coastal zone of Taman peninsula over the last 4 Ka has been considered.

MATERIAL AND METHODS

The sediments of deltaic plain of the Kuban's have been investigated to provide a detailed and continuous record of the effects of paleogeographical events in the late subboreal-early subatlantic time. Several boreholes have revealed the sedimentary structure of the deltaic plain and sandy barrier that contain the coastal marine, lagoon and deltaic sediments facies (Fig. 1). Samples were taken for study by lithological, palynological and paleontological analysis.

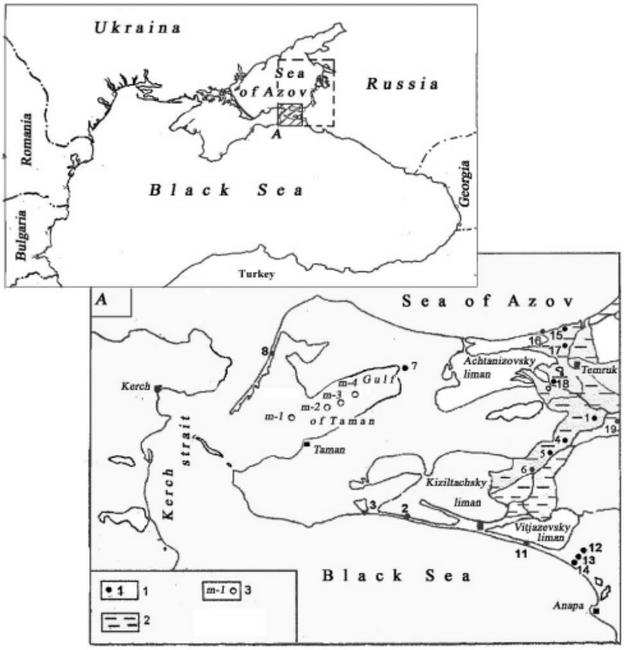

Figure 1. Location of the study area on the Taman Peninsula.
1- site and number of cores; 2- Deltaic plane of Kuban; 3- site and index of vibrocores in Gulf of taman

The lithological study has been carried out for sediments of the Black Sea delta of the Kuban and Bugaz spit (Fig. 2).

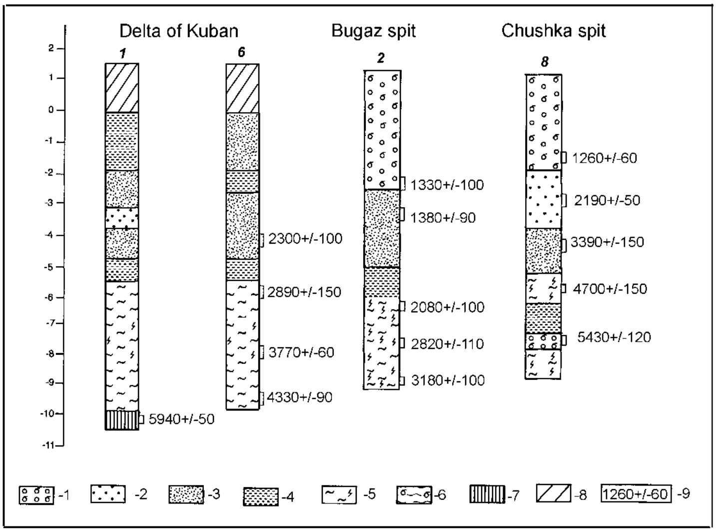

Figure 2. Sediment structure of Black Sea cost lane of the Taman Peninsula (location of cores see in Fig.1).
1- cores shelly sands,; 2- medium sands; 3- fine sands; 4- silt; 5- silt clay with shell; 6- clay with shell; 7- peat; 8- loamy soils; 8- radiocarbon age, yrs BP

They represent a transgressive-regressive sequence which comprise the intercalated layer of peat being replaced by pelitic clay and gradually replaced by silts and sands. Silts and fine-grained sand that are overlapped by a subsurface layer of sandy loamy soil represent the upper section of deltaic sediments.

This lithological sequence reflects the stages of formation of an ingressional gulf in a place of the modern delta of the Kuban and changes of sedimentation that are connected with fluctuations of the Black sea level and also a gradual promotion of Kuban delta and infilling of paleo-liman.

The sediment structure of the Bugaz spit comprises the single transgressive sequence that consists of lagoonal clay at depth of 5.5-10 m below present sea level that is related to paleoshoreline at the present depth of 6-9 m. These paleolagoonal deposits are overlapped by subsurface silty sands-shelly coarse sands, which form the present-day (recent) barrier spit.

Pollen data were analysed for three cores whose formation corresponds to an interval from 6000 to 1000 years BP. Results of palynological study have shown a significant amount of redeposited old pollen and spore grains belonging to Neogene (prevailing) and Cretaceous taxa. The percentage of allochthonous palynomorphs in the samples changes from 4 up to 95 % comprising the pollen grains of Coniferae, Pinaceae, *Picea, Pinus, Tsuga* (less often than others), *Juglans, Carya, Pterocarya, Platycarya*, Ericales, *Zelkova, Ulmus, Liquidambar, Ephedra,* Araliaceae, *Sequoia, Metasequoia*, Betulaceae, Fagaceae etc.. The pollen spectra of all samples contain pollen brought by the river and by air from various areas of the Kuban river basin.

The chronology of the palynological and geomorphological data was based on ^{14}C ages of shell material from the deltaic and coastal marine sediments. The comparison of a radiocarbon scale (standard at subdivisions of the Holocene) with historical date was carried out on the basis of the calibration program Calib. 3 (Stuiver, Braziunas, 1993; Stuiver, Reimer, 1993). The " reservoir effect " correction was based on results for the Black and Mediterranean sea's region (Facorellis, Maniatis, 1998; Morhange, Oberlin, 2000). The substantiation of the established sequence paleogeographic events and their synchronization with a historical scale is considered as one of the tasks for future research with supplementary study of the cultural layers of Bronze - Early Iron Age (Classic time).

ENVIRONMENTAL AND CLIMATIC CHANGES

According to palynological data the Subboreal period is characterized by the seven climatic and phytocoenotic phases (Fig. 3, 4).

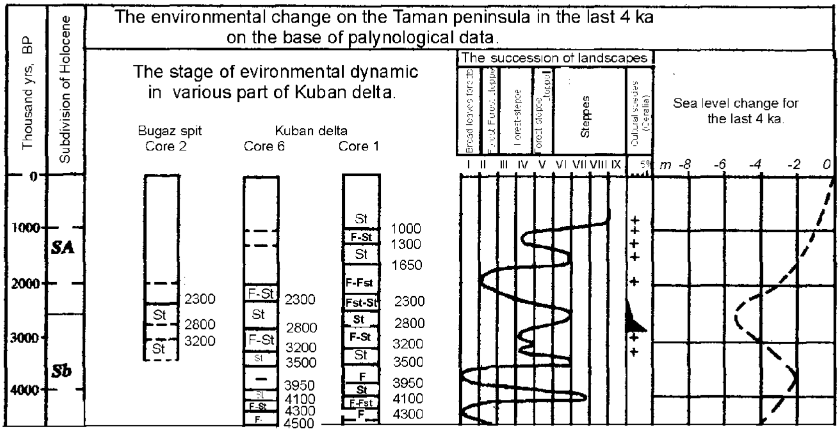

Figure 3. The landscape dynamic on the Taman Peninsula in the last 4.0 ka.The principal stages of landscape: F-broad-leaves; F-FSt-transition landscape from forest to steppe; F-ST- forest steppe; FSt_St- transitional landscape from forest to steppes; St-steppes.Successions of landscape: I- broad-leaves (beech-oak-hornbeam) forests; II-transitional from forest to forest-steppe; III- forest-steppes landscape with beech-oak-hornbeam forest; IV- forest-steppes with beech-oak-hornbeam forest; V-transitional landscape from forest steppe to steppes; VI-motley grass-gramineous plant's steppe with bog meadow ecotypes and flood land's hornbeam-oak forest; VII- motley grass and wormwood's steppes with beach-oak-hornbeam forests; VIII- gramineous plant's and wormwood's steppes with flood-land's oak-hornbeam-elm forests; IX- gramineous plants and wormwood's steppes.

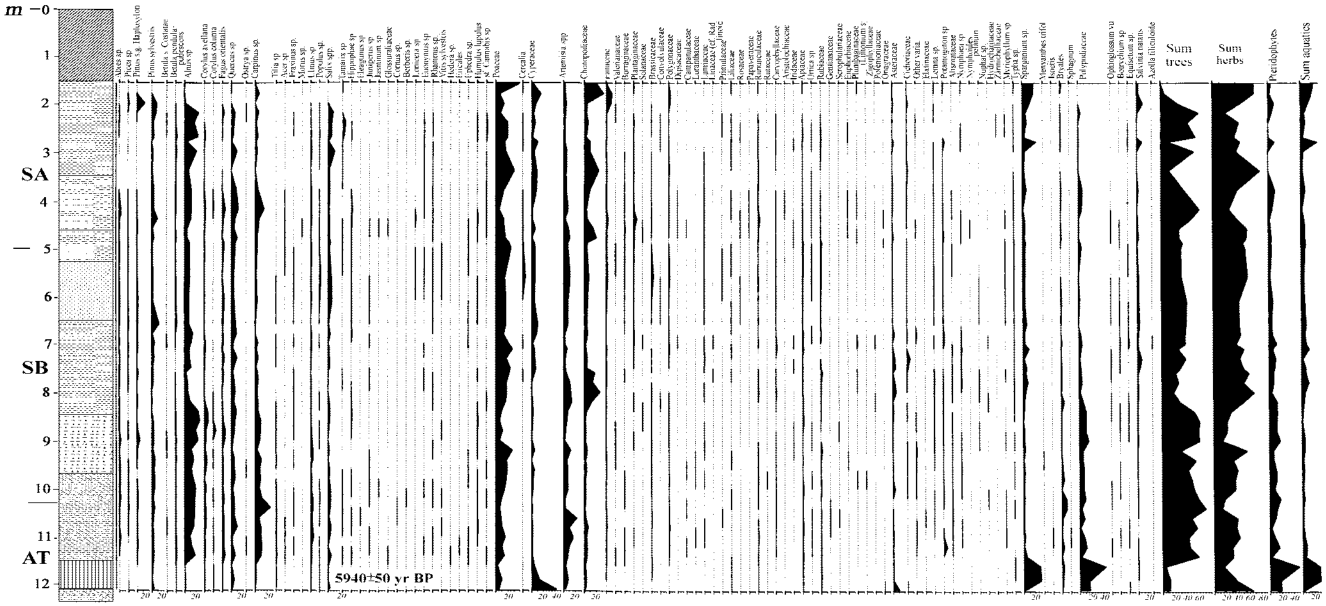

Figure 4. Pollen diagram of sediment core no1 from part of the delta of the Kuban River (location see from Fig.1.)

At the beginning of this period (2,5-2,3 ka BC), increasing humidity caused a reduction in the steppe areas that were almost fully replaced by woodlands which prevailed during the previous forest-steppe stage. In addition the floristic variety of tree species and bushes increased. For this period deciduous broad-leaved forests with a prevalence of beech-oak-hornbeam and oak-elm-hornbeam associations mainly occupied the area of the Taman peninsula. The coniferous-broadleaved stands of alder and willow were widespread.

Subsequently (around_the 2,3-2,1 ka BC) increasing dryness gave rise to a degradation of woods and a predominance of forest-steppe vegetation. Like the Late Atlantic period, the vegetation composition was composed of steppe biotopes such as grass and other herbs and goosefoot-sagebrush coenoses prevailed. The most significant expansion of steppes and aridity of climate have been dated to approximately 4000 yrs BP. In the streamside woods of the Lower Kuban valley the alder and willow forest stands prevailed. Beech-hornbeam-oak woods with participation of Tilia, Fraxinus, Acer, Castanea and other trees grew in the most optimum habitats. For this time Cerealia pollen have been seen for the first time indicating a human impact on the natural landscape of the Taman peninsula during the Early Bronze time.

During the subsequent phase of vegetation evolution of the Taman peninsula (approximately 3950-3500 BP.) the new wave of humidization and probably cold climate contributed to restoration of the wood ecotopes. Woodlands were composed of the oak-beech-hornbeam and coniferous-broadleaved communities. In the river valley forests the participation of alder (*Alnus glutinosa, A. incana*) and willow increased. In the herbaceous-low shrub cover the main components were the representatives of Poaceae (Gramineae), motley grass (Polygonaceae, Apiaceae, Lamiaceae, Plantaginaceae, Caryophyllaceae, Brassicaceae, Solanaceae, Rubiaceae, Urticaceae, Valerianaceae, Iridaceae, Scrophulariaceae, Asteraceae and others) and Polypodiaceae ferns (*Athyrium filix-femina, Dryopteris sp.*). This was the last time when the forests determined the zonal type of the landscape. From the middle of the Subboreal, the history of vegetation of the investigated area represents a smooth interchange between steppe and forest-steppe type.

The middle of 2nd millennium BC has been characterized by a new expansion of steppe vegetation. In the herbaceous-dwarf shrub cover of the open landscapes Poaceae, wormwood-goosefoots and motley-forbs formations include Fabaceae, Ranunculaceae, Apiaceae, Lamiaceae, Plantaginaceae, Caryophyllaceae, Brassicaceae, Solanaceae, Rubiaceae, Linaceae, Liliaceae, Urticaceae, Valerianaceae, Iridaceae, Scrophulariaceae, Plumbaginaceae, Cichoriaceae, Asteraceae and others. Pollen sections and diagrams show the pollen of cultured species (*Cerealia*). New ^{14}C data have allowed us to test the assumption stated earlier (Bolikhovskaya et al., 2001) about the widespread nature of agricultural activity in the Kuban delta area. Apparently it was not earlier than second half of the Bronze Age.

The main peculiarity of the mixed steppe - forest-steppe landscape of the late Bronze time – the Early Iron Age (1,2 – 0,8 ka BC) was determined by the predominance of motley grass-Gramineae communities. Restricted extended forests were represented by the hornbeam-beech-oak associations. The oak (*Quercus robur*) and hornbeam (*Carpinus caucasica Grossh*) have taken part as edificators of automorphic landscapes. In the forests of the damper areas the alder and the willow predominated. Like the previous phase the plant covering of the coastal area was represented by wormwood-goosefoots groupings.

Paleophytocoenoses of the studied region in the middle of the 1st millenium. BC (0, 8-0, 3 ka BC) based on floristic composition of forest-forming trees and steppe communities were close to forest-steppe and steppe associations of the previous period. Optimum (for wood vegetation) habitats, both watershed areas and a coastal zone of the sea and paleo-Kuban valley were occupied by broad-leaved forests from oak (*Quercus robur, Q. petraea*), hornbeam (*Carpinus betulus, C. orientalis*), beech (*Fagus orientalis*), elm (*Ulmus carpinifolia*), ash (*Fraxinus sp.*), linden (*Tilia cordata*) etc. Beech-hornbeam-oak communities prevailed. The floristic and phytocoenotic peculiarities of woodlots were determined by the significant role and composition of the underbrush and shrub, which included hazel (*Corylus avellana*), tamarisk (*Tamarix*), sea-buckthorn (*Hippophaë*), euonymus (*Euonymus*), jasmine (*Jasminum*), honeysuckle (*Lonicera*), buckthorn (*Rhamnus*), juniper (*Juniperus*), gooseberries (*Grossulariaceae*), vine (*Vitis sylvestris*), hop (*Humulus lupulus*). The deltaic wetlands have been covered by alder-tree (*Alnus glutinosa, A. incana*), poplar (*Populaceae*) and willow (*Salix*). The pollen diagrams of this phase have relatively high percentages of pollen of cultured cereals *(Cerealia)* that exceed their quantity in the previous time-layers as in subsequent times and reflect the intense agricultural activity in the Asian Bosporus in early Hellenistic time.

The last essential shift of climatic condition to humidity have been reflected by pollen diagrams from the sediment layers with age of 0,3 ka BC - 0,5 ka AD. Such a change has been accompanied by expansion of transitional (from steppe to forest-steppe) types of vegetation. Analytical data have shown the great diversity in the composition of arboreal and non-arboreal taxa. The forests were represented by beech-oak-hornbeam communities (*Carpinus betulus, C. caucasica, C. orientalis, Quercus robur, Q. petraea, Q. pubescens, Fagus orientalis*) with addition of elm (*Ulmus spp.*), maple (*Acer*), nut-tree *Corylus colurna*) and alders (*Alnus glutinosa, A. incana*). In the herbaceous-dwarf shrub cover of the steppes the cereals (Poaceae) and various motley grass (Brassicaceae, Rubiaceae, Ranunculaceae, Fabaceae, Boraginaceae, Lamiaceae, Apiaceae, Papaveraceae, Plantaginaceae, Liliaceae, Dipsacaceae, Polygonaceae, Iridaceae, Solanaceae, Campanulaceae, Caryophyllaceae, Urticaceae, Plumbaginaceae, Asteraceae, Cichoriaceae etc.) have dominated. In the middle of the first millennium AD (cal. 1650-1300 AD) the increasing dryness of climate has determined the predominance of motley grass–cereal and wormwood-chenopods steppes with a wide spread of the meadow vegetation and a sharp decrease of wood ecotopes. The Kuban river deltaic plain was occupied by the broad-leaved hornbeam-oaks woods with participation of elm (*Ulmus cf. suberosa, U. cf. foliacea*). Damper areas in the river's valley were covered by alders (*Alnus glutinosa, A. incana*) and willows.

The palynological data of the second half of the 1st millenium. (cal. 700-1000 AD) reflected the increasing humidity of the climate. The forests-steppe type of vegetation included the beech-oak-hornbeam formations (*Carpinus betulus, C. caucasica, C. orientalis, Quercus robur, Q. petraea, Q. pubescens, Fagus orientalis*) with elm *(Ulmus spp.)*, maple (*Acer*), nut tree (*Corylus colurna*) and alder (*Alnus glutinosa, A. incana*) predominating in the extensive inner area of the Kuban delta. The deltaic wetlands were covered by alder (*Alnus glutinosa, A incana*), poplar (*Populaceae*) and willow (*Salix*).

The last paleoclimatic phase of the Subatlantic period related to early medieval time (cal 1100 – 800 AD) and differed in aridity from the second half of the Holocene. The drastic warming and dryness of climatic conditions caused almost the complete disappearance of forests and the predominance of cereal and goose-foot - wormwood steppes. The percentage of non-arboreal pollen does not exceed 1%.

SEA-LEVEL CHANGES AND COASTAL EVOLUTION

Recent studies of the Holocene transgression of the Black sea (Ostrovsky et al., 1977; Balabanov, Izmiylov, 1988) have shown that the main regional peculiarity of postglacial sea level rise is related to a superposition on the general trend of small-amplitude fluctuations of sea level. Such intermittence of sea level has given the transgression a reciprocal character which comprises a short-term phase of accelerated sea-level rise and following this, a stage of its stabilization or slow sinking with a relative amplitude up to 3-5 m. Despite these small amplitudes which did not exceed 3 - 5 m, these fluctuations have caused substantial changes in the coastal environments and related paleoecological impact on maritime population.

The validity of these fluctuations has been based on the litho-facial structure of holocene coastal sediments and on the geomorphology of sandy barrier plains in various lowland sites on the shoreline of the Black and Azov seas and has been related to eustatic variations despite the lack of a reliable model of climate - sea-level interactions under climatic change in the late Holocene. The difference between the existing reconstruction of late-holocene sea-level change in Black Sea and Mediterranean Sea (Pirazolli, 1992) which has been developed under a consistent interchange of water-mass in the last 7,0 ka should be noted. Comparison of the reconstructions of the Holocene Black sea level change by various authors has shown a great regional variation which reflects not only reliability and accuracy of data but also the possible regional impact of recent tectonic activity (Pirazolli, 1992; Kaplin, Selivanov, 1999). Hitherto many questions such as quantity and age of different regressive-transgressive phases remained open. Similar uncertainty is related with the assessments of the Black sea - level change in the 1st millenium BC – the so called "Phanagorian regression". The relatively low positions of the sea level since the Late Bronze Age and in Classic times are supported by the numerous archaeological remains and to a lesser degree – by geomorphological evidence but the nature and real amplitudes of such sea level declines require more detailed reconsideration.

Obtaining a reliable reconstruction of sea-level change in the late Holocene faces several obstacles which include the poor preservation of old coastal features and erosion of related coastal facies, the use of different types of indicators of former sea-level position and various types of organic material (terrestrial, marine etc.) to recreate comparable chronologies of the paleoshoreline.

The general data base contains the results of age-determinations that have been performed in the last few decades and in various laboratories; they require care in their comparison. In addition the widespread use of archaeological data for paleogeographical reconstruction determines the necessity of correlation with historical and geochronological dates. In the case of using marine organic material the wide range of possible uncertainty due to the "reservoir effect" created additional uncertainty when we try to reconstruct paleogeographical events on the basis of different types of chronological information.

The study of litho-facial structure and geochronology of coastal sediment in various tectonic zones of the Black sea's shoreline on the Taman peninsula (Fig. 2) have produced new data to reconstruct proxy sea level change in the late Holocene and to assess the related coastal environment evolution. On the basis of the study of lithology, paleontology and geochronology of sediment structure, traces of two transgressive stages for the last 5.0-4.5 ka have been identified. The first transgressive stage (4,3-3,7 ka BP) was revealed in the sediments of the Anapa and Chushka spits and located at a depth of 2,5- 4 m below the present day sea level. On the tectonically active coastal stretches, fragments of the low terrace of this transgressive stage (4,3-4,0 ka BP) have been traced to the present heights up to + 3,5-4 m. On the deltaic area, sea level change has determined temporal and spatial changes in litho-facial structure of sediments and to a lesser degree – in shell assemblage that reflected fluctuations of fresh water input in the inner part of the paleolagoons The reconstruction of sea-level in this stage of transgression is much rougher due to approximate estimate of the depth of paleolagoon and the lack of any trace of a concurrent coastal barrier whose remnants could be situated in the nearshore zone and could have been eroded during the subsequent transgressive phase. The litho-facial structure of coastal sediments, archaeological and geochronological data have shown the existence of a sharp change in the coastal sedimentation at the end of the 2nd millenium. BC that could be related to the relative drop of sea level in the so called “phanagorian regression”. The majority of researchers have proposed that the sea level dropped in the middle of the 1st millennium BC but the time-interval and the value of sea-level fall are still uncertain and vary according to different sources (Balabanov, Izmailov, 1988) For our purpose estimation of the final stage of this regressive phase has been of primary importance due to the evaluation of possible environmental impact of sea-level rise in the second half of 1st millenium BC – first half of the 1st millenium AD on human settlements in the coastal region of the Asiatic Bosporus and adjacent areas of the Azov-Black seas shoreline.

The difficulty in precise evaluation of the sea-level position since the Late Bronze Age is related to poor preservation of traces of the old shoreline due to wave erosion and in any case their latter burial under younger sediments. One example of the phanagorian coastline is represented by the submerged spit barrier in the open part of the Taman gulf. The study of the sediment structure and its age has shown that this spit was formed in the middle of the 1st millenium BC with sea-level 5-6 m below present-day levels. Similar estimates of the value of the relative sea-level lowstand has been obtained in different coastal stretches of the Taman peninsula on the basis of sediment structure dating. In many places the old lagoonal facies are lying at a depth of 5-6 m below present sea-level. The detailed radiocarbon study of relic lagoonal and overlapping beach-barrier’s facies has permitted an evaluation that the drop in sea-level started at the end of the 2nd millenium BC and kept on till the middle of the 1st millenium AD.

Similar estimates of sea-level fluctuation in the Early Iron Age for the North-Eastern shoreline of the Black sea have been obtained on the basis of various archaeological sources (Fig. 5).

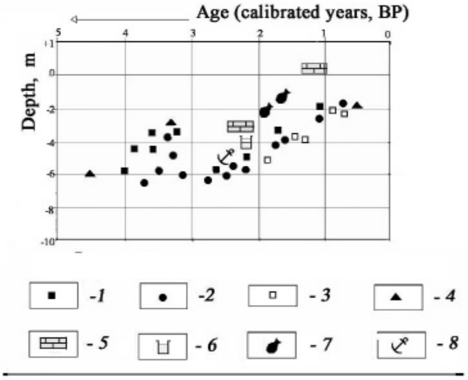

Figure 5. Age-depth distribution of index points for mean sea level in different site of Black sea’s coastline of the Taman Peninsula: 1- Anapa spit; 2- the Kuban River delta; 3- Gulf of the Taman; 4- Chushsks spit.Depth various types of archaeological remains: 5- pavements; 6- wells; 7- ceramics; 8- anchors

The numerous submerged remains of classic time in the near shore zone of Taman peninsula (Blavatsky, 1985; Abramov, 2000) and the eastern part of the Crimea peninsula have shown that in the second half of the 1st millennium.BC the relative sea level rested at a depth of 5,5-6 m below present (Kulikov, 1997; Zinko, 1997; Nikonov, 1998). The results of underwater archaeological studies in this region have confirmed that the new phase of sea level rise could be traced to the end of the 1st millenium AD. Evidence of the relatively late start of sea level rise is based on the presence of an undisturbed cultural layer of early medieval age (VII-VIII cent. AD) at a depth of 2-3 m below present and the age of the young generation of beach ridges on adjacent coastal stretches (12-14 cent. AD). The resulting estimate of age formation of the recent coastal forms on the shore-line of the Azov and Black sea coastline have the same temporal limits (Izmailov et al., 1989).

The study of the present position of the different traces of sea-level positions since the 2nd mill. BC in the different tectonic zones of the north-eastern Black sea coastline have allowed us to evaluate the impact of neotectonic subsidence of coastal areas. The comparison of the altitudinal position of the old shoreline has shown that the average rate of subsidence is up to 1,5-2,5 mm/yr (Nikonov et al, 1994; Fouache et al, 2004). This value requires a careful approach to estimation of the real amplitude of eustatic sea-level drop in the so called “neoglacial time” which did not exceed 2.5-3m

CONCLUSIONS

The results of this study have allowed for the first time an assessment of the environmental changes in some coastal areas of the Black Sea that reflect the climatic patterns for the last 4 ka and local geomorphologic changes under the influence of fluctuations in sea level.

The palynological results have shown that the warmest and dry conditions prevailed in the intervals 4100-3950, 3500-3300/3200, 2800-2400, 1650-1300 and 1000-900/800 yrs BP. The maxima of humidity for the studied period correspond with the chronological intervals 4500-4300 and 3950-3500 yrs BP, with which the spreading of wood communities have coincided. During an interval from 2500 up to 1500 BP (V centuries BC - V centuries AD) the dominance of the steppes formation has been interrupted by phases of damper climate which has caused here at first an expansion of the wood-steppe vegetation, and then a wide expansion of deciduous broad-leaved woods. The palynological data have allowed us to reveal a peculiarity of pollen analysis that is connected to the economic activity of the local population. Since the Late Bronze Age the occurrence of the pollen of cultured C*ereals* reflects intensive agricultural activity, which is marked by the occurrence of *Plantago* pollen and other weeds.

The study of the structure and age of coastal sediments have revealed the regional features of sea level change in the last 4.5 Ka. The coastal morphology and sediment structure contain traces, at least, of two transgressive phases in relative sea level change for the time under consideration the first of which is in the age interval 4.2-3.7 ka BP, the second - covers the last 1.5 ka. Complex litho-facial, archaeological and geochronological data testify to the existence of a period of a relative downturn in sea level, which covers an interval from the end of the 2nd millenium BP up to the middle of the 1st millenium AD. The most significant paleoecological consequence of the transgressive phase in the middle Bronze age (end III - first half II thousand yrs BP), was a shift in the settlement area in coastal regions due to submergence and flooding of the coastal lowlands. The impact of the last transgressive phase has been revealed more locally, mainly due to an increase in coastal erosion and the retreat of the shoreline under sea level rise and at rather insignificant scales of flooding of the coastal land. At the same time, many classic settlements on the Black sea's shore (Olbia, Phanagoria et others) have seen submerged part of their lower lying -town area. However the possible paleoecological impact of the final stage of the Black sea transgression on socio-economic processes in late antiquity is difficult to state, since sea level started to rise again in early medieval time (since 9-11 ka AD).

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Chapter 18

PREHISTORIC ENVIRONMENT, HUMAN MIGRATIONS AND ORIGIN OF PASTORALISM IN NORTHERN EURASIA

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ABSTRACT

Development of early human societies in Northern Eurasia depended on large-scale migrations combined with an indigenous evolution. The initial colonisation of Northern Eurasia by anatomically modern humans was proceeded by several migratory waves generally directed from the west to the east. Human displacements were triggered by environmental stress, and coincided with the coldest stages of the Last Ice Age (40,000 – 10,000 years before present, B.P.), when the conditions for livelihood were less severe in Eastern Europe and Siberia.The transition to Holocene at c. 10,000-9,000 yr. B.P. marked profound changes in the environment, with the rise of temperature by at least 6-12°C and increased humidity, leading to the extension of forests and the gradual establishment of present-day biogeographical zonality. Mesolithic lifestyle featured an increased sedentariness, combined with limited-scale seasonal transhumance. In the conditions of the northbound advancement of forests at 9000-7000 yr. B.P., a network of Mesolithic sites emerged north of the current arctic circle. This included the shelf of the Arctic Ocean, which became accessible, as the coastline was at least 150 km north of its present position.The 'Neolithic revolution' in Northern Eurasia occurred in the conditions of the thermal optimum, which became established at 8,000-7,000 yr. B.P., and led to the maximum expansion of forests, further increase of precipitation, the global rise of the sea level, and increased biological productivity of boreal landscapes.

The spread of Neolithic in northern Eurasia is seen as a combination of human migrations, cultural diffusion, with local inventions and adaptations, the intensity of which depended on the local natural and cultural environment. Based on the analysis of radiocarbon dates, archaeological and environmental evidence, we distinguished three basic processes in the Neolithisation of Northern Eurasia which are discussed in the article.

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Key words: Mesolithic, Neolithic, Holocene environment, chronology, radiocarbon dates, statistics, human migrations.

INTRODUCTION

Large displacements of human populations occurred throughout Prehistory and early History. Existing theories normally link up migratory processes with interplay of socio-economic and biological factors. This includes ecological pressure, overpopulation, scarcity of food resources, warfare, political pressure and related factors. The aim of the present paper consists in reviewing the existing archaeological and palaeoenvironmental evidence and models pertinent to prehistoric human dispersals.

INITIAL SETTLEMENT

The greater part of Northern Eurasia sustained groups of hunter-gatherers throughout the Last Ice Age. The settlements attributable to the Neanderthals which in most cases corresponded to the early and middle periods of the Last Ice Age (115,000 – 50,000 years ago) were concentrated in Europe, Western Asia, Caucasus and Crimea. Uzbekistan is apparently the easternmost area of the Neanderthals' dispersal. Moving along river valleys, the Neanderthals occasionally ventured further into the northern plains, reaching the latitude of 52-53ºC.

According to molecular genetic evidence, anatomically modern humans (AMH), originated in Africa, and reached western Asia 100,000-80,000 years ago (Cann *et al.* 1987; Stringer *et al.* 1998). The oldest radiometric dates of Aurignacian industries in Europe which are conventionally associated with *Homo sapiens*, are of the order of 40,000 BP, although the actual occurrences of skeletal remains have younger ages, 35,000-30,000 BP (Howell 1998).

Judging from radiocarbon dates, the initial appearance of AMHs on the East European Plain occurred in the time-span of 39-36 ka (Dolukhanov *et al.* 2000). The sites of that age were evenly scattered on the East European Plain including the area north of the Polar Circle, and occurred in landscapes dominated by pine forests (Spiridonova 1991). As the climate grew colder, spruce forests and the cold-resistant 'periglacial' tundra-steppe developed. The wild horse was the principle hunting prey, followed by the mammoth and reindeer (Praslov and Rogachev 1982).

The early Upper Palaeolithic sites on East European Plain belonged to at least three distinct cultural traditions: Streletsian, Aurignacian, and 'Protogravettian' (Sinitsyn *et al.* 1997: 42). The Streletsian inventories initially identified in the Kostenki area on the Don, were later found on the Severski Donets River in the Ukraine, in Central Russia (Sungir'), and on the Kama River (Bradley et al., 1995). These inventories included archaic Mousterian elements combined with advanced 'laminar' technology. Both the Aurignacian and 'Protogravettian' featured the fully developed 'core-and-blade' technique (Sinitsyn *et al.* 1997).

The 'transitional' industries, such as Châtelperronian in France, Uluzzo in Italy, Szeletian and Buhunician in Central Europe, and also Streletsian in Russia are often viewed either as a product of 'acculturation' of the Neanderthals under the impact of modern humans (Mellars 1999), or as an independent Neanderthal invention (Errico *et al.* 1998). Yet, fossil remains of the Neanderthals have been identified only at a few Châtelperronian sites. Based on the lack of evidence, it seems reasonable to suggest that archaic Upper Palaeolithic industries, such as Szeletian and Buhunician in Central Europe, and Streletsian in Russia were manufactured by anatomically modern humans. Their archaic elements probably denote the cultural contacts of early modern humans with the Neanderthals. The evidence of mitochondrial DNA excludes genetic relationships of either European or Caucasian Neanderthals with modern humans (Ovchinnikov *et al.*, 2000). The plasticity of early human cultural behaviour, as well as the absence of rigid relationships between the anthropological types and technology are well attested. The archaic industries were often found together with the remains of modern humans. Thus, the remains of both Neanderthals and modern humans, who apparently coexisted, were found in the Levant in an essentially similar context of the 'Levantine Mousterian' (Lieberman 1998).

Currently several Palaeolithic sites in the Altai Mountains, including those with the Mousterian and 'transitional' industries, were radiocarbon dated to 40 – 46 ka BP (Derevyanko *et a*l. 2001; Vasil'ev *et al.* 2002) Following the above-cited arguments one may assume that all these industries may equally be attributed to modern humans (Dolukhanov *et al.* 2001). Significantly, Alexeev (1998) found in the teeth from the 'Mousterian' levels at the Okladnikov Cave in the Altai Mountains 'no major deviations' from the modern human morphology. The archaic element combined with advanced 'laminar' technology is inherent in the Siberian 'Upper Palaeolithic' (Grigor'ev 1977; Okladnikov 1981; Sitlivy *et al.* 1997). Archaic elements are abundant in the inventory of the Salawusu site on the Ordos Plateau in Inner Mongolia dated to 50,000-37,000 BP and associated with the remains of *Homo sapiens* (Jia Lanpo and Huang Weiwen 1985; Wu Xinzhi &Wang Linghong 1985).

Hence, one can argue that the Palaeolithic sites in the time span of 46-32 ka BP in northern Eurasia reflect the initial colonization of that area by anatomically modern humans (Fig. 1). Their advancement stemmed from the core area in the Levant, encompassed the whole of Europe, including the East European Plain; led into Southern Siberia, Mongolia and Russian Far East, and, further, into Northern and Central China. As the land bridges linked the

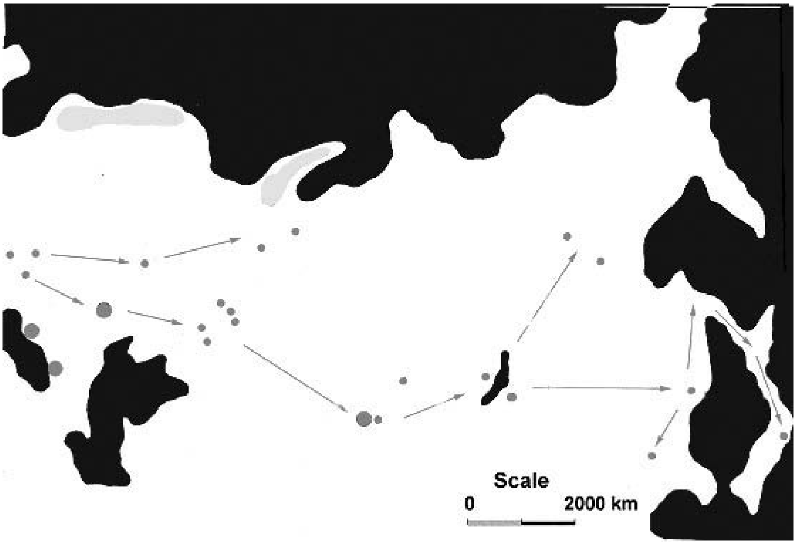

Figure 1. Migrations during 46,000-32,000 years BP;

Siberian mainland with the Sakhalin Island and Hokkaido, groups of early modern human could penetrate the Japanese Archipelago. This is confirmed by the skeletal remains of an anatomically modern human child at Yamashita-cho on the Okinawa, with the radiometric age of >32,000 BP. (Trinkaus & Ruff 1996).

The frequency of radiocarbon dated sites shows a clear increase in the range of 29-26 ka forming an all-time maximum at 24-18 ka. This time span corresponds to the coldest period of the Last Ice Age, and includes the Last Glacial Maximum, at ca. 20-18 ka. The sites of that age were found mainly in the 'periglacial' zone of the East European Plain, usually on elevated river terraces facing the widened flood plains (Gribchenko and Kurenkova 1997). Their natural habitat consisted of treeless 'periglacial' grassland with rare cold-resistant shrubs (Spiridonova 1991). The mammoth dominated the animal remains, with rare occurrences of reindeer and polar fox (Praslov and Rogachev 1982). Traditionally, the sites belonging to this time-span in Eastern Europe were summarily labeled as the 'Eastern Gravettian'. Grigor'ev (1993) has identified among them the 'Kostenki-Avdeevo' Culture exposing stylistic similarities with the sites in Central Europe, notably, Willendorf, Předmostí and Dolní Věstonice.

During that period the frequencies of sites increased throughout Siberia, including Yakutia and Russian Far East (Dolukhanov *et al.* 2001). This suggests a significant eastbound migration of human population at the time of the Last Glacial Maximum (Fig. 2).

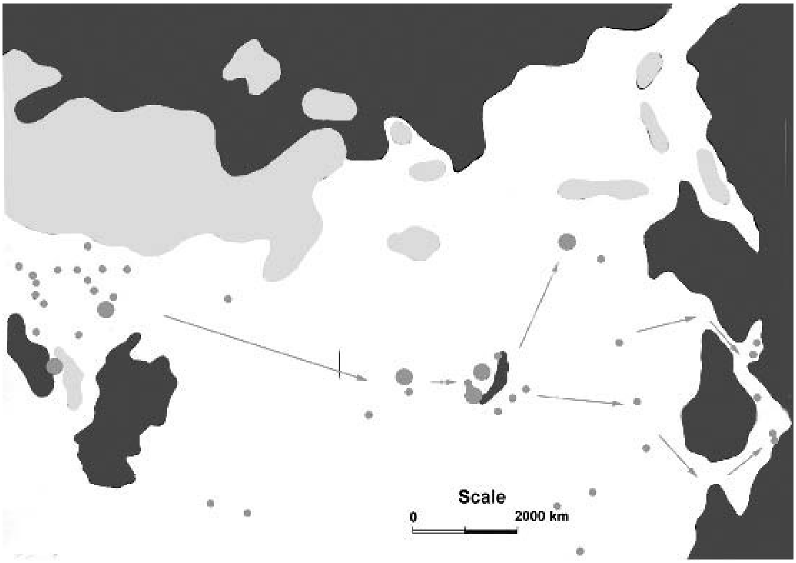

Figure 2. Migrations during 32,000-18,000 years BP

Grigor'ev (1993) and Soffer (1993) linked the emergence of the 'Willendorf-Kostenki-Avdeevo' cultural unit with the outflow of the population from Central Europe in the eastern direction. This suggestion was later substantiated by the radiocarbon measurements that show the greater part of Western and Central Europe to become depopulated during that time, where only sporadically sustaining scarce human groups remained (Housley *et al.* 1997, Street and Terberger 2000).

Large-scale human displacements were supposedly triggered by the environmental stress and inbreeding avoidance. Existing evidence suggests that the environmental conditions of the Glacial Maximum adversely affected the herds of large herbivores, particularly in the western areas. According to quantitative estimates (Tarasov *et al.* 1999), despite the low temperatures, the annual precipitation during the Glacial Maximum in western Eurasia remained sufficiently high to produce a thick snow cover. The precipitation in Siberia, being basically similar to the present-day values, would have formed only a thin snow cover (similarly to Central Mongolia where the winter snow cover is between 5 and 30 mm). The conditions for the survival of animals in harsh winter conditions were more favorable in the east: large herds of herbivores were well provided with the fodder easily available beneath the thin snow cover. Similar behaviour had been noted among the primates: the individual and group dispersal of the baboons in their natural habitats became considerably extended in the periods of the low availability of food (Lee 1983).

Regarding the second factor, Chaney (1983) observed, that among the Old World monkeys, males tend to migrate to neighbouring groups while the females prefer to remains in their native units. Cavalli-Sforza and Bodmar (1971) note that these displacements considerably diminish the inbreeding depression.

The final stage in the colonization of northern Eurasia by modern humans falls to the time-span of 17,000-10,000 years ago. At that time, the frequencies of Palaeolithic sites on East European Plain form a new maximum, yet their topography and cultural characteristics became distinct from the previous stage. At that stage the frequencies of sites in Siberia formed an all-time maximum. Networks of Palaeolithic sites arose in the river system of the extreme north-east including Yakutia and Kamchatka, and also in the Lower Amur and Maritime Province in the Far East (Fig. 3).

Figure 3. Migrations during 46,000-18,000 years BP

During that period, human groups stemming from North-East Siberia spread to America. This has been substantiated by the find of the Clovis-type fluted point at the Uptar site on the Upper Kolyma River in north-eastern Siberia. This find was made in the deposits of the Late Glacial age, beneath the volcanic ash radiocarbon dated to 8200±330 BP (King & Slobodin 1996). Existing evidence suggests that this was a predominantly coastal migration:

along the southern margin of the Bering Land Bridge and further south along the Pacific Coast of the Americas (Dixon 2001).

Hence the colonization of Northern Eurasia by Anatomically Modern Humans visibly occurred in three consecutive waves, spreading from the west towards the east in the time-span between ca. 40,000 and 10,000 years ago. These groups of humans manufactured and used various types of stone industries, including those that had strong Mousterian elements. These migrations were caused by a combination of environmental stress and inbreeding avoidance.

THE NEOLITHISATION

The spread of the Neolithic, is often viewed as a classical example of a major migration. The model of the Neolithisation as a result of direct migration is omnipresent in the works of Childe (1958). More recently, this idea took the form of the demic expansion or 'wave of advance' (Ammerman and 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 (1987, 1996) linked up the dispersal of farming with the proliferation of Indo-European speech.

There are several varieties of the migrationist concept. This includes a direct colonisation of a hitherto unpopulated area or the annihilation of the previous Mesolithic groups (Childe, 1958; Ammerman and Cavalli-Sforza, 1973), and the model of *élite* dominance (Renfrew, 1987). 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 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 (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. Gronenborn (1999) and 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 the 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 (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 (1972: 29–30) considered this process as a combination of diffusion and local inventions.

An analysis of a large dataset of Neolithic radiocarbon dates by Gkiasta *et al*. (2003) has basically confirmed the earlier results of Clark (1965) and Ammerman and Cavalli-Sforza (1973), showing a correlation of the earliest occurrence of the Neolithic with the distance from an assumed source in the Near East. Gkiasta *et al*. (2003) conclude that both a wave of advance of a cultural trait and a population replacement are consistent with the data.

The migratory model is often tested against the evidence of Linear Pottery ceramic Culture (LBK), the early farming entity in Central Europe. The model of Childe (1925) has been questioned by Whittle (1996), Gronenborn (1999) and Price (2001), who attach much greater significance to indigenous adoption and contacts between invading farmers and local foragers. These views were strengthened by the discovery of a distinct cultural tradition in the north-western part of the LBK area, La Hoguette. This was viewed as belonging to local Mesolithic groups that started practicing horticulture and herding before the arrival of the LBK (Price *et al.,* 2001).

The emergence of numerous radiocarbon dates has affected the earlier chronological schemes for the LBK. Using 'traditional' radiocarbon dates, Gronenborn (1999: 156) suggested that the earliest LBK sites appeared in Transdanubia at around 5700–5660 BC, and reached Franconia at about 5500 BC. Price *et al.* (2001) argue that the 'initial' LBK appeared in Hungary at around 5700 BC and spread further west. Our analysis does not reveal any temporal structure in the entire sample of the radiocarbon LBK dates for Central Europe.

The currently performed statistical analysis of LBK radiocarbon dates (Dolukhanov *et al.,* 2003) shows that these dates satisfy the criterion of contemporaneity, forming a Gaussian distribution spread in the range of 5600–4800 BC (2σ range), with the most probable age of 5154 ± 62 BC. This analysis indicates that the LBK propagated at a rapid rate that cannot be subdivided into distinct events using radiocarbon dating alone; this is the reason why most of the LBK sample can be characterized in terms of a single date (presumably corresponding to the culture peak) with a relatively small error.

With the largest dimension of the LBK region of about 1500 km (from Transdanubia to Franconia) and the time taken to spread over that area of about 360 years (twice the standard deviation of the dates in the coeval LBK subsample), the lower limit for the propagation rate of the LBK is obtained as about 4 km/yr. This value is consistent with the earlier estimates of about 6 km/yr obtained by Ammerman & Cavalli-Sforza (1973) and Gikasta *et al.* (2003) from data for a significantly larger region. The LBK propagation rate is in a striking contrast to other European Neolithic spread rates of 1 km/s.

A different model of Neolithisation is acknowledged on the East European Plain, where the Neolithic in most cases is associated with sedentary pottery-making hunting and food-gathering communities. The probability distribution of radiocarbon dates for Neolithic cultures on the East European Plain (Dolukhanov *et al.,* 2003) reveals a different spatio-temporal structure extended over a long time interval. The statistical age estimates for key cultural entities indicate that they form a clear temporal sequence from Yelshanian (6910 ± 58 BC), through Bug-Dniestrian (6121 ± 101 BC) and Rakushechnyi Yar (5846 ± 128 BC), to Upper Volga (5317 ± 30 BC). The rate of spread of the pottery-bearing cultures in East European Plain, estimated from the extent of the region involved (ca 2500 km for the distance from Yelshanian via Bug-Dniestrian to Upper Volga) and the time of spread (ca 1600 years, the time lag between the Yelshanian and Upper Volga cultures as estimated above), is about 1.6 km/yr. This is significantly smaller than the rate of spread of the LBK and yet comparable to the other European Neolithic rates. This fact stresses again the unusual nature of the LBK. On the other hand, the comparable magnitudes of the rates of spread of farming in Western Europe and ceramics production in Eastern Europe are compatible with—although do not prove—their common Neolithic nature.

These results reveal a clear spatio-temporal trend (Fig. 4) indicating that the Yelshanian–Rakushechnyi Yar temporal sequence (perhaps including the earlier Bug-Dniestrian) exhibits systematic expansion from the east, and so can be a manifestation of an impulse emanating from the Eastern steppe area.

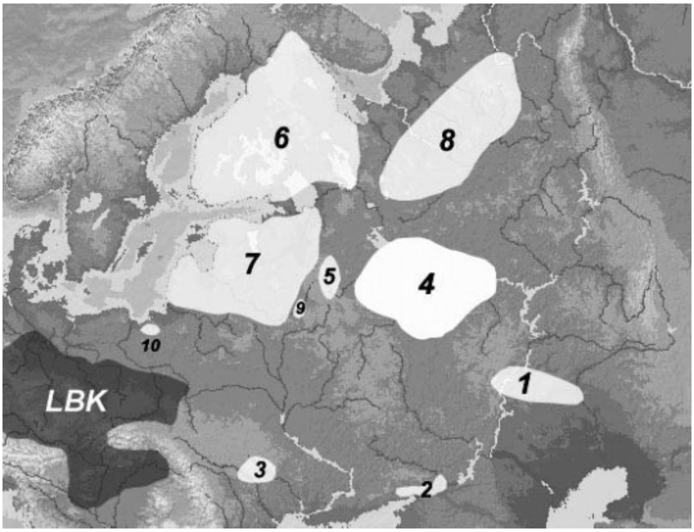

*Figure 4***.** Early Neolithic cultures in the central and eastern Europe, with the dates obtained here: Linear Pottery Culture (LBK); Yelshanian (1); Rakushechnyi Yar (2); Bug-Dniestrian (3); Upper Volga (4); Valdai (5); Sperrings (6); Narva (7); Chernoborskaya (8); Serteya (9); and Zedmar (10).

Recent evidence shows a very early appearance of pottery making in an area further east, stretching along the southern edge of the boreal forest in Eurasia. This includes Jomon Culture in Japan, with the earliest 'incipient' stage at ca 11000 BC (Aitkens and Higuchi, 1982). An centre of pottery making of an even earlier age (c. 11000-12000 BC) has been identified in the lower stretches of the Amur River (Derevyanko and Medvedev, 1997; Kuzmin and Orlova, 2000). A group of early pottery sites in the Trans-Baikal province in southern Siberia (Ust-Karenga, Ust-Kyakhta and Studenoye) has yielded a similar age (Kuzmin and Orlova, 2000). At these sites, the subsistence was based on hunting-gathering and intense procurement of aquatic resources. These pottery assemblages are stylistically unrelated and are believed to be local inventions (Khlobystin, 1996). One may only speculate that pottery making independently developed in the context of broad-spectrum hunter-gathering economies with reliance on aquatic resources. This technical novelty initially emerged in the forest-steppe belt of northern Eurasia starting at 11000-10000 BC, and spread to the west to reach the south-eastern confines of East European Plain by 7000 BC.

The Upper Volga and other early pottery-bearing cultures in the boreal central and northern Russia show the age of 5300–4900 BC, which coincides with the epoch of the LBK in Central Europe. Significantly, this period corresponds to the Holocene climatic optimum, characterized by the maximum rise of temperature and biological productivity of landscapes in both Central and Eastern Europe.

The model recently advanced by Aoki *et al.* (1996) can be relevant in explaining these phenomena. These writers model the advance of expanding farmers accompanied by partial conversion of the indigenous population into farming. The intruding farmers can spread either as a wave front or as an isolated, solitary wave. However, either intruding or converted farmers remain behind the propagating wave (front) in both cases. There are no definite signs of widespread farming in the East European Neolithic sites, even though there is clear evidence of the interaction of those cultures with farming (Zvelebil and Lillie 2000). This suggests yet another scenario where an advancing wave of farming is not accepted by the local hunter-gatherers, but still results in considerable demographic and cultural modifications. The approach of Aoki *et al.* (1996) can be further developed to incorporate the advantages of the wave of advance, adoption and other models in a single mathematical framework. Reliable assessment of these possibilities requires further analysis, including detailed numerical simulations.

PASTORALISM

The spread of farming communities into the forest-steppe area of East European Plain is clearly reflected in the expansion of Tripolye Culture. The Tripolye communities reached their climax during the middle phase (4,440-3,810 BC cal.; Telegin *et al.* 2003), when the settlements spread far to the east and grew in size. Several sites became particularly impressive: Vesely Kut reached 150 ha in size; Talyanki was still larger: 450 ha with at least 2,800 houses; Maydanetskoe's area was 200 ha with more than 2,000 houses. All these settlements were surrounded by fortifications with walls and ditches. At this stage the Tripolye sites show a growing social inequality, primarily signalled by the occurrence of élite burials under the kurgan barrows.

At the same time distinct cultural entities arose in the steppe to the east of the Tripolye core area including the Sredni Stog and Mikhailovka. The Sredni Stog unprotected dwelling sites and cemeteries were located in forested river valleys, between the lower Dniepr and Don. These sites are considered to contain the earliest evidence of horse domestication in Eurasia. The apparent distinctions in subsistence stemmed primarily from the ecology: a growing aridity of climate towards the east makes agriculture in the areas east of the Dniepr less sustainable and less predictable.

Vasil'ev (1981) and Vasil'ev & Sinyuk (1985) distinguished a 'Mariupol' cultural entity stretching from the Dniepr in the west to the Urals in the east, from which several cultures, including the Sredni Stog, Samarian and Khvalynian later developed. The Mariupol cultural entity, however, should predate the Khvalynian which has been recently dated by a series of radiocarbon measurements to a time-span of 5200 - 4500 BC cal. The Mariupol-related sites which shared several common stylistic and symbolic features, were uniformly based on cattle-dominated stock-breeding with early evidence for the domestication of the horse. This suggests that the 'agricultural revolution' took the character of stock-breeding in exceedingly dry areas east of the Dniepr,. Levine (1999) argues that the horse had initially been hunted and used for meat. However, humans would rapidly have recognized the greater potentiality of the horse as a means of transport and a powerful cultural symbol. The horse burials at S'ezhee form a conspicuous example of this (Antony and Brown 2000).

Grazing in an environment of dry steppe with seasonal, annual and long-term fluctuations in the biomass depending on rainfall, necessarily acquired a peripatetic and dispersed character. According to Masanov (1970), the annual distance covered by nomadic groups in 19th century Kazakhstan reached 1,200 km. It has been noted that particularly during the 'lean' periods, nomadic groups tended to form larger agglomerations headed by élite families, which control the grazing grounds and migratory routes, and instigate armed conflicts with neighbouring groups aimed at appropriating the livestock, land and the exploitation of agricultural communities being by far the most important (Khazanov 1984, Cribb 1991).

The westward expansion of stock-breeding communities proceeded during the Sub-Boreal climatic phase in an environment of increased aridity. Relationships between the Tripolye farmers and Sredni Stog stock-breeders were strained from the beginning. Significantly, the largest Tripolian fortified settlements emerged predominantly in the areas bordering the Sredni Stog. At the same time, the Tripolye sites can be seen to have recognizable trade contacts with the Sredni Stog, primarily in the form of imported ware (Videiko 1994).

Deep transformations are acknowledgeable within the Tripolye societies at its latest stage (3780-3320 BC). One of the Late Tripolye groups, Usatovo, spread in the Prut-Dniestr-Southern Bug interfluve. Its economy became increasingly dependent on stock-breeding, especially of the horse and sheep/goat. Defensive structures became more common. Deep transformations in social structure became conspicuous in the burial rite, particularly at the eponymous site, Usatovo, north-west of Odessa (Patokova 1979). Three large kurgans stood out from the rest and apparently belonged to the local élite; they contained individual male burials with rich inventories that included Aegean-type arsenic copper daggers, copper flat axes and chisels (Zbenovich 1976). Rich female graves included pottery and personal adornments. The near-by cemeteries consisted of clusters of flat graves, each cluster apparently belonging to kin relatives, as evidenced by the occurrence of the figurines of a similar type. Consequently, the Usatovo society may be viewed as a military-oriented chiefdom, with a strong local power base as shown by élite burials, and consisting of several lineages with conspicuous symbols of kin identity.

The further socio-economic development resulted in the total collapse of the Late Tripolye agricultural societies and the gradual rise of the Pit-Grave or Yámnaya Culture. This culture reached its peak during the course of the third millennium BC, encompassing the entire area of the East European steppe, from the Urals in the east to the lower Danube in the west.

The Pit-Grave Culture is traditionally viewed as consisting of groups of pastoral stock-breeders, their herds consisting of cattle, sheep/goats and horses. Nonetheless, recently available archaeobotanical evidence supports an earlier view that this cultural area also included a sedentary agricultural component (such as Mikhailovka) in areas sufficiently rich in agricultural resources (Pashkevich 1997). Mikhailovka grew to a size of one and a half hectares at its final stage and was surrounded by fortifications with stone ramparts and ditches.

Merpert (1968), views the Pit-Grave Culture as a ‘culture-historical entity’ based on a common ideology (primarily the kurgan mortuary rite) which resulted from the integration of various local cultural traditions. Yet the kurgan rite was not a complete novelty in the steppe area, as they were in use at Usatovo and earlier still during the Middle Tripolye stages. Pit-Grave burials may be viewed as symbols of enhanced power of local chieftains. The prestige artefacts in the rich graves included imported items of gold and copper, mace heads (Nikol’ski and Mariupol groups) and wheels or even complete wheeled carts (*e.g.* Storozhevaya Mogila, near Dnepropetrovsk on the Dniepr).

The substitution of the Tripolye culture by the Pit-Grave was generally peaceful, with few indications of hostilities. There is much evidence for both trade and social interaction between the Late Tripolye and the Pit-Grave cultures, particularly conspicuous in the form of pottery diffusion. There is also evidence for the direct replacement, as at Maidanetskoe where Pit-Grave mounds were erected directly on top of the fortified Late Tripolye settlement (Videiko 1994). Direct military occupation of the entire area seems unlikely, as according to Videiko (1994) the Late Tripolye population outnumbered the Pit-Grave groups by far.

It has been noted (Renfrew 1979, 142-143), that the ‘abrupt termination’ of the ‘prosperous Chalcolithic cultures’ occurred quasi-simultaneously in various parts of south-eastern Europe. These changes can be viewed as adaptations to social crisis, triggered by the adverse climatic conditions and the ensuing scarcity of food resources.

CONCLUSIONS

1. The initial colonization of Northern Eurasia by anatomically modern humans occurred during the Last Ice Age and took the form of three consecutive waves stemming from Africa and Western Asia and consequently spreading from the west to the east.

2. The initial spread of agricultural/stock-breeding communities took the form of an accelerated immigration of farming groups from outside the region and their interaction with the local groups of hunter-gatherers in an environment of climatic optimum (4900-4500 BC).

3. Starting with the early Holocene a gradual spread of pottery-making proceeded from the Far East, across the southern Siberia into East European Plain. This was a process of cultural diffusion with limited-scale migrations.

4. Due to the instability of the climate, agriculture was usually supplemented by alternative modes of subsistence, hunter-gathering and stock-breeding being prominent in the areas not sufficiently rich in water resources.

5. The growing aridity of climate and diminished agricultural potentiality led to socio-cultural shifts observable throughout south-eastern Europe beginning around 3800-3300 BC. In the forest-steppe area this took the form of a general decline in agricultural productivity and the development of pastoral stock-breeding as an alternative subsistence strategy, accompanied by the rise of numerous local centres of power.

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Chapter 19

ENVIRONMENTAL STUDY OF THE BRONZE-IRON AGE TRANSITION PERIOD OF EASTERN EUROPE

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ABSTRACT

The migration of Scythians depended on climatic changes during the Bronze/Iron Age transition, which corresponds to Subboreal/Subatlantic climate periods. Data from oxbow lake sediments were used to distinguish climatic and environmental fluctuations. Climatic cooling started and humidity increased in the Late Subboreal. In the Bronze Age Subboreal draught farming spread and in the beginning of the Iron Age Subatlantic farming declined in East Europe. About 3500 years ago all the temperatures indices were about 1^{o} higher and the precipitation was 50 mm more than nowadays. During the succeeding cooling at about 2500 years BP, the temperature was about 1^{o} lower and the precipitation was a little greater in comparison with the modern indices. Precipitation decreased between the warming (3500 BP) and cooling (2500 BP). The biodiversity during the Bronze/Iron Age transition had an impact on the economy of Scythian cultures.

Key words: Scythian, Bronze-Iron Age, palaeoclimate, oxbow-lake sediments, Eastern Europe

INTRODUCTION

The migration of Scythians and the evolution of their culture depended on climatic changes and environmental conditions during the Bronze Age-Iron Age transition in the Eurasian territories. The Bronze Age-Iron Age transition

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period was connected with Subboreal/Subatlantic climate inversion in East Europe.

Different natural records and archives exist:

1) lake sediment sequences,
2) peat bogs,
3) river evolution and sediments,
4) oxbow lake deposits,
5) loess,
6) soils,
7) dendro remains
8) archaeological cultural layers

and others.

The data from palaeobotanical, palaeozoological, lithological sedimentological, dendrochronological, absolute dating, geochemical and other investigations were used to distinguish the climatic and environmental fluctuations during the Bronze / Iron age transition.

OXBOW LAKE SEDIMENTS

We should like to draw attention to oxbow lake sediments in river valleys for identifying palaeoenvironmental evolution. In oxbow lake sediments organics – peat, wood remains and other organic remains which may be used for radiocarbon dating can be found. These sediments are horizontally layered or laminated and reflect the cyclical nature of fluctuations at different scales: megacycles, macrocycles, microcycles and nanocycles.

The three complexes of Holocene oxbow lake – bog sediments were distinguished: the lower (pollen zones IX-VII) – 10,000-8,000 BP, the middle (pollen zones VI-IV) – 8,000-4,300 BP and the upper (pollen zones III-I) – 4,300 BP (Table 1). Deposits of the middle and upper complexes were formed during the Bronze/Iron age transition, when the Scythian culture began its existence and evolution. Oxbow lakes in the river valleys are most often located on the floodplain itself and on the first terrace above the floodplain. Only rarely have they been observed on the higher terraces in the river valleys.

Table 1. Stratigraphic subdivision of Lithuanian Late Glacial and Holocene lake deposits according A. Gaigalas and V. Dvareckas, 2001 (using Kabailienė, 1998)

Data of bounda-ries 10^3 y ^{BP}	Stage	Chronozone	Index	Pollen assemblage zone (PAZ)	Pollen zones (L. von Post)	Oxbow lakes Sediments
	HOLOCENE	SUBATLANTIC	SA	*Pinus-Betula-Cerealea*	I	Peat
1,0				*Picea 2* (second max.)	II	
2,5				*Picea-Alnus*		
		SUBBOREAL	SB	*Betula-Pinus 2*	III	Loamly sand and peat
				Picea 1 (first max.)	IV	
4,0				*Alnus-Picea*		
5,0 6,7		ATLANTIC	AT	*Tilia-Ulmus-Quercus*	V	Sapropel
				Alnus-Ulmus	VI	
8,0		BOREAL	BO	*Pinus-Corylus*	VII	Loamly sand, silt and sand
8,1				*Pinus 2*	VIII	
9,0		PREBOREAL	PB	*Betula*	IX	Loamly sand
10,0	PLEISTOCENE LATEGLACIAL	YOUNGER DRYAS	YD	*Artemisia-Betula*	X	Varved clay, silt and sand
10,9		ALLERÖD	AL	*Pinus 1*	XI	Peat, varved loamly sand
				Betula-Pinus 1		
11,9		OLDER DRYAS	OD	Poaceae-Artemisia-Betula	XII	Varved clay, silt and sand
12,3		BÖLLING	BÖ	*Betula-Pinus - Poaceae*		Peat, varved clay, silt, sand

They are usually crescent – shaped, but other configurations are also possible (Gaigalas, Dvareckas, 2002). Sometimes in the lake–bog sediments, archaeological remains are found.

VALAKUPIAI (VALAKAMPIAI) SECTION

A natural exposure of oxbow lake deposits at the Valakupiai (Valakampiai) site, which is located in the left bank of the Neris River in Vilnius (capital of Lithuania), have been studied in 2003. (Figure 1). The coordinates of Valakupiai (Valakampiai) outcrop in Vilnius is 54°43’58”; 25°18’33”.

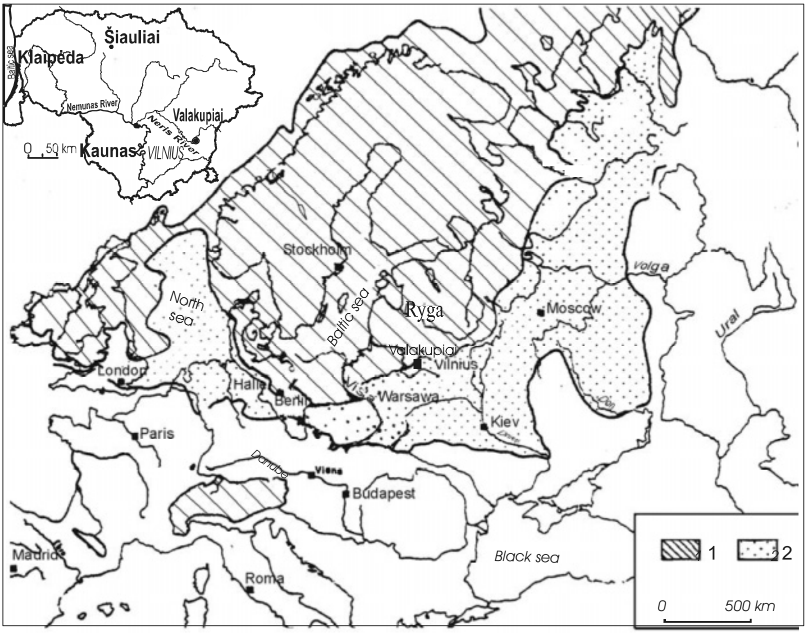

Figure 1. The areas covered by the Scandinavian ice sheets during the Last (Nemunas = Vistulian = Valdai) glaciation about 20,000 years ago and maximum of Pleistocene glaciation before 250,000 years ago. 1-an area covered by ice sheet of Last glaciation; 2-an area covered by the Scandinavian ice sheet during the maximum of Pleistocene glaciation.

The Valakupiai exposure reveals the oxbow-lake sediment in the first terrace above the floodplain (Fig. 2).

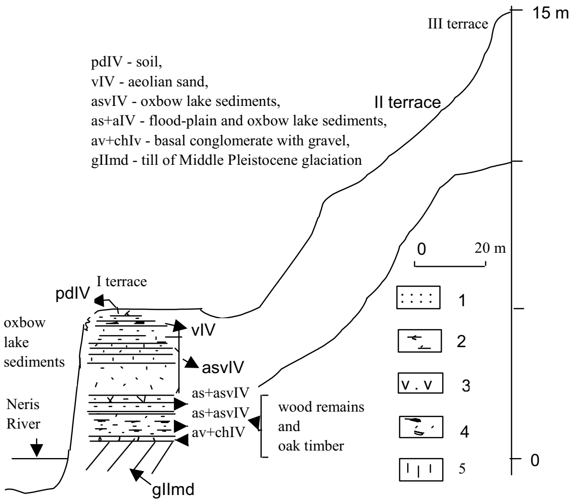

Figure 2. The Neris River terraces in the Valakupiai meandra with section of oxbow lake sediments in the first terrace above floodplain. 1-sand, 2-peaty sand, 3-ferreousgenised sand, 4-sand with humic interlayers, 5-pebbles conglomerate.

Dark oak-wood remains of the Atlantic climatic period are found at the bottom of the alluvium (Fig. 3).

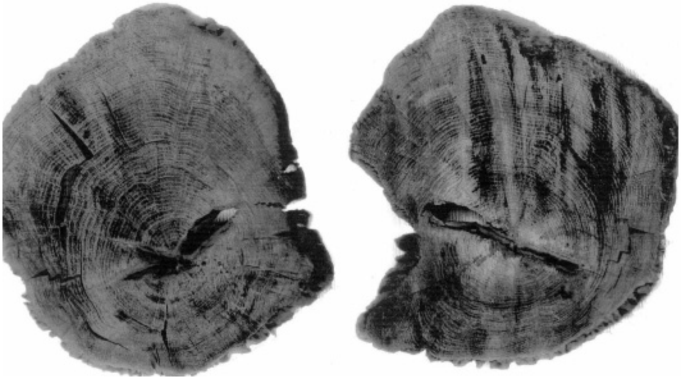

Figure3. Oak found in the alluvium deposits

Grey coloured oak trunks characterize the end of the Atlantic period as follow from radiocarbon dates (Table 2). The oxbow lake deposits, which covered the bottom of I-st terrace above the floodplain, were formed in the Subboreal and Subatlantic periods. The oxbow lake sediments are characterized by sand and loamy sand deposits and, in particular mineralised peat deposits with wood remnants.

The radiocarbon age of oak in the base of I-st terrace above the flood-plain show the end of Atlantic period and beginning of Subboreal (Table 2).

Table 2. Dates of wood samples from Valakupiai (Valakampiai) section.

No	Material	Lab. No.	^{14}C age, years	Calibrated radiocarbon dates	Depth, m
1	Oak timber	Vs-162	5800±140	6760÷6460 BP	4.7
2	Oak timber	Vs-163	4900±130	5810÷5490 BP	4.7
3	Oak timber	Vs-164	5690±160	6660÷6340 BP	4.7
4	Oak timber	Gd-11720	4200±4/50	4808÷4688 BP	3.63-3.68
5	Oak timber	ЛУ-5069	4190±60	4850÷4570 BP	3.63-3.68
6	Oak timber	Hv-2663	4040±40	4565÷4415 BP	3.63-3.68
7	Oak timber	Gd-12538	4040±65	4850÷4300 BP	3.63-3.68
8	Wood remains	Gd-15529	3460±65	3900÷3550 BP	3.38-3.40
9	Wood remains	Gd-15531	2845±85	3900÷3550 BP	3.24-3.26

Specimens No 4 and No 7-9 were dated in Gliwice, Technological University Radiocarbon Laboratory (Gliwice reports, 2003), No 5 - in Saint Petersburg University, Radiocarbon laboratory (Arslanov report, 2003), No 6 – in Hannover Leibniz Institute for Applied Geosciences, Geochronology and Isotope Hydrology Laboratory (Frechen report, 2003), No 1-3 was dated in Vilnius Geological Institute, Radiocarbon Laboratory (Gaigalas et al., 1976).

The oxbow lake sequences are characterized by sand and loamy sand with organic material and, in particular, mineralised peat deposits without detrital sapropel. The oxbow lake sediments in the Valakupiai section formed in the near-river stage at the beginning of their evolution and in the lake-bog stage at the upper part of section. In the course of the development of the oxbow lake separate dynamic phases were recognized (Gaigalas, Dvareckas, 2002). During the beginning (first phase) of development, both ends of the oxbow lake ravine were still open. During the second phase only the lower end of the lake remained open, while the higher end was being filled with sand, i.e. it was gradually being cut off. During the third phase (end of development) the oxbow lake was completely closed with sand and loamy sand. It was isolated and had a hydrological connection with the river only during high floods. The oxbow lake sediments provide specific information for palaeoecological reconstructions. In the lowest deposits of Valakupiai section the shells of fresh water molluscs are common. These shells reveal warmer climatic conditions during the Atlantic period.

The dendrochronogram of oak timber from the oxbow lake sediments of Neris River demonstrated the deterioration of climatic conditions after the Atlantic period during the Subboreal (Fig. 4).

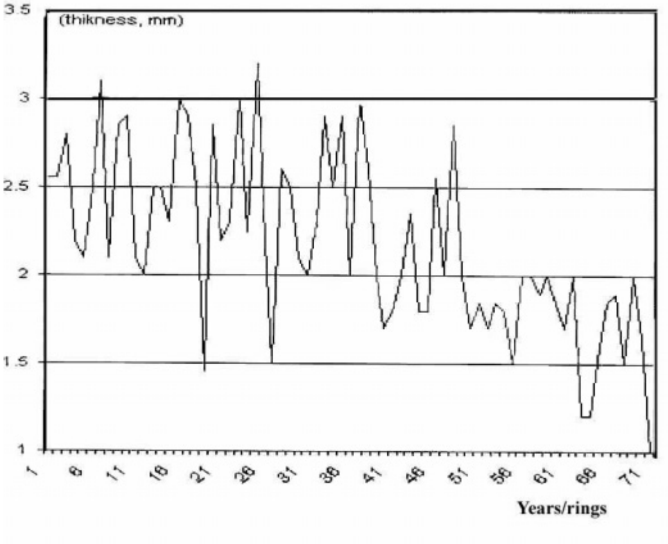

Figure 4. Dendrochronogram of oak timber from oxbow lake

CLIMATIC CHANGES

During the second half of the Subboreal period, approximately 4,000–2,500 BP, the climate became drier, spruce stands decreased, whereas birch, pine and white alder spread. About 3,500 BP, the semiclosed lagoons and lakes became overgrown and peat began to form. In the Subboreal period there was less precipitation and the mean annual temperature was close to that experienced in recent time. In the Subatlantic period the climate was slightly warmer and more humid than at present. The first fir (Picea) peak (4th zone according L. von Post) corresponds to the beginning of the Subboreal climatic period, the second - to the early Subatlantic.

The slight rise in microscopic charcoal particles could relate to human interference and the use of fire to clear the land for fields. From 1300 BC to 300 BC the enormous rise in the graph of charcoal particles suggests that fire was repeatedly used as a tool in landscape management, mainly to clear forest for agricultural practices. During the Late Iron Age the amount of charcoal particles is extremely low. Farming has been practiced in the area. (Table 3). In the transition zone of the Bronze-Iron time Subboreal draught farming widespread. The people had a significant effect on the vegetation in the Subboreal (accelerated replacement of deciduous trees by Picea).

The forest cover continued to decrease in the Subatlantic period, as a reflection of greater human activity. Agriculture and stock keeping took on an important role at the Late Subboreal to Early Subatlantic (transition from Bronze to-Iron time). Palaeoclimatic reconstructions were made for different regions of the East European plain for Subboreal and Subatlantic periods of Holocene. The climatic cooling started and increased humidity in the Late Subboreal. The Subboreal was characterized by great changes in summer and winter temperatures as well as in the total annual precipitation in Belarus (Fig. 5). The climate was moderately cold and damp.

Table 3. Correlation of farming history stages with chronozones and archaeological periods (according Seibutis and Savukynienė, 1998)

Climatic Periods	Years, BP	Archaeological periods	Farming phases
			Fallow agriculture (6)
	1000		
Subatlantic		Iron Age	Flourishing rye cultivation (5)
	2000		Subatlantic farming decline (4)
	3000		Subboreal draught farming (3)
		Bronze Age	
	4000		Meadow pasture cattle rearing (2)
Subboreal			
	5000	Neolithic	
			Forest pasture cattle rearing (1)
	6000		
		Mesolithic	
Atlantic	7000		

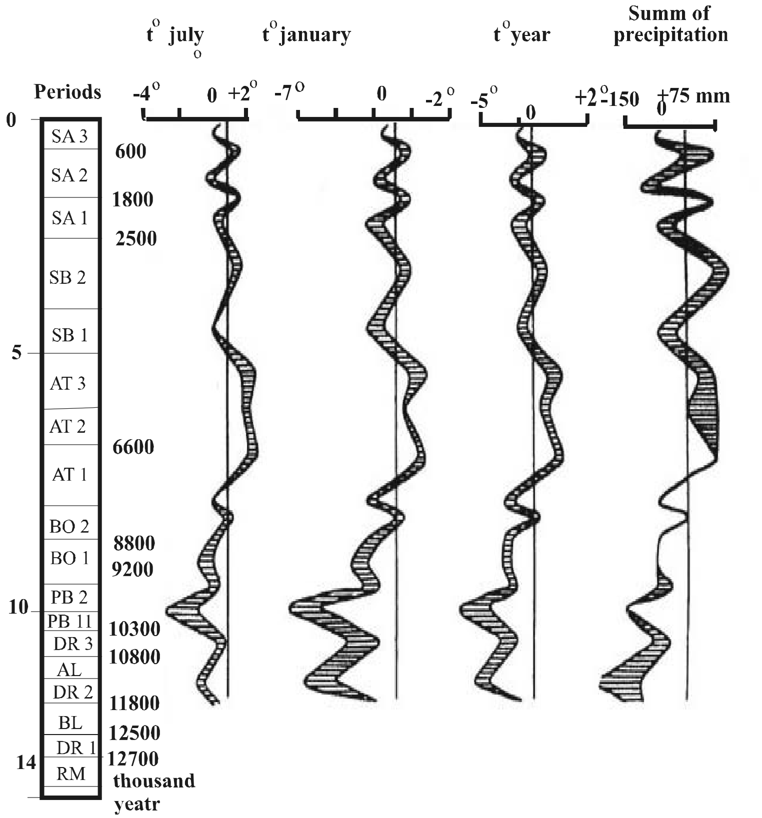

Figure 5. Palaeoclimatic curves of the Late-Glacial and Holocene of Belorus. After Ya. Elovicheva and I. Bogdel, 1987.

A distinct climatic cooling occurred on the boundary of the Subboreal and Subatlantic periods (about 2500 BP) in the Central region of the East Europe plain (Fig. 6). The mean July and January temperatures were respectively 1° and 2-3° and the mean annual temperatures 2-2.5° lower than nowadays. The precipitation was 50 mm less.

The most distinct extremities of warming of different magnitude were observed over the East Europe about . . .3,500, 2,700, 2,000, 1,300 . . . . The main extremities of cooling were about . . . 3,600, 3,100, 2,500, 1,500 years BP. . . .About 3,500 years ago all the temperatures indices were about 1° higher and the precipitation was 50 mm greater than nowadays. During the succeeding cooling about 2,500 years BP the temperatures were about 1° lower and the precipitation was a little greater. Precipitation decreased between the warming (3,500 BP) and cooling (2,500 BP).

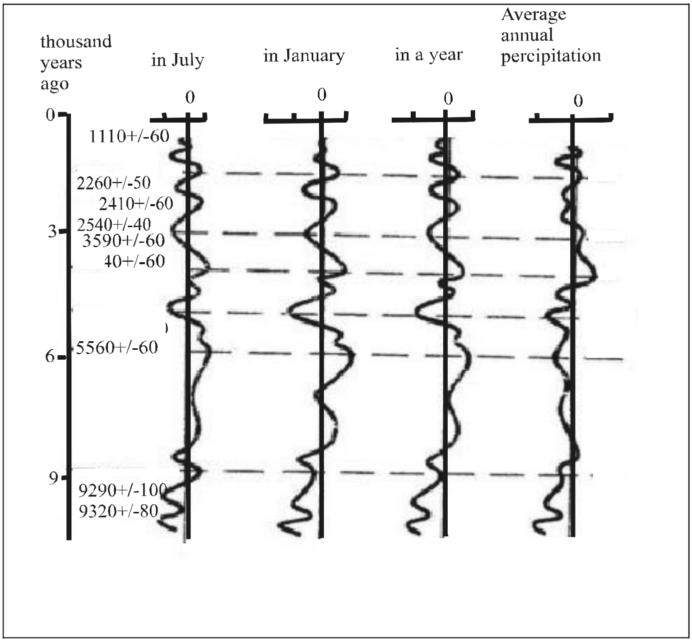

Figure 6. Average Holocene palaeoclimatic curves)deviation from present-day values for four sections located in the center of the central Russian Uplands. After V. Klimanov, 1987.

CONCLUDING REMARKS

The Bronze Age-Iron Age transition was unique during the creation and development of Scythian cultures in the history of Eastern Europe. In comparison with the Atlantic climate (Holocene optimum), the Subboreal and Subatlantic periods are considered to be the coldest. The decline of broad-leaved forest, the growth and formation of dark-coniferous forests due to climatic cooling and increased humidity, started in the Late-Subboreal and continued in Subatlantic time (SA1, SA2) (Table 4). The Bronze Age economy was based mainly on cattle breeding and agriculture. An expansion of human impact on the landscape and the extensive land use for new agricultural areas in the Iron Age are traceable in all regions. Cultivation indicators occur more often and the use of slash-and-burn agriculture is common. Nevertheless the majority of human impact indicators are derived from fresh meadow and grazing indicators. At the Bronze Age, Subboreal draught farming spreads and in the beginning of the Iron Age Subatlantic, farming declines.

Clearance areas were made during the Late Bronze Age-Early Iron Age. The Bronze Age-Iron Age transition saw increasing erosion of soils, aeolian processes, lateral erosion of rivers, flood plain terraces and oxbow lakes formation. In oxbow lake sediments peat with wood timber remnants prevail. The biodiversity during the Bronze Age-Iron Age transition had an impact on the economy of Scythian cultures in East Europe.

Table 4. Natural environment evolution.

Climatic periods	Character of climate
Neoboreal (1450-3650 years AD)	Slow decrease of temperature after furious and inclement (rigorous) climate of enter into a new phase about 2000 years AD. Fluctuations rather weak than in earlier cycle. Temperature of the phasial maximum about 2.5°C higher than recent. Furious end of years earlier period.
Subatlantic (600 BC- 1450 years AD)	Three great fluctuation in the phase of maximum, temperature lower 1 - 1.5°C than recent time; the end of period furious and cold. A new rise of the water level in lakes and acceleration of the water-flow in rivers. The water level was much higher as compared to Atlantic one. In the Early Subatlantic, when the climate became more humid and warmer, alder spread at first, and later began to dominate and the of bogs increased. The water level in the lakes during the Early Subatlantic was a little higher than at present. Due to the developing agriculture, wide areas of primeval forests (especially spruce stands) were destroyed.
Subboreal (2800 - 600 years BC)	Medium warm and arid climate, temperature was 2.5°C higher than recent time, a gradual fall in temperature during period, at the end of period decrease of temperature and increase of humidity. In the Late Subboreal, when the climate became drier, spruce decreased and was replaced by birch and white alders. The forests became lighter and meadows became more abundant. The water level in the lakes was low. At the border-line of the Atlantic and Subboreal periods minimum annual precipitation (500 - 400 mm) is registered.
Atlantic (5100 - 2800 Years BC)	Climatic optimum, warm and humid climate, temperature was 2.8-4°C higher than recent time. Higher average monthly temperatures in July (+20°C - +19°C) and increased annual precipitation (700-800 mm). In second half of Atlantic high summer temperatures preserved, but the decrease of precipitation began.

One of the most discussed problems at present is the climate of the second half of the Middle horizon Holocene - the climate of the Subboreal period, the time of the formation of the "border("Grenzhorizont"). In connection with this it would be useful to organize in a number of countries additional studies of the "border" horizon according to a specified program common to all the countries. Changes of temperature indices in different parts of the region were synchronous. No distinct synchronicity was observed in the variations of annual precipitation. Some provincial differences are fixed in palaeoclimatic indices

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Chapter 20

APPLICATIONS OF GEOCHEMISTRY TO PALEOENVIRONMENTAL RECONSTRUCTION IN SOUTHERN SIBERIA

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ABSTRACT

This study presents results of paleoclimatic reconstructions during the Holocene in Southern Siberia and Central Asia by means of a geochemical approach. For investigations the deposits of Kutudjekovo Lake (Minusinsk Depression), White Lake (Uyuk Depression), aeoline-paleosoil deposits from Arzhan -2 monument (Uyuk Depression) and loess-paleosoil deposits from Tepsey cross-section (Minusinsk Depression) were sampled. The determination of chemical composition was done by ICP-AES, SNC analysis and the Wesemael method. X-ray diffraction was applied for determination of clay compositions in the deposits. The granulometric composition was determined by means of the grain-size analysis. The correlation analysis and method of principal components was applied for processing. Radiocarbon dating and archaeological dating were applied for determination of age of the deposit. The results allow the possibility of reconstructing the climatic factors, affecting the sedimentary processes. The investigations showed the differences of local paleoclimatic conditions between Minusinsk and Uyuk depressions during the Holocene. The Uyuk Depression is characterized by warmer and drier paleoclimate, while the climate in the Minusinsk Depression was milder and damper. Most likely the landscape features of these depressions influenced the local climate. The synchronous climatic variations during the Holocene can be noted for both depressions. These developments have correlation with paleoclimatic events in the Mongolia region. On the whole, the climate in the period from 5000 years ago to 3000 years ago can be characterized as dry. About 3000 years ago in a cold climatic period the rise in humidity began. The humidity

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maximum was around 2500 years ago (1st millennium BC). The period from 2500 to 1500 years ago was most humid and warm.

The differences in occupation of the depressions by ancient people, probably, were linked to their paleoclimatic peculiarities. The occupation processes in the Minusinsk depression were more intensive and more diverse, then in the Uyuk depression. The abrupt increase of humidity, which was dated to about 2500 years ago in both areas, probably, resulted in the appearance of numerous tribes of the Scythian culture over the whole territory.

Key words: inorganic and organic geochemistry; geochemical indicators; environments; Holocene; paleoclimate; Southern Siberia; Central Asia; Scythian time.

INTRODUCTION

The diversity of archaeological cultures in the Southern Siberian and Central Asian regions and the close interaction of prehistoric man with paleoenvironment during the Holocene necessitate landscape-palaeoclimatic reconstruction. Application of geochemical methods for palaeoenvironmental reconstruction is based on the dependence of mineral weathering grade on temperature and precipitation. Farrand W.R (1985), Keller (1963) noted the different mineral stability to chemical weathering as an indicator characteristic of palaeoclimate. The chemical composition variations of deposits respond to climatic change most sensitively.

Arid and semiarid climate predominated in Southern Siberia and Central Asia during the Holocene. K.I.Lukashev (1955) explains the mountain chain, which was formed in the South in a period of Alpine tectonism, prevented the interchange of Southern and Northern air masses. That influenced the expanse of the polar basin in the north and the trengthening of climatic continentality in all of Siberia. The eastern part of Southern Siberia and Central Asia form the Eurasian steppe belt. The steppe areas are located in the Sayan-Altay intermountain depressions. Southern Siberia and Central Asia is an interior region and is far away from the effects of Pacific, Arctic, Atlantic and Indian oceans. The prevalence of evaporation under precipitation determines the character of sedimentary processes in the lakes and loess deposits in that area. The climatic shifts to more humid conditions were the cause of an increase in erosive-denudation and sedimentary processes. These influenced the destruction of mineral complexes which were stable in arid climate and resulted in other deposits of mineral and chemical composition occurring.

Study region.

The Southern Minusinsk depression is located in the South of the Krasnoyarsk district and Khakassia Republic (Fig.1).

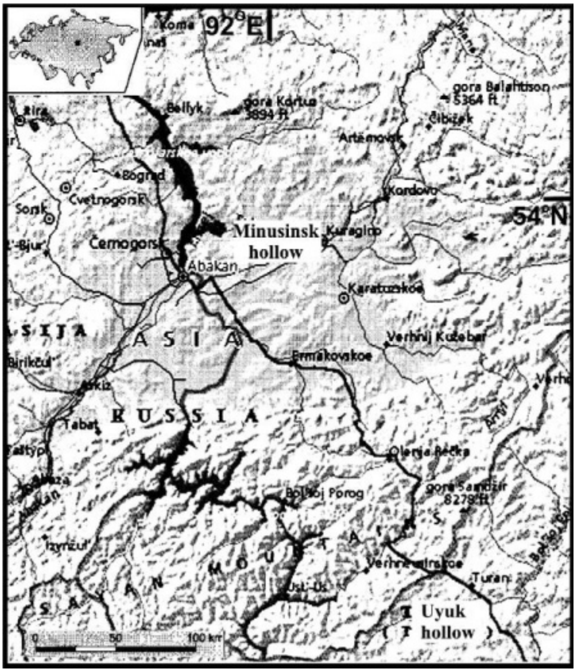


Fig.1. Map of the regions under study

The deposits of the Kutuzhekovo freshwater lake and the Tepsey cross-section were sampled for research. An open steppe characterizes the southwestern part of the area, whereas a forest-steppe is established in the more humid southern and eastern areas. The amount of precipitation is 300-1000 mm per year (Gavlina, 1954a). Precipitation during the year is characterized by irregularity with a maximum during summer and a minimum during winter. According to Chlebovich et al.(1976) air circulation in the Southern Minusinsk depression has some peculiarities. In winter the Asian anti-cyclone, the focus of which is located in the North-Western part of Mongolia, promotes air-cooling and low temperatures in Asia. However, air mixing, which arises from a large pressurec gradient in the Southern Minusinsk depression, results in increasing average annual winter temperatures. In summer, the convective processes because of fierce-warming of the ground and air provide a hyper precipitation in the submontane areas. Besides, the local cyclones in the summer period give rise to a precipitation similar to submontane areas and to the interior of the depression. Therefore, the local climate in the Southern Minusinsk depression is milder, than in the adjacent more southerly Tuva depression.

The Uyuk hollow is part of the Turan-Uyuk depression in the Northern part of the Tuva Republic. This hollow is located in the Center of Asia and is bounded by the Sayan Mountains on the West and East, and by the Uyuk mountain ridge on the South. The true altitude of the mountains is 1800-2300 m. The present climate is extremely continental with annual temperature amplitudes of 50^0C. The annual precipitation is about 300 mm per year. An open steppe is characteristic of the Tuva intermountan depressions. The littoral part of White Lake 2 and cross-section of aeolian-soil deposits, buried under Arzhan –2 monument were researched in the Uyuk depression.

METHODS

The chemical composition of samples was obtained by means of ICP-AES, CNS analysis. The concentrations of the following elements - , Na, Ca, Mg, Al, Fe, Mn, P, Ti, Zn, Cu, Ni, Cr, Ba, Sr, S were determined by ICP-AES (PerkinElmer 5000) in ppm (mg/kg). The concentrations of sulfur, nitrogen and total carbon were determined by CNS analysis. The Wesemael method was used for determination of the carbon dioxide concentrations. The concentration of organic carbon in the samples was calculated according to the equation $C_{org}= C_{tot}-C_{min}$, where $C_{min}=CO_2x12/44$.

For determination of the clay composition in the deposits an X-ray diffraction method was applied.

The granulometric composition of some samples was defined by means of grain-size analysis.

Statistical analysis was used to aid interpretation of the results. The correlation between chemical elements allows us to determine on the basis of elemental groupings, the mineral complexes in the samples. The method of principal components shows the relationships between these mineral complexes in the samples. It presents the possibility to reconstruct the influence of climatic conditions on sedimentary processes during the Holocene.

Sedimentological parameters along with the factor analysis data were applied as paleoclimatic markers. In arid and semiarid climatic conditions vegetation reacts to humidity very sensitively. Xiao, Nakamura (2002) came to the conclusion that the organic carbon concentration is associated with the density of vegetation. The vegetation density will increase, as the humidity increases. Therefore, total organic carbon concentration (TOC) according to Meyer (2003) is an indicator of humidity in arid and semiarid environments. The C/N ratio of lake sediments may reflect proportions of terrestrial and algal carbon contributing to the accumulation of sediment (Schmidt et al. 2002). The partial pressure variations of carbon dioxide control the carbonate sedimentation. The intensive decay of vegetation during cold periods increases the CO_2 concentration within deposits. Such processes destroy carbonate minerals (Eusterhaues et al.2002). The prevailing precipitation under evaporation results in the destruction of carbonate minerals too. The dry environments are favorable to carbonate precipitation (Hassan F.A., 1985). The Ba/Sr ratio can be used as a marker of relative temperature variations according to data of Chen, An, Head.(1999) and Goldberg E.L. (2000). The CIA (Chemical Index Alteration) was applied for estimation of relative temperature. This indicator determines the weathering grade during increase of temperature and humidity. (CIA= ratio of $(Al_2O_3/(Al_2O_3+CaO^*+Na_2O+K_2O)x100)$ of Nesbitt and Young (Bor-ming Jahn et al., 2001). Note that CaO* is the amount of CaO in silicates, corrected for the carbonate and sulfate contribution. The increasing of CIA in the soil profile indicates a warm climate.

RESULTS

The Southern Minusinsk Depression.

The Kutuzhekovo Lake (53° 36' N, 91° 56'E) is located between dune hills. The dune sandy hills are some kilometers wide. Dunes are covered by pine forests. Quartz-mica even-grained sand composes the dune hills. Some of the hills rise to 10-15 m. The samples were collected by Russian hand drill from a core, located at the littoral part of the lake. The depth of the core is 2 meter 38 cm.

Granulometric composition.

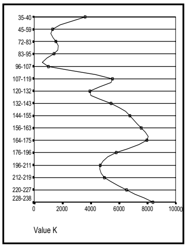
For grain-size analysis the samples from different stratigraphical horizons were selected: sample 33 (60-71 cm) – light-brown pit, sample 37 (107-119 cm)-dark-brown gyttja, sample 39 (132-143 cm)-sandy light-brown gyttja, sample 45 (212-219 cm)-sandy dark-brown gyttja. The greatest concentration of sandy particles (2000-250 μм) is in sample 39 (132-143 cm). The aleurite fraction (250-32 μм) prevails in sample 42 (164-175 cm). The clay fraction with grain-size of 32-2μм, ≤2μм predominates in sample 45 (212-219 cm). These data allow us to assume, that deposits at the depth of 212-219 cm and 164-175 cm were formed in a deep-water lake. The deposits at the depths of 132-143 cm, 107-119 cm, 60-71 cm were formed under shallower conditions.

Inter-elemental relationships.

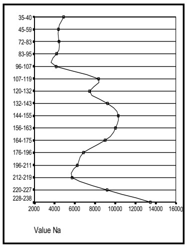
Principal components analysis and correlation analysis were performed on the dataset in order to identify elements with similar behavior and their relationships. Distribution of individual chemical elements is shown in Table 1. The results can be summarized as follows. (1) a detrital (alumosilicate) element group, comprised of K, Na, Al, Ti, Ba, Fe; (2) a carbonate group, consisting of Ca, Sr, CO_2; (3) an organic group, comprised of N, Corg, S. The first factor of the factor analysis with the square loading 67,40% denotes the antagonism between alumosilicate elements and elements included in organic material. The increase of detrital sediments in the lake deposits in comparison with organic material can take place in cool climatic conditions or as a result of soil erosion. The amount of aluminum is the detrital (alumosilicate) index. The increase of the clay-feldspar concentration in the lake deposits depends on the terrigene sediment supply in the cold period (Eusterhaues, Jutta , Lechterbreck, 2002).

Table 1 Distribution of individual elements in the Kutuzhekovo Lake core , ICP-AES and CNS analysis (ppm**)**

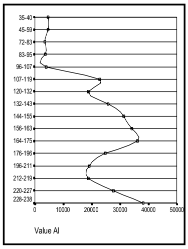
Elements of alumosilicate complexes



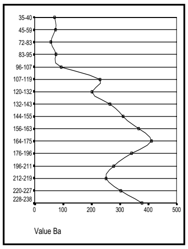
K



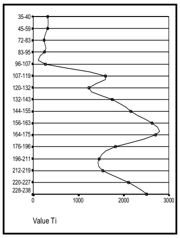
Na



Al

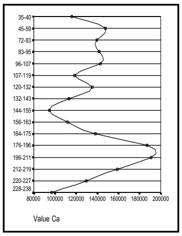


Ba

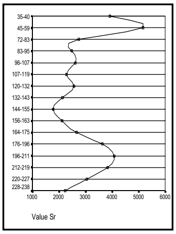


Ti

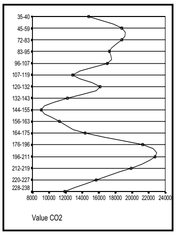
Carbonate elements



Ca

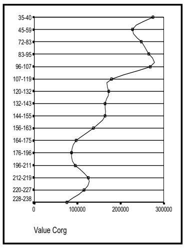


Sr

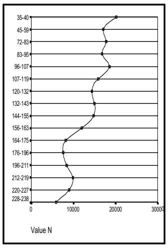


CO_2

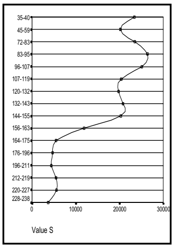
Elements of organic complexes



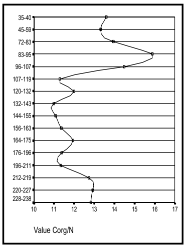
Corg



N



S



Corg/N

The values of first factor and Ba/Sr ratio show a good correlation. These data allow us to conclude, that the first factor can define relative temperature fluctuations. The second factor with the square loadingof 17,10% denotes the antagonism between elements of carbonates and organic substances. The meaning of the second factor can characterize the relative humidity grade.

Sedimentary processes in Kutudzhekovo Lake

The kind of the deposits and the reconstruction of the environmental changes is presented in Fig.2

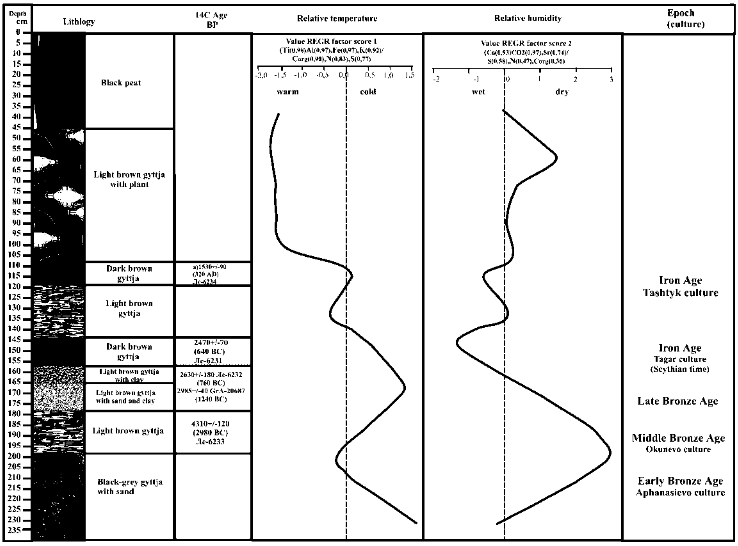


Fig..2. Paleoclimate geochemical records from the Kutuzhekovo Lake and the stages of cultural development in this area.

Layer 1. The dark-gray sand with organic at the depth of 238-228 cm was deposited in the deep-water basin, in the cold and humid climatic stage. The concentrations of alumosilicate elements and TOC, C/N ratio in this layer are higher then the carbonate element concentration.

Layer 2. The sandy gyttja at the depth of 228-165 cm was deposited in a shallow basin, in a cold and dry climate. The composition of sandy dark-brown gyttja at the depth of 211-196 cm reveals changes in the sedimentary environment. In this interlayer the amount of carbonate increased and the amount of detrital material decreased as compared to organic material. The climatic conditions of layer sedimentation agree with some warming in the dry environment. The interlayer of clay light-gray gyttja at the depth of 196-176 cm was formed in cold and dry climatic conditions again. The radiocarbon date of this interlayer is 4310±120years BP(Le-6233). The sandy-argillaceous light-brown gyttja at the depth of 176-165 cm was deposited in the deep-water lake. The decrease of carbonate materials in parallel with the increase of detrital material and the TOC and C/N ratio indicates the humidity and a fall in temperature. The radiocarbon age of the lower interlayer at the depth 176-158 cm is 2985±40 BP (Gr-20687).

Layer 3. At the depth of 165-119 cm the light-brown gyttja was formed. On the whole these deposits are characterized by an increase of organic and clay concentration and a decrease of carbonate material. These deposits have accumulated, probably, in the conditions of some warming and humidity, when the near-shore zone of the lake was overgrown with plants. The sedimentation of sandy gray gyttja occurred at the depth of 165-156 cm. The radiocarbon age of upper part of the layer (176-158 cm) is 2630±180 years BP (Le-6232). The increase of organic material parallels the considerable decrease of carbonates in the interlayer at the depth of 156-144 cm corresponding to a sharp increase in moisture. The radiocarbon age of the interlayer (146-158 cm) is 2470±70 years BP (Le-6231).

Layer 4. The light-brown peat-gyttja with plants was formed at 119-30 cm depth. This layer is characterized by higher concentrations of TOC and C/N ratio and low concentrations of carbonate and alumosilicate elements. Its accumulation took place in e conditions of lake swamping, in a warm and humid environment. In the composition of deposits at the 119-107 cm depth, the concentration of alumosilicate elements increase in parallel with Ba/Sr increasing. This reflects a fall in temperature. The radiocarbon dates of interlayer (120-106 cm) are 1600±150 BP (Le-6234b), 1530±90 BP (Le-6234a).

The loess-palaeosoil sequence of the Tepsey cross-section.

The loess-palaeosoil sequence is located on the Yenisei left-bank terrace near the foot of the Tepsey mountain. The coordinates of the cross-section are 53°59’ N, 91°33’ E. The terrace height is 9 meters. The deposits consist of light-gray aeolian fine-grained sand with interlayers of dark-brown humus burial soils. The age of the burial soil layers are determined by means of radiocarbon dating and archaeological data. The samples were collected from the section between 230 and 380 cm in depth. The grain-size composition was obtained by means of the granulometric analysis. Most of the clay particles are found at the depth of 230 cm at the bottom of the section. The layers enriched in clay particles contain fair quantities of aluminum. The considerable amount of aleurite particles occurs in the upper part of the section at the depth of 380 cm at the bottom. The increase of the Ti/Al ratio shows the weathering grade in the layers and denotes the most transformed layers. These data and data from the factor analysis allow us to determine the temperature-humidity variations, which effect the sedimentation. Sedimentary processes in the loess-paleosoil sequence at Tepsey are seen in Figure.3.

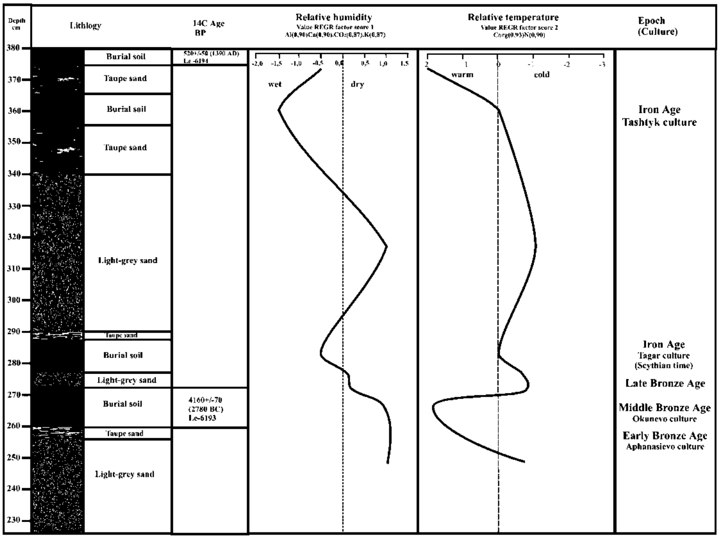


Fig3. _Paleoclimate geochemical records from loess-paleosoils Tepsey cross-section and stage cultural development in this area.

The light-gray fine-grained aeolian sand was bedded at a depth of 230-246 cm at the bottom. It is characterized by high contents of Al, Fe, Ca, Sr, Ba, CO_2 and low concentrations of TOC, N. The higher carbonate concentrations are in parallel with an increasing organic to alumosilicate ratio which shows that layer formation was during a warm and dry climatic stage.

At 256-260 cm is found brown fine-grained aeolian sand formation. The concentrations of Ca, Sr, Ba, Mg, CO_2 elements decrease, but the amounts of Copr, N, Copr/N, S increase. The layer was deposited in the warm, dry climatic stage. From the archaeological data the age of layer corresponds to the Early Bronze Age, Aphanasievo culture.

265-272 cm is the depth of a dark-brown humus layer. This layer is characterized by a low concentration of all elements. The ratio of organic to carbonate elements is higher than in the bottom layers and it suggest a higher humidity during layer sedimentation. The high ratio of alumosilicate elements to organic elements in the sample characterizes a cold climatic condition for sedimentation. In general, the present layer was deposited in a cold and dry climatic environment. The radiocarbon age of the deposit is 4160±70 years BP (Le-6193).

272-277 cm is the depth of a light-gray fine-grained aeolian sand layer. The concentrations of all elements in this layer are low in comparison with the bottom deposits. The increase of organic material as compared to carbonate and alumosilicate contents characterizes the increasing of humidity and the rise of temperature during layer formation. From the archaeological data the age of layer corresponds to the Late Bronze Age.

277-287 cm is the depth of a dark-brown humus palaeosoil layer. The contents of Ca, Sr, Ba, CO_2 elements are low, but the concentrations of Copr, N, Copr/N, S are higher then in the bottom layer. The high ratio of organic elements to carbonate and alumosilicate elements allows us to assume the layer was formed during wet and warm climate. From the archaeological data the age of layer corresponds to Scythian time.

327-330 cm is the depth of a light-gray fine-grained aeolian sand layer. It is characterized by a high concentration of Ca, Sr, Ba, Mg, CO_2 and a low concentration of Copr, N, Copr/N elements. The increase of alumosilicate and carbonate ratio to organic complexes shows the shift to more dry and cool climatic conditions.

355-365 cm is the depth of a gray fine-grained sand formation. The increase of the organic complex in comparison with the carbonate complex reflects the humid climatic condition during layer formation. The high ratio of values of the alumosilicate complex to the organic complex characterizes a cool environment. From the archaeological data the age of layer corresponds to the Iron Age, the Tashtyk culture.

375-381 cm is the depth of a dark-brown humus paaeosoil layer. This layer is characterized by high contents of organic elements and low contents of carbonate elements. That reflects the wet climatic condition of layer formation. The rise in temperature promoted the high ratio of organic to alumosilicate complex. The radiocarbon age of the layer is 520±50 years BP(Le-6194).

THE CLIMATIC VARIATIONS AND ANCIENT SETTLEMENT FEATURES IN THE SOUTHERN-MINUSINSK HOLLOW.

5000-3000 years ago (3000 BC to 1000 BC).

On the whole, this period is characterized by cool and dry climatic conditions. The appearance of Bronze Age cultures occurred in the Southern-Minusinsk depression at this time (Van Geel B., Zaitseva G.I.et. al). The *Afanasievo culture* with the first use of metals (copper) occupied this region during the 4th to the 3rd millennium BC. Some rise in temperature and dry conditions is registered about 4500 years ago (2500 BC). The beginning of the cultures of the Middle Bronze Age (Okunevo culture) in this area is dated to the end of the 3rd millennium BC. The

Andronovo culture spread in the North part of the hollow during 1800-1400 years BC, when the climate became cool again.

3000-1500 years ago (1000 BC – 1000 AD).

In this period climate became warmer and humid. The beginning of the humid period occurred at 2985±40 ^{14}C yr BP, 2630±180 ^{14}C yr BP (the 13th -8th centuries BC), however this period was cold. The cultures of the Late Bronze Age (Karasuk culture) from the 14th to 10th century BC occupied this territory**.** The stage of maximum humidity and temperature rise was at 2470±70 ^{14}C yr BP (7th century BC). The expansion cultures of the Iron Age (nomadic cultures of the Scythian time – Tagar culture) occurred in the 1st millennium BC. Some cool and humid climatic conditions are identified about 1600 years ago (3th-4th centuries AD). The existence of Tashtyk culture in this area was from the 1th centuries BC to 4th centuries AD.

THE TURAN-UYUK HOLLOW.

The White Lake 2.

The White Lake group is located in the Turan-Uyuk intermontane depression at the Northern part of Tuva. The samples were collected by Russian hand drill and Dachnovskiy drill from a core, located in the littoral part of White Lake 2. The coordinates of the core are 52°03'(N), 93°43'(E). The depth of the core is 1 meter 35 cm.

Granulometric composition.

For grain-size analysis the samples from different stratigraphical horizons were selected: sample 13 (22-25 cm) is dark-gray gyttja; sample 16 (34-42 cm) is sandy gray gyttja; sample 20 (66-73 cm) is yellow loam with organic impurities; sample 25 (106-117 cm) is red clay sand. The biggest concentration of sand fraction with grain-size of 2000-250 μм is observed in sample 16 (34-42 cm). The aleurite fraction with grain-size of 250-32 μм predominates in sample 25 (106-117 cm). The clay fraction with grain-size of 32-2μм, ≤2μм predominates in sample 20 (66-73 cm). Taking these into consideration we suggest that sedimentation of sample 20 (66-73 cm) was in deep-water. The formation of sample 16 (34-42 cm) occurred in a shallow lake.

X-ray diffraction analysis of clay minerals.

For determination of clay minerals the following samples were selected: dark-gray gyttja -13 (22-25 cm), sandy dark-gray gyttja -15 (30-33 см),_yellow loam with organic impurities - 20 (66-73 cm). The results of analysis showed, that all samples contain chlorite and lesser amounts of muscovite and smectite. The basal rock on this territory contains chlorite in its composition. This fact explains the higher chlorite concentrations in the samples. In arid climatic conditions the processes of physical weathering prevailed, therefore the hypergene alteration was developed weakly. The appearance of smectite minerals occurred under weathering processes, chlorite and mica appeared in the climatic conditions of low precipitation (Minerals in Soil Environments, Ed. J.B.Dixon, Wisconsin, 1977). The total composition of clay minerals in the lake deposits shows that the parent metamorphic peach stones containing chlorite and mica were the source of the lake sediments.

The results of elemental concentrations in the samples were calculated by correlation and factor analysis. The individual distribution of elements is shown in the Table 2. Three groups of elements can be determined: (1) a detrital (alumosilicate) element group, comprised of K, Al, Ti, Ba, Fe; (2) Sr, Ca, S, CO_2, N, Corg is elements of carbonates, sulphates and organic complexes. Since all CO_2 is bound with Ca in carbonate form, the calcium excess combined with strontium constitutes sulphate complexes. (3) Na has minor correlation with all elements. It, probably, combines into halogen minerals. The first factor of factor analysis with a square loading of 52,7% denotes the antagonism between alumosilicate elements and elements included in organic material. This factor can be characterized as the relative temperature variations with the changing water level. The Ba/Sr ratio can be characterized by cold-warm conditions and the changing of water level too. Barium has high correlation with Al, K, Fe elements and belongs to alumosilicate minerals. Strontium has a high correlation with Ca, S, CO_2, Corg elements and with sulphate, carbonate and organic complexes. The warm climate and a shallow basin favors sulphate, carbonate and organic sedimentation and consequently Sr accumulation. These mineral complexes had not been deposited in the cool and deep environments. In these conditions the alumosilicate minerals prevail.

The second factor denotes the antagonism between organic-carbonate complex and halogen complex. The salinity of the lake and the Na increase as a result of it reflects a dry environment in this region. Consequently, the second factor can be determined as the index of humidity. The sedimentary processes in White Lake 2 is shown in Figure 4.

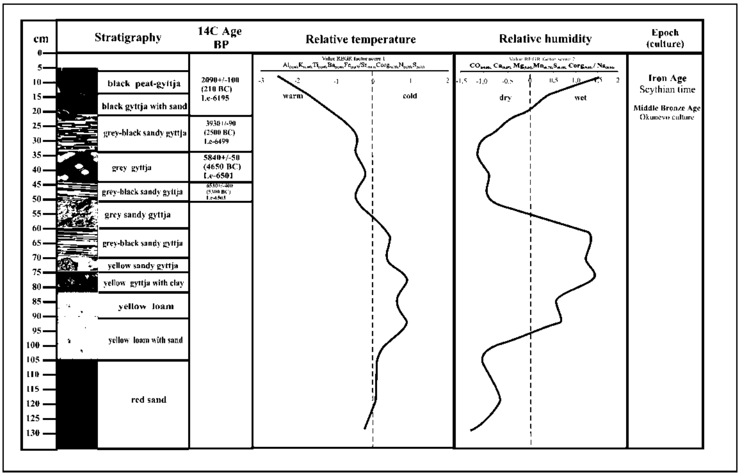
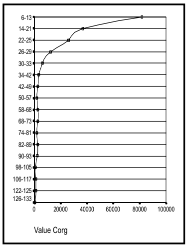


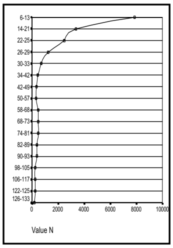
Fig.4. Paleoclimate geochemical records from White Lake 2 and stages of cultural development in this area.

Table .2 Distribution of individual elements in the White Lake 2 core , ICP-AES and CNS analysis (ppm)

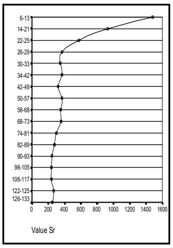
Elements of organic, carbonate and sulphate complexes



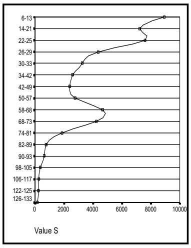
Corg



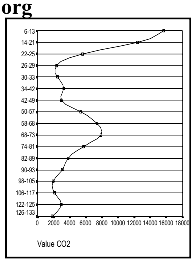
N



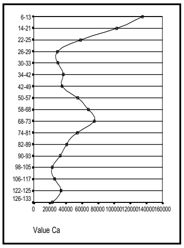
Sr



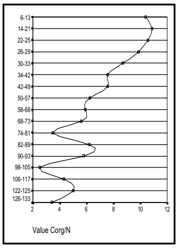
S



CO_2

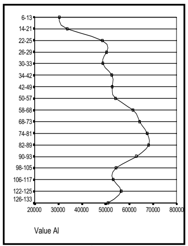


Ca

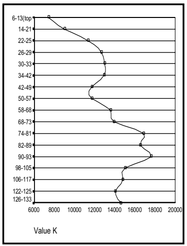


Corg/N

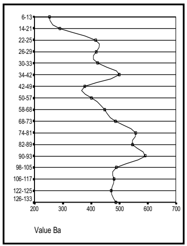
Elements of alumosilicate complexes



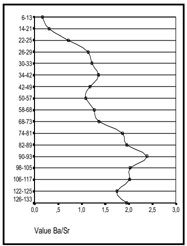
Al



K

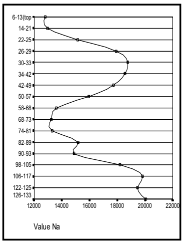


Ba



Ba/Sr

Element of halide



Na

Layer 1. The fine-grained red sand at the depth of 133-98 cm (samples 27(133-126 cm), 26(125-122cm), 25(117-106cm), 24(105-98cm)) was deposited during cool and dry conditions in the shallow lake. Some shift to warm and humid climate is identified in the period of layer sedimentation at the depth of 122-125cm. In this layer the Ba/Sr ratio and Al, K, Fe concentrations are low.

Layer 2. The depth is 93-58 cm (sample 23 (93-90 cm), 22 (89-82 cm), 21 (81-74 cm), 20(73-68 cm), 19 (68-58 cm). The sedimentary change is reflected in the stratigraphic succession. The fine-grained red sand gives way to yellow loams. The loam layers conain more alumosilicate elements and they are characterized by increasing Ba/Sr and the prevalence of carbonate and organic complexes over halogens. In general, this layer was formed during cold and wet climatic conditions in a deep lake.

Layer 3. At the depth of 57 cm the yellow loam gives place to sandy gray gyttja, samples 18 (57-50cm), 17 (49-42 cm), 16 (42-34 cm), 15 (33-30 cm), 14 (29-26 cm). In these samples the increase of halogen and the decrease of alumosilicate complexes result in a fixed Ba/Sr ratio. The appearance of halogen marks the prevalence of evaporation under precipitation. The climate during this layer formation was warm and dry and the lake was shallow. The time of the layer sedimentation at the depth of 57-30 cm from radiocarbon dating was from 6500 to 4000 years ago (6530±400 (Le-6503); 5840±50 (Le-6501); 4670±400 (Le-6502); 3930±90 (Le-6499) years BP, ^{14}C).

Layer 4. The dark-gray gyttja enriched organic material was formed at the depth of 29 cm, samples 13 (25-22 cm), 12 (21-14 cm), 11 (13-6 cm). The geochemistry features of these deposits mark that the climate became wet and warm. The lake shores have become marshy. The increase of Corg., N concentrations is the index of an increase in bioproductivity. The radiocarbon date of layer on the depth of 21-5 cm is 2090±100 (Le-6195) years BP.

THE CROSS-SECTION OF AEOLIAN-SOIL DEPOSITS, BURIED UNDER THE ARZHAN –2 MONUMENT.

The famous Arzhan-2 monument ($52^0$03’ N; $93^0$35’E) is located near White Lake 2.

Correlation analysis allows us to associate elements of aeolian-soil deposits with three mineral groups: K, Na, Al, Ti, Cr are elements of clay minerals (smectite, chlorite, muscovite\illite, kaolinite, on the basis of X-ray diffraction analysis) and feldspars, Ca, Mg, Sr, CO_2, S are elements of carbonates and sulfates, Corg, N are elements of organic complex. The first factor of factor analysis with a square loading of 57,2% denotes the antagonism between elements of alumosilicate and organic complexes and elements of carbonate and sulfate complexes. The first factor, probably, marks the relative change of precipitation. The increase of carbonate and sulfate minerals show a dry climate, while the increase of alumosilicates denotes a wet environment. The higher Ca and CO_2 values mark dry climatic conditions. The increasing of CIA in the soil profile indicates a warm climate. The Corg/N ratio and TOC are indicators of humidity. These geochemical indicators allow us to reconstruct the environments of soil formation.

Sedimentary processes in the Arzhan-2 cross- section are shown in Figure 5.

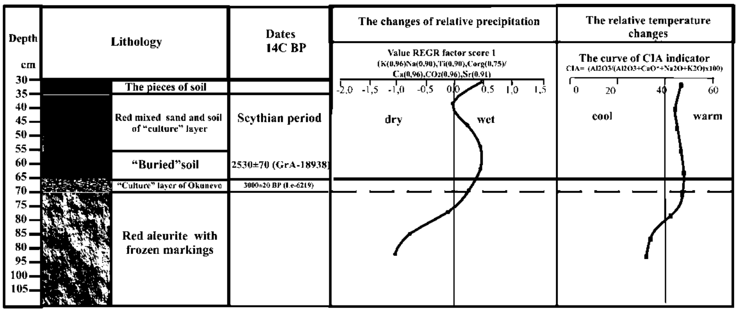


Fig. 5. Paleoclimate geochemical records from Arzhan 2 aeolian cross-section and stages of cultural development in this area.

At the depth of 105-70 cm the fine-grained pinkish-red aleurite with season checks was formed. The particles with grain-size of 250-32 µm predominate in these deposits, whereas they contain 1,0% of sandy particles with grain-size of 2000-1000 µm and 9,1% of clay particles with grain-size of 32-2 µm. The prevalence of carbonate and sulphate complexes over TOC, C/N ratio relate to dry climatic conditions. The low CIA values indicate weak layer alteration, which is possible in a cold environment. The fissured texture of deposits supports this too.

70-65 cm is the depth of dark-red aleurite layer with gravel. This is the cultural layer with artifacts of Okunevo culture. The coal age from this layer is 3000±20 years BP(Le-6219) from radiocarbon dating. The concentration of clay particles (32-2 µm) amount to 10,5% related with an increase of organic and alumosilicate material over the carbonate component. These geochemical indicators denote a humidity rise.

65-55 cm is the level of brown burial soil. The amount of sand (2000-1000 µm) decreases to 0,8% but the amount of clay particles (32-2 µm) increases to 11,5%. The prevalence of organic and clay material over the carbonate component in parallel with increasing CIA index and C/N ratio marks a climatic shift to humid and warm condition. The radiocarbon age of burial soil is 2530±70 (GrA -18938).

55-35 cm is the depth of a brown aleurite layer. The amount of sand particles of 2000-1000 μm decreases to 0,3% and the amount of clay particles decreases to 10,7%. The amount of aleurite particles increases in this layer. In the composition of this layer some decrease of the organic component was determined. The climate was warm and wet during this layer sedimentation.

The climatic variations and ancient settlement features in the Uyuk hollow

The period at 6300-4000 BP (4650- 2500 cal.yr BC) is characterized by a dry and warm climate. Evaporation prevailed over precipitation.

The humid period began after 4000 BP (ca 2500 cal.yr BC). According to the archaeological data, the tribes of Okunevo culture occupied this area in the 2nd millennium BC.

The period of wet, warm climate at 2530±70 ^{14}C yr BP (ca 810-470 BC) corresponds with the expansion of Scythian cultures. They began to occupy this territory during the 1st millennium BC.

CONCLUSION

The investigations showed differences in local paleoclimatic conditions between the Minusinsk and Uyuk depressions during the Holocene. The Uyuk depression is characterized by warmer and drier paleoclimate, while the climate in the Minusinsk depression was milder and damper. Most likely the landscape features of these depressions influenced the local climate.

The synchronous climatic variations during the Holocene can be identified in both depressions. A period of very dry and warm climate occurred in the Uyuk hollow during 6,3 – 4 kyr BP, in the Minusinsk hollow some warming in a dry and cold period occurred around 4500 BP. The beginning of a humid and cold climatic stage is registered around 4 kyr BP in both hollows. The maximum of humidity and some warming in both hollows is noted at 3 kyr BP. Figure 6 shows the comparison of these paleoclimatic findings with paleoclimatic data for Mongolia, Western Siberia and Baykal Lake regions by Karabanov et al. (2000).

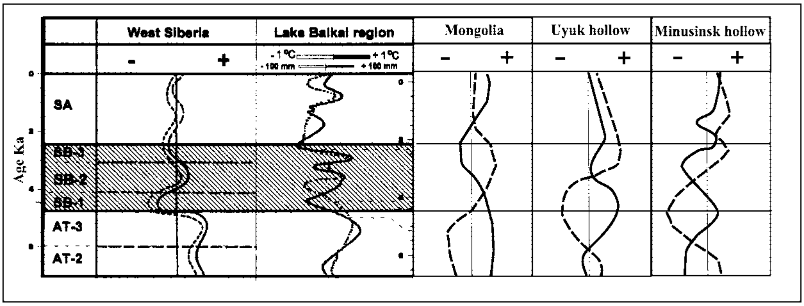


Fig.6. Comparison of regional paleoclimate reconstructions for Minusinsk and Uyuk depressions with Holocene paleoclimate records from Lake Baykal, for Western Siberia region, for Mongolia and continental interior Asia according to Karabanov et al (2000) and John A.Peck.(2002). Solid line shows temperature variations, dashed line corresponds to humidity changes.

From the data of Karabanov et al. and John A.Peck et al.(2002) the most arid conditions in Mongolia and Inner Asia region were recorded to 6260 cal. years BP. During 6260-4390 years ago the humidity began to rise, but the climate remained dry. In general, the most humid environment is noted after 4390 cal. years BP. The period 2710-1260 yr.BP and the last 680 years BP is characterized by wetter conditions than present. In North Mongolia from the geochemical and pollen data obtained from loess-paleosoil succession the period from 8300 to 4070 years ago is characterized by a dry and warm climate and the humid climate is recorded after 4070 years. In the Uvs Nuur and Bayan Nuu lakes the higher lake level was recorded about 2800 years ago. The positive hydrology balance in Lake Telmen was after 4390 cal. years BP and during 1260-2710 cal. years BP. These data have a good correlation with data obtained for the Minusinsk and Uyuk depressions. On the whole, the climate in the period from 5000 years ago to 3000 years ago can be characterized as most dry. About 3000 years ago in a cold climatic period, the rise of humidity began. The maximum humidity was around 2500 years ago (1st millennium BC). The period from 2500 to 1500 years ago was most humid and warm.

The differences in occupation of the hollows by ancient people, probably, were linked to their landscape-paleoclimatic peculiarities. The occupation processes in the Minusinsk depression were more intensive and more diverse, then in the Uyuk hollow. The synchronous increase of humidity in the both hollows at 3 kyr BP (1st millennium BC) was the likely cause of pasture development. These changes resulted in the appearance of numerous tribes of Scythian culture over the whole territory.

ACKNOWLEDGMENTS

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Chapter 21

POLLEN AND PLANT MACROREMAIN ANALYSES FOR THE RECONSTRUCTION OF ENVIRONMENTAL CHANGES IN THE EARLY METAL PERIOD

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ABSTRACT

A sharp increase in human population density and the same time fundamental changes in the location of settlement, moving away from earlier inhabited places points to significant changes in the environment.
This period with a sharp decrease in anthropogenic indicators and poor records of slash and burn cultivation and field crop-growing is named "transition" period (Vasks et.al.1998) and indicates the lack of stable and continuous inhabitant sites. This phenomena can be explained by the small size of settlements at the Early Iron Age, expressed by a weak cultural layer and these could be defined as separate farmsteads. Modern farming practices, especially modern tillage, adversely affected the preservation of these settlements. Pollen and plant macrofossil analyses were used as tool to discover traces of human activity and environmental changes during the Early Metal Period.

Keywords: Early Metal Period, pollen, plant macroremains, Holocene, Subatlantic Time, Latvia

INTRODUCTION

The reconstruction of past vegetation is very important in archaeological investigations, because it helps us to imagine and understand living conditions of ancient man. Vegetation reflects ecological conditions of the particular area, which depends on the geological, hydrological, soil and climatic conditions, as well as anthropogenic factors. Pollen and plant

E.M. Scott et al. (eds.), Impact of the Environment on Human Migration in Eurasia, 275-289.

remain records from exact sediment layers are one of the best indicators reflecting the character of environment and vegetation during its formation.

The reconstruction of the environment and determination of the immediate human impact on nature on the basis of the pollen and plant macroremain data is an extremely complicated task because of the variety of factors affecting the formation of the pollen spectra and preservation degree of plant remains.

Human impact on vegetation is different in various areas. The pollen data from Western and Central Europe diagrams indicate earlier and greater human impact on vegetation, than these from Eastern Europe, especially in the northern boreal zone traces of human impact are smaller. Also, some very local factors might result in differences in the environment and of human influence upon vegetation in neighbouring areas. Human impact was much greater in sites close to the water bodies, lakes and rivers, where conditions were favourable for early man to live.

There are a few sites found in Latvia containing the records, which reveal a lot of cereal grains, seeds and pollen of cereal and perennial weeds (*Stellaria, Rumex acetosella* etc.). This and the finds of ploughshares and crop-growing tools in these settlements lead us to conclude that in general at the beginning of the 1st milleniuml BC slash and burn cultivation dominated and field crop-growing was also being practised.

Different approaches to the interpretation of the results of pollen and plant remains analysis have been used to reconstruct the process of environmental development as well as human impact, both regional and local.

Earlier, the pollen and macroremain data had been used in studies of the environment concerning the Stone Age inhabitants. The development of the investigation techniques and methods nowadays allow us to obtain considerable data also for other historical periods, including the Iron Age.

BACKGROUND

The role of fishing, hunting and gathering of wild food significantly decreased in the late 3rd and early 2nd millennium BC, when food production economy - stock keeping and crop growing started.

The earliest bronze artefacts from Latvia are dated to the mid-2nd millennium BC, and in the mid-1st millennium BC the earliest iron artefacts appear. The Early Metal Period in Latvian archaeology is considered to last from 1800 - 500 BP, which corresponds to the Scythian time or the Early Iron Age in Eastern Europe. In Latvia this is a time, when the metals were known, but when they were not important for economic development.

The warm and dry Subboreal climate, with wide distribution of spruce forests, rich in fauna was changed by colder and more humid Subatlantic climate. The volume of the obtainable wild food decreased, and this stimulated the development of food production, but the requirement of food increased along with the population growth.

The very end of the Subboreal and the beginning of the Subatlantic is characterised by declining temperature and increasing humidity, and as a consequence of this, bog formation and increasing soil leaching. Land vegetation changed - spruce trees, which earlier were dominant, decreased in favour of birch, alder and open meadows and heaths appeared.

The occurrences of the beginning of clearance farming have been found at the end of the Subboreal and beginning of the Subatlantic time. The main tool for forest clearance still was the stone axe. With wooden and stone hoes it was possible to plough only small areas with light sand or peat soil, where forests were absent. The fields used for crop-growing without manuring quickly lost their fertility, and the meadows also soon became depleted, so human communities frequently moved, looking for new pasture for animals and new unforested locations.

The fertility of such cleared fields was increased by ash from burnt trees. Probably, in the area envisaged for clearance, the trees were barked and after drying set on fire. With the use of fire, not only trees were destroyed, but also peat. These fires could be connected with common finds of the charcoal dust in sediment.

The evidence from the excavated settlement sites shows that from the middle of the Bronze Age, alongside clearance agriculture, cultivation of fields used for an extended period and tillage using the plough was also important. Only in the Early Iron Age (approx. 2000 BP) agriculture - particularly stimulated by the introduction of iron tools - was of primary importance (Vasks, 2001).

The aim of this paper is to give some insight into environmental changes and human activity during the Early Metal Period, with attention to the sites, where artefacts have not been found in significant number. Two sites were chosen from western Latvia and two sites from eastern Latvia (Fig.1).

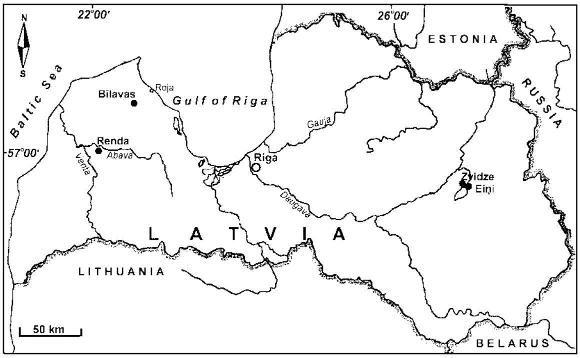


Figure 1. Location of the studied sites.

METHODS

PLANT MACROREMAIN ANALYSIS

The finds of plant remains are comparatively rare in the soils of Early Metal archaeological sites, which is why data are available from few sites. The first investigations of plant macroremains were carried out by A. Rasins in 1970-80, when information about crop growing agriculture had been obtained from seeds and grains found in the cultural layers of Mukukalns and Kivutkalns (Rasiņš, 1983) dated approximately to 3000 BP. Remnants of them allow us to conclude that people living in Ķivutkalns cultivated mainly wheat (*Triticum dicoccum*), and barley (*Hordeum sativum*), as well as millet (*Panicum miliaceum*) and peas (*Pisum sativum*), while beans (*Vicia faba*) were less important. The fat hen (*Chenopodium album*), pale persicaria (*Polygonum lapathifoilum*) and Gold-of-pleasure (*Camelina sativa*), have been found, which also were used for food that time, but nowadays are considered as weeds.

The large amount of grain recovered, as well as weed flora - common chickweed (*Stellaria media*), corn spurry (*Spergula arvensis*), white campion (*Melandryum album*) and sorrel (*Rumex acetosa*) - show that in addition to clearance fields there were also permanent fields (Graudonis, 2001).

Plant macroremains, such as, seeds, leaves, nuts, etc. have been analysed from Zvidze settlement cultural layer, Lubans Plain in this study. The results of plant macroremain analysis from Neolithic sites can be used for understanding of environmental changes, which caused movement of people away from areas used for settlement for a long time.

POLLEN ANALYSIS

During last the two decades multidisciplinary investigations have been carried out in archaeological sites. Since then the investigation of the microscopic evidence such as pollen has become important, because of its better preservation and broad information.

It is very important to choose the right place to take a sediment sequence for analysis with the aim of getting pollen data, which gives an idea of vegetation and environmental changes in the area. It is reasonable to take samples in nearby lakes or bogs besides the site cultural layer, because sediment layers at the archaeological site often are disturbed.

Pollen analysis principally is based on a well-known method described by B.E.Berglund and M.Ralska-Jasiewiczowa (1985). The pollen zones are distinguished as local, which firstly are selected as biostratigraphic units defined purely upon their pollen content, then multivariable methods for data analysis are applied and comparison with regional zones made. The zone boundary is placed at those levels where changes in the pollen spectra are most marked. Pollen zones in studies of archaeological sites usually are not so much subdivided for the sake of the pollen stratigraphy but, rather, as a tool that enables us to reconstruct vegetation history of the site, as well as spatial development and character of the past ecosystems. Radiocarbon data is very important for interpretation of results, to correlate events and find out local factors.

The interpretation of pollen data is focused on the changes in the forest composition, indicators of agriculture and other anthropogenic indicators.

The pollen data from three sites have been presented and compared in this study: Renda site (pollen from site itself and nearby depression), Bilavas (both western Latvia) and Eini site, Lubans Plan (eastern Latvia).

RESULTS AND INTERPRETATION

POLLEN ANALYSIS

Further the data of pollen analysis are represented from the following sites:

- Renda depression and Lielrenda tarand grave on the left bank of the Abava River, middle part of western Latvia,
- Bilavas "Devil boat" north-eastern par of western Latvia and
- Eini site, Lubans Plain, eastern Latvia (Fig. 1.).

Renda

The Lielrenda tarand grave is situated on the right bank of the Abava, right at the edge of the steep riverbank. The cemetery consists of a mound with stone structures. The basic structure of the grave consists of a 9,5× 6,5 m rectangular enclosure of large boulders. The interior of the enclosure was filled with dark earth and smaller rounded stones. 62 finds were obtained in the course of excavation. Most of these are broken and fragmentary artefacts. These finds date from the 2nd to 6th century, and such a date can be given for Lielrenda tarand grave.

Pollen analysis has been carried out from an undisturbed sediment sequence from the Renda depression located near (50 m) the Lielrenda tarand grave. Pollen data reveal vegetation development since the Subboreal till present. Five local pollen zones have been subdivided (Table 1, Figures. 2 and 3).

Table 1. Overview of the local pollen zones and their correlation with regional zones.

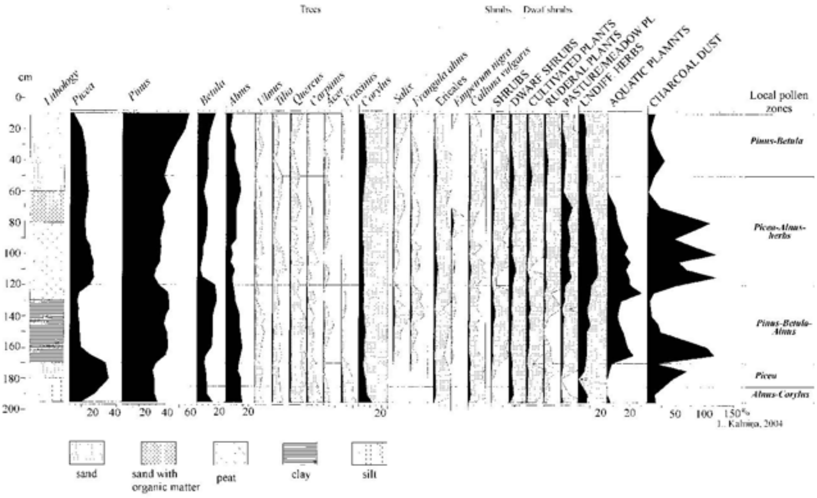
Local pollen zone	*Significant characteristics of zone*	*Correlation*
Pinus-Betula	Increase in *Pinus, Betula, Corylus, Artemisia*, Poaceae, decrease in *Picea, Alnus*, charcoal dust.	SA3
Picea-Alnus-herbs	Increase in *Picea*, appearance of *Secale*, increase in *Cannabis/Humulus* and *Urtica*, maximum of herbs, including pasture/meadow plants, peaks of charcoal dust	SA2
Pinus-Betula-Alnus	Increase in *Pinus, Betula, Alnus*, herbs, cultivated plants (*Hordeum, Avena* type) high peak of charcoal dust in the lower part of zone	SA1
Picea	Maxima of *Picea*, peak of charcoal, continuous curve of Cerealia (*Hordeum, Triticum*) pollen	SB2
Alnus-Corylus	Increase in *Picea*, charcoal, presence of *Hordeum, Cannabis/Humulus* type*, Urtica, Plantago* pollen	SB1

Pollen data reveal spruce forest distribution in the area with alder, hazel and some pine, oak, linden and elm in the lower part of sediment sequence (Fig.2). Significant presence of herb pollen through the entire interval investigated point to the wide and open areas around the Renda depression.

The appearance of aquatic plant pollen in the interval of zone *Pinus-Betula-Alnus* leads us to assume that depression was filled by water during

accumulation of the corresponding sediment interval. This phenomenon might be connected with some climatic deterioration, increase in groundwater level and wetter conditions. Grey clay with organic matter was deposited during lake condition in the depression. Since the depression was shallow it gradually overgrew, which is supported by a maximum of Cyperaceae and Poaceae pollen in the corresponding interval, as well as, by the formation of a peat layer above clay.

The presence of cultivated, ruderal plant and undifferentiated herb pollen and fluctuation of their curves in the pollen diagram reveals changes in human activity and climate in the area. Pollen curves of the ruderal (*Plantago, Chenopodium*), pasture/meadow and cultivated plant (*Hordeum, Cannabis/Humulus, Avena* type) pollen have continuous curves (Fig. 3) through the investigated sequence. They start from the bottom of diagram and point to human presence and crop-growing in the area already at that time, which probably can correspond to the middle of the Subboreal. Increase in herbs, as well as in cultivated plants can be correlated with peaks of the charcoal dust curve (Fig. 2).



F*igure 2.* Tree, shrub, dwarf shrub and summary percentage pollen diagram from Renda depression, western Latvia

The data described above from Renda depression has been correlated with those from the Lielrenda tarand grave. The pollen sequence reveals that the tarand grave was created during the second part of the local pollen zone

Picea-Alnus-herbs, when the small lake in Renda depression was overgrown. As Lielrenda tarand grave has been dated as Early Iron Age, then comparison of data leads us to admit that people lived in the surroundings of the Renda depression during the Early metal period, because of comparatively strong evidence of anthropogenic indicator pollen.

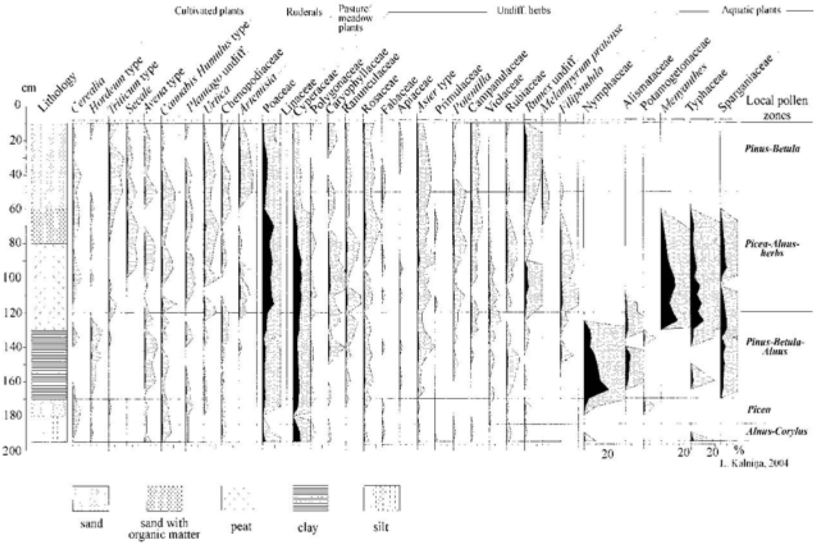


Figure 3. Herb pollen percentage diagram from the Renda depression.

Bilavas

The boat-shaped stone settings, the so-called Devil's Boats (*velna laivas*), comprise a group of Late Bronze Age burial monuments in the vicinity of Valdemārpils, Talsi District. Five such sites have been recorded, with a total of nine Devil's Boats. All of them were excavated already in the second half of the 19th century. At present only the boats at Birznieki and Bilavas remain to be seen. Since these are the only preserved boat-shaped stone burial monuments on the whole of the eastern shore of the Baltic, the idea was conceived of re-excavating and reconstructing the Bilavas boat. At present the chosen boat-shaped stone burial is located in the state forest. Two boats had been constructed here, arranged end to end. The south-eastern boat was chosen for excavation and reconstruction. 20 out of 38 stones along the sides of the boat were still present. Within the boat, the remains of the stone cobbling was found in a small area. Although undisturbed burials were not found, it was concluded that there had been at least 3–4 cremations of the Late Bronze Age in the boat, one possibly in a pottery urn.

Sediment samples from several places (between and under the stones) were taken during re-excavation and reconstruction of the "Bilavas Devil's Boat". The length of the sediment sequence analysed varied from 15 to 30 cm and provided similar information. Samples taken under the stones show a decrease in *Picea* and an increase in *Betula, Alnus* and *Pinus,* as well as in charcoal dust (Table 2). Samples between stones indicate *Betula, Alnus* and *Pinus* dominance, almost complete absence of broadleaved tree and a large amount of herb (25-30%), including ruderal and pasture/meadow plant pollen. Large numbers of Poaceae, Cypreaceae pollen and *Equisetum* spores leads us to suppose that the water level in the Roja River was much higher during the creation of "Bilavas Devil's Boat" than nowadays. It should be mentioned that Cerealia pollen has not been found in samples. Cultivated plants have been represented by two *Avena* type pollen, while such anthropogenic indicators as *Plantago major/media* and *Rumex acetosa/acetosella* type pollen has been found in almost all the samples. It might point to human activity during that time, but there are weak traces of some agriculture. The relation among tree-shrub pollen and herb pollen total, as well as the omposition of herb pollen indicate an open area.

Table 2. Character and comparison of pollen data of sediment sequences from the Bilavas site.

Name of sample	BVL-K	BVL-DA	BVL-A	BVL-B
Location of sample sequence	below stones	between stones	below stones	below stones
Local pollen zone	*Picea-Alnus*	*Betula-Alnus-Pinus*	*Alnus-Betula-Pinus*	*Alnus-Betula-Pinus*
prevailing tree pollen:	*Alnus*	*Alnus, Betula*	*Alnus, Pinus*	*Alnus, Pinus*
cultivated plant pollen	no any	*Avena* type	no any	*Avena* type
herb pollen	Poaceae, Asteraceae	large amount of Poaceae, Cyperaceae and undifferentiated herbs	herb pollen 30% Poaceae	Poaceae, Cyperaceae and undifferentiated herbs
ruderal plant pollen	*Artemisia, Urtica*	*Artemisia, Rumex*	*Artemisia, Urtica, Rumex*	*Artemisia, Urtica*
remarks	decrease of *Picea*, few grains in upper part, increase in *Alnus*	large number of *Equisetum*	large amount of *Alnus* and *Betula* represented by *B. pubescens* 48% and *B. pendula 52%*	*Picea* decrease, sharp increase in *Alnus,* some *Equisetum*

Eini settlement

During the history of the Lubans Lake, G. Eberhards distinguishes the following changes of the lake water level (Loze I., 1988): one transgression during Preboreal-Boreal (accumulation of the grey clay), two transgressions during Atlantic and Subboreal Time, and one transgression during Subatlantic Time. Long lasting regression phases have been distinguished

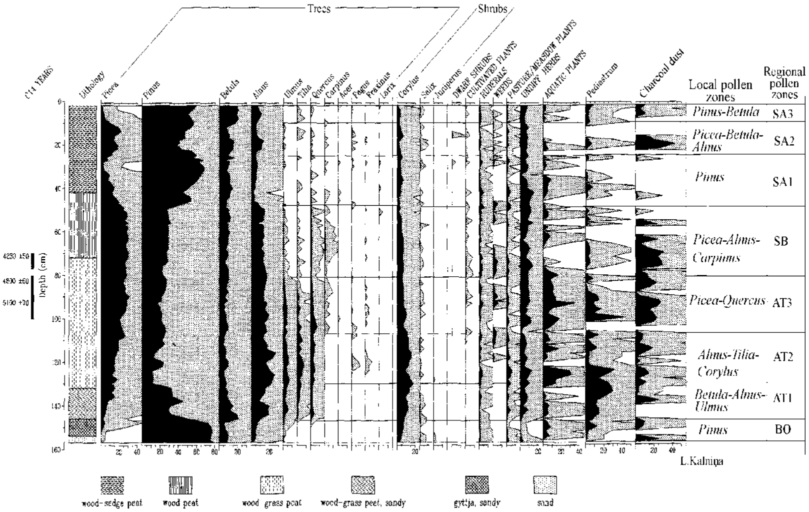


Figure 4. Pollen percentage diagram from Eini settlement

during the Atlantic Time, which can be correlated with Early and Middle Neolithic. The water table of the lake sharply decreased during the second part of the Subboreal Time, when overgrowing of the lake and development of bogs over a wide area took place.

The Eini settlement is located on the north-western shore of the Lubans Lake, approximately 0.5 km to the north of the overgrown Lake Eini. The cultural layer in the site reached a thickness of 0.6 m. One radiocarbon date has been obtained – 4000 BP (Loze, 1979) during excavation and three intervals were dated of palynologically studied sediment sequence (Fig. 4).

Palynological data, a set of geological and archaeological studies in the area demonstrates in detail the Holocene vegetation development and the increase in human impact. The studies of the sediments from both cores (Eini Lake and Eini site) provide comprehensive information on the vegetation history and environment development and identified a limited human impact (the presence of anthropogenic indicators- *Plantago lanceolata*, *Plantago major/media*, *Rumex acetosa/acetosella*, *Polygonum aviculare*, Brassicaceae) on the local environmental conditions during the Atlantic time (AT2) Neolithic (Lacis *et.al.,* 1998). The palynological indications suggest a fluctuating character of human activities. The first few *Cereales* are found in the Middle Atlantic, but the real start of the introduction of *Cereales* is likely to have happened at Subboreal (int. 0.9-0.6m Eini site section), Late Neolithic, when hunting and fishing dominated, but early farming had a secondary subsistence strategy. The human impact on the environment is traceable in both the investigated diagrams: a relatively short-term minimum of *Corylus* is accompanied by the decline of *Ulmus* and *Tilia* and the increase in the meadow and ruderal plant community graphs along with the appearance of *Cereales* (Fig. 5).

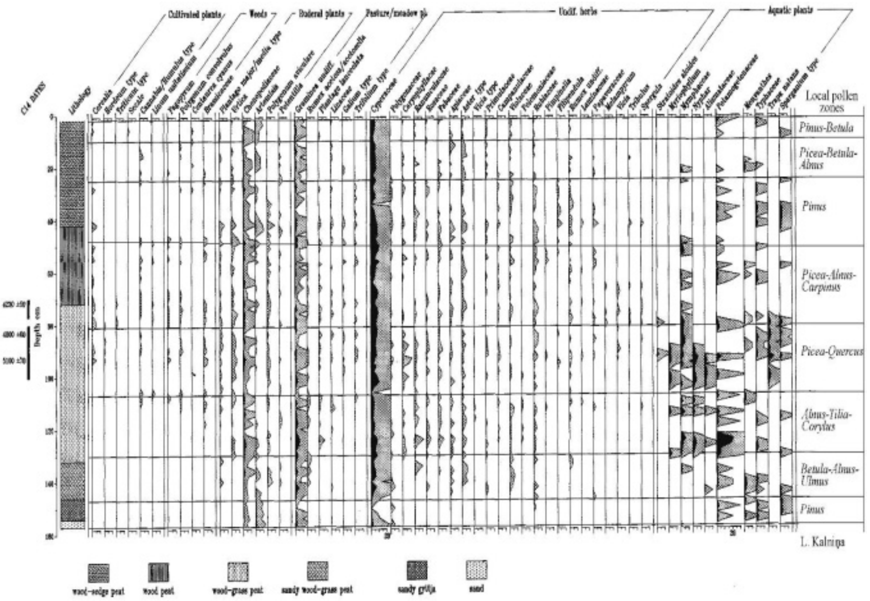


Figure 5. Herb pollen percentage diagram from Eini settlement, showing fluctuations in human activities and vegetation composition.

PLANT MACROREMAIN DATA

Zvidze

The Zvidze settlement was located on the western bank of the ancient Lake Lubana. The settlement occupies 0.3 to 0.5 ha and the area of 407 sq. m was excavated there. The settlement has a complicated geomorphological and limnoglacial structure – fourteen layers of different deposits were identified reaching a depth of 1.8 m. There are the Mesolithic layers below the Early Neolithic layers, and above them are layers of the Middle Neolithic (Loze I. 1993).

As shown by radiocarbon dates, Zvidze settlement was inhabited in the period between 7650 BP and 4370 BP(Loze I. 1988)

Among the finds of the Middle Neolithic there were tools for tillage – wooden, antler and stone mattocks, a wooden spade and digging sticks. Grindstones have also been found there, and, of particular importance, pollen of barley and hemp (Cannabis sativa). It should be noted that hemp pollen appears sporadically at the Zvidze site already in Early Neolithic layers (Loze I. 1997).

The appearance of animal husbandry already in the Middle Neolithic at Zvidze site is attested by palaeozoological material. Of the total number of animals (559), 49 individuals (8.9 %) were domestic animals. These 49 animals included 25 cattle, 18 pigs and 6 ovicaprids (Loze I. 1988).

There are determined remains of 49 plant species in sediments of the Zvidze settlement (4 of trees and shrubs species, 10 of ruderals, 15 of coastal plants, 20 aquatic plants), as well as shells of molluscs and ostracodes, fish bones, fragments of amber, flint and charcoals.

Palynological investigations (I. Jakubovska) and ^{14}C dating (A.Liiva) at the Zvidze settlement was done in 1982. A sediment layer containing Late Mesolith finds (depth 1,35 –1,55 m), was dated at 7650±180 (TA-1722), 7180+- 100 (TA-1723) and 7480 ±80 (TA-1745). Peat with gyttja interlayer in the depth 0.7 – 1.30 m corresponds to the Early Neolith dated to 6350±60 (TA-1746) – 5320±50 (TA-1800). The pollen composition of the overlying sediment layer dated to 4750+-60 (TA-1802) – 4430±50 (TA-1802) and is characterised by an increase of *Picea* and *Pinus* amount and corresponds to the Subboreal Time.

New data of the macroremains are compared with pollen and algae data (Loze, 1988; Jakubovska, 1998) at the same sediment sequence. The plant macroremain zones subdivided in the sediment sequence of the Zvidze settlement are described below.

I - Aquatic plant zones (depth int. 195 – 105 cm) mainly contains remains of aquatic plants and small amounts of coastal and meadow plants (Fig. 6).

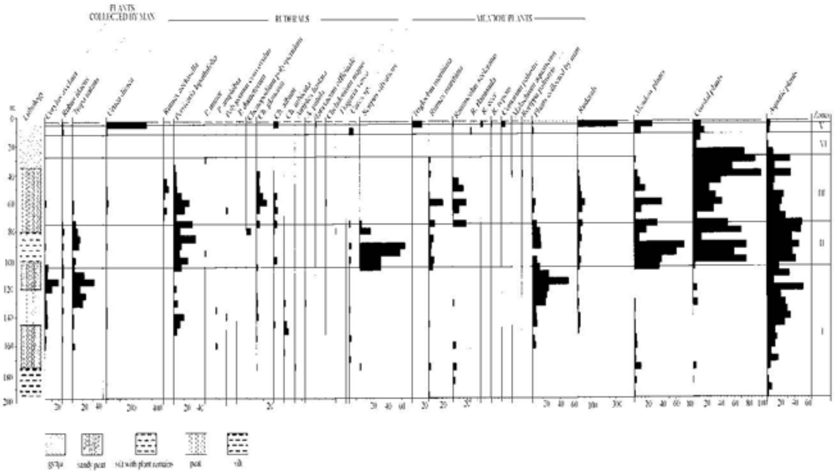


Figure 6. Coastal and aquatic plant macroremain diagram from Zvidze settlement (excavation profile B, 1982).

The diversity and increase in ruderal plant remains is marked at the depth interval 155 – 130 cm, which according to archaeological data corresponds to the Late Mesolithic Age. A large amount of charred *Trapa natans* nuts fragments has been found at the depth interval 130 – 105 cm, where the largest number of waternuts was found as well. This feature indicates the most favourable growing conditions for this plant in the surroundings.

II - Aquatic-Coastal-Meadow plant zone (depth interval int. 105 – 80 cm) contains large number of *Nymphaea*, *Calinia flexilis*, *C. minor, Salvinia natans*, as well as *Trapa natans*, but in smaller numbers. A sharp increase in coastal and meadow plant remains point to a lowering of the lake water level.

III - Coastal - Meadow – Aquatic zone (depth interval 35-70 cm) is marked by maximal distribution of the ruderal plants. In this zone there is a characteristic appearance of a new species, for instance, *Rumex acetosella,* an increase in *Chenopodium,* and a decrease in charred water chestnut fragments and hazelnuts. All the above facts provide indirect proof, that collection of wild plants lost importance in food and the development of agriculture started. The interval described corresponds to the Late Neolithic according to archaeological finds.

There is an increase in the number of shallow water (Batrachium sp.) and coastal plants remains, which suggests a transgression of the lake and a gradual increase of water level.

IV- Coastal -Aquatic plant zone (depth interval 30 – 10 cm), has a decrease in the total number of plant remains and almost only coastal and aquatic plant remains have been found (Fig.7). Probably, this interval corresponds to the Subatlantic transgression, when area was submerged.

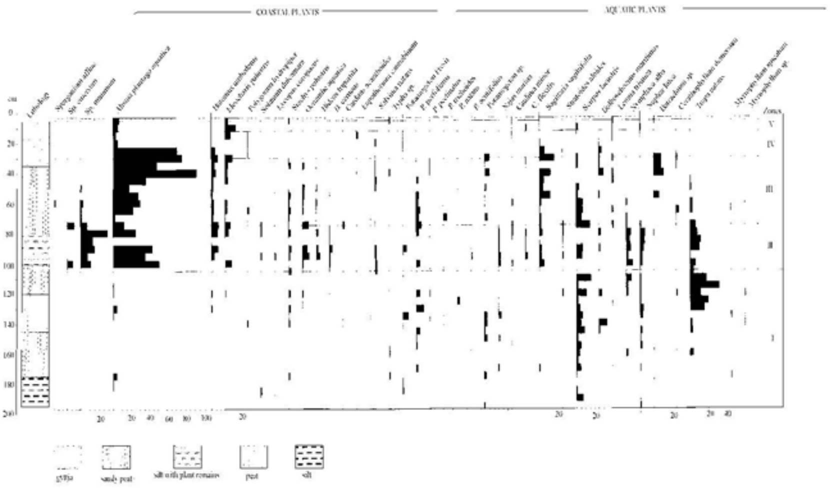


Figure 7. Coastal and aquatic plant macroremain diagram from Zvidze settlement (excavation profile B, 1982)

V - Ruderal - Meadow plant zone (depth interval 5 – 10 cm) corresponds to the Late Subatlantic Time. A large number of *Urtica dioica* seeds indicate nitrogen in the soil.

DISCUSSION

A large number of the settlements, especially those in areas near lake shores, show a rapid decrease in the habitation of the earlier settlements which were suitable for Neolithic hunting and fishing economy. Those areas characteristically depended on the areas at the river valleys and morainic uplands.

Pollen data reflect the traces of human influence on vegetation and development of crop growing in different regions since 3000 - 4000 BP, but later these records became weak at the end of the Subboreal and beginning of the Subatlantic Time. In general pollen diagrams from many sites lead us to suppose that the distribution of forests decreased and open areas increased, as well as some of them became boggy. Starting from that time the species variety increase in the pollen diagrams.

In many sites inhabited during the Neolithic anthropogenic indicators decrease or disappear. This period without anthropogenic indicators is named "transition" period (Vasks et.al.1998) and indicates the lack of stable and continuously inhabited sites.

The Lagaza settlement was dated to 3700-3300 BP by I Loze. The settlement was situated in the typical environment of the previous age. The basis of the economy was hunting and fishing. Among the animal bones only 1.3% belonged to domestic animals. Once again pollen analysis show the presence of *Cerealia*. It is important to note the finds of clay crucibles for bronze casting in Lagaza (Loze, 1979). Also, the newly inhabited ecological areas, which were suitable for the development of the crop-growing and stock-breeding economy, indicate burial fields (Raganukalns, Kalniesi, Rēznes, Kivutkalns) dated to the first half of the Bronze Age and stray finds of bronze articles (Altene, Saikava).

Settlements at the Early Metal Period were comparatively small, defined by a weak cultural layer and they could be defined as separate farmsteads. Modern agricultural practice, especially modern tillage, adversely influenced the preservation of such settlements.

At the archaeological monuments of the newly inhabited areas little evidence of crop-growing has been found. At the Daugmale hillfort two bronze sickles have been found (Urtans, 1969), and dated to the Late Bronze Age.

Slash and burn cultivation dominated at first in the layers dated to the Late Bronze Age. Hundreds of stone shaft hole axes which are the main slashing tools are found in the fields. There has been considerable finds of cereal grains, seeds of perennial weeds (*Stellaria, Rumex acetosella* etc.), ardmarks, ploughshares, and crop-growing tools in the settlements, which allow us to conclude that at the beginning of the 1st millenium BC slash and burn cultivation dominated, field crop-growing was practised, too (Graudonis, 1989). Therefore, in this connection we can speak about agriculture as a system, a complex of evidence including cleared and arable fields, fallow lands, grazing lands, meadows and other areas.

CONCLUSIONS

The results of pollen and plant macroremain analyses allow us to reconstruct the following environmental changes during the Early Metal Period:

1. Pollen data indicate a decrease of cultivated plant pollen from the sites studied. Pollen diagrams show that the initial phase of agricultural land use began by Early Neolithic man, but the traces of its activities are weak, and later disappear. The low position or even disappearance of pollen curves of cereals and weeds indicate interruptions in the crop-growing at the site studied or erosion of the sediment layer containing records of this time span.
2. *Hordeum*, known to be the oldest cereal in Latvia, has been cultivated for at least the last 4000 years. The pollen of *Hordeum*, as well as of *Avena* and *Triticum*, has been found in small, but larger numbers in the sediments accumulated during the early Iron Age.
3. The first *Secale* pollen has also been found at the very end of the Early Metal Period at the sites of western Latvia (Renda, Bilavas). Pollen of *Centaurea cyanus* occurs at almost exactly the same level as *Secale* pollen. The correspondence between the pollen curve of Poaceae and that of the cultivated *Cerealia* indicates that agricultural activity has the effect of increasing the values of Poaceae.
4. The presence of the pollen of anthropogenic indicators like *Plantago lanceolata*, *Rumex acetosa/acetosella, Polygonum aviculare*, Cruciferae etc increasing in level at the end of the Earlier Metal Age is the most reliable evidence of human activity, however pollen productivity, dispersal and deposition problems make the interpretation quite complicated. Due to the impacts of continuous human activity in the area the semi-natural meadows or secondary-type plant communities increased.
5. The distribution curve of charcoal particles shows some correlation between the number of charcoal particles and composition of the pollen spectra. The numbers of the herb pollen *Urtica*, Caryophyllaceous, *Trifolium* and *Rumex* increase in the interval above increased charcoal content.
6. Data of pollen and plant macroremain analysis used for the reconstruction of environmental changes show that the changes of the landscape structure were not very remarkable due to climatic reason during the Early Metal Period, but vegetation structure becomes mosaic due to human impact.

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Chapter 22

MID TO LATE HOLOCENE CLIMATE CHANGE AND ITS INFLUENCE ON CULTURAL DEVELOPMENT IN SOUTH CENTRAL SIBERIA

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ABSTRACT

The emergence and the cultural blooming of the Scythian cultures in the steppe of South Central Siberia occurred from the 9th century BC (ca. 2700 cal yr BP), much earlier than in the western part of Eurasia. To understand a possible climatic cause of this cultural phenomenon, we have studied sediment cores from the Kutuzhekovo Lake in the Minusinsk depression (Southern Siberia) and the White Lake in the Uyuk depression (Tuva, Central Asia). Both pollen records indicated an arid climate during the mid-Holocene up to ca. 4 kyr BP; increased moisture but still predominantly dry conditions at 4-3 kyr BP interval; a sudden change to more-humid-than-present climate in relatively cold conditions since ca. 3 kyr BP, and a return to drier/warmer climate after ca. 1.6 kyr BP. The reconstructed climate changes correlate well with cultural changes reported for both depressions. The scarcity of Mesolithic-Neolithic (10-5 ka) findings there is in good agreement with the mid-Holocene aridity, which did not provide favorable living conditions for the ancient tribes. By contrast, wet climate establishment since ca. 3 kyr BP corresponds to the Scythian cultures expansion to the Asian steppe which started in the 9th century BC. The data obtained suggest the close relationship between climatic and cultural changes within these arid areas. We conjecture that increased effective moisture balance changed initially arid areas into attractive steppe with a higher biomass production which may have launched the cultural development and blooming of the Scythian cultures.

Key words: pollen; arid; Siberia; steppe; Scythian cultures; effective humidity

E.M. Scott et al. (eds.), Impact of the Environment on Human Migration in Eurasia, 291-307.

INTRODUCTION

Little is known about the Holocene environments in the arid-semiarid intermountain depressions of South Central Siberia. This large area is subdivided by the high ridges of the Sayan mountain system to Southern Siberia (including Khakassia and south of Krasnoyarsk province) located to the north of Sayan, and Tuva, which lies south of Sayan and belongs to the Central Asia region (Fig. 1). Until now, only a few studies have provided us with paleoenvironmental information for both areas (Savina, 1986; Yamskikh, 1995), however, these results were supported by poor age control and appear to be quite discrepant. In contrast, the regional history of cultural development has been quite well investigated by archaeologists and supported by a large radiocarbon dating programme (Alekseev et al., 2001; Zaitseva, this volume). Nevertheless, some cultural phenomena seem to have no archaeological explanation. Indeed, according to recently available information, traces of the Mesolithic-Neolithic cultures (10-5 ka) appear to be almost absent in both areas. On the other hand, a sudden increase in human population density followed by cultural blooming has occurred there at the transition from the Bronze to Iron Ages, since the 9th century BC (ca. 2700 cal yr BP), when the most impressive Scythian cultures have emerged and begun to occupy the Asian steppe and forest-steppe. This date can be compared with the early Subatlantic shift to cool/wet climate dated in Europe to ca. 850 cal yr BC or 2750 ^{14}C yr BP (Speranza et al., 2002). To understand a possible relationship between climate change and the cultural development in Southern Siberia and Tuva, we focused on the reconstruction of the mid-late Holocene paleoenvironments for both areas.

STUDY AREA

The Minusinsk depression located in Southern Siberia and the Uyuk depression in Central Asia both are bounded by the high mountain ranges of the Sayan (Fig. 1). The regional climate is mainly controlled by Siberian air masses; moreover, these areas may also be influenced by the Westerlies and the Asian monsoon, which reach their limits here (Gavlina, 1954; Efimtsev, 1957).

The Kutuzhekovo Lake (53^0 36'N, 91^0 56'E, 320 m a.s.l.) is one of the few fresh-water lakes located at the southeastern part of the Minusinsk depression within the area of sand dunes. The existence of these lakes is supported by the patches of pine forest, which are common on the dunes. However, the forest around the Kutuzhekovo Lake is absent nowadays due to human activities and the lake is currently shrinking. Originally covered by steppe vegetation, the major part of the depression has been recently modified by agriculture and settlements. The forest-steppe ecotone extends up-slope from mountain base to 700-1000 m, where it is replaced by mountain coniferous forest. Mean annual temperature is estimated at 0^0 C with the seasonal temperature variations over 50^0 C. The bottom of the depression receives about 250-350 mm of annual precipitation, while the mean annual rainfall on windward slopes of Sayan high-mountains may reaches 1500 mm. The maximum rainfall occurs in summer (Gavlina, 1954).

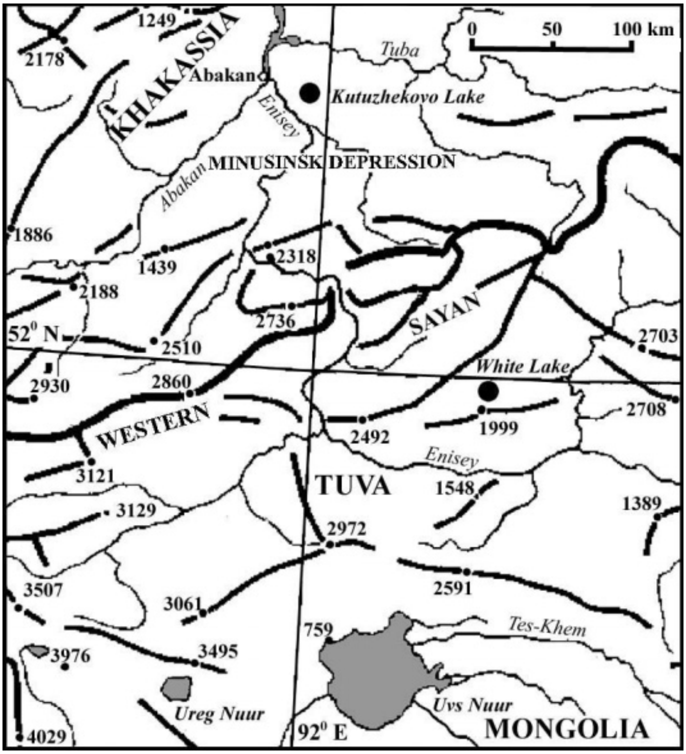

Figure 1. Regional orographic scheme and location of studied sites (bold circles). Bold lines - ridges with main peaks and their absolute heights. Shaded areas with Italic symbols - main lakes. Rivers are also indicated.

The White Lake (52^0 03'N, 93^0 43'E, 830 m) is situated approximately 210 km southeast of Kutuzhekovo Lake within the Uyuk depression in northern Tuva. This lake is one of a few brackish lakes, which originally formed a large ancient lake. Saline marshes and meadows occur around these lakes. The largest part of the depression is covered by bunchgrass and shrub steppe, which are strongly disturbed by agriculture and overstocking resulting in the digression process and even in secondary desertification. The forest-steppe extends from 1200 m being replaced up-slope by mountain coniferous forest. Narrow bands of deciduous forest spread along the rivers in the depression. Modern climate is extremely continental with the mean annual temperature of - 3^0 C. The annual amplitude of the temperature reaches over 60^0 C. The mean annual precipitation is 331 mm, concentrated between April and October (Efimtsev, 1957).

METHODS

We collected lacustrine sediment cores from the lakes using a Russian corer for soft gyttja and a Dakhnovsky corer for sand deposits at the basal part of cores. The subsamples from the longest cores KTH and WL-2 derived from Kutuzhekovo and White Lake respectively were used for pollen and geochemical analyses and radiocarbon dating. Geochemical results are presented in Kul'kova et al., this volume.

Pollen preparation was processed at the University of Amsterdam following a standard method. A tablet of *Lycopodium* was added per sample to calculate an absolute pollen concentration. An average of 507 and 384 pollen grains were counted in each sample of WL-2 and KTH cores respectively. The results are given as percentage diagrams of selected taxa (Fig. 2, 3). The percentages are based on a total pollen sum excluding local aquatic taxa and spores. WL-2 core samples having scarce pollen were omitted from the calculation. The pollen concentrations of selected taxa are also given in the diagrams.

The chronology of cores was established by conventional ^{14}C dating except for the lower sandy part of both sediment cores, which are too poor in organic material for radiocarbon dating.

RESULTS

The KTH and WL-2 pollen records have been subdivided into zones on the basis of pollen assemblages' similarity and variations of pollen concentration. In a recent paper we focus mainly on the most pronounced pollen fluctuations at the period corresponding to the transition from mid to late Holocene. This chronological frame is limited by poor dating of basal and uppermost parts of both cores.

The White Lake Pollen Record (WL-2)

Of 33 samples only 19 contained sufficient pollen for percentage calculation. The following zones of the diagram are recognized (Fig. 2):

Zone WL-I (105-60 cm)

From the base of the core, *Artemisia* pollen dominates absolutely and reaches the highest value of the whole record (around 70%), while Chenopodiaceae, Poaceae and *Ephedra* are present permanently as minor components. Tree pollen percentages are very low and stable. Pollen concentrations are extremely low except for the sample at the basal part of zone. All these features suggest low local and regional pollen

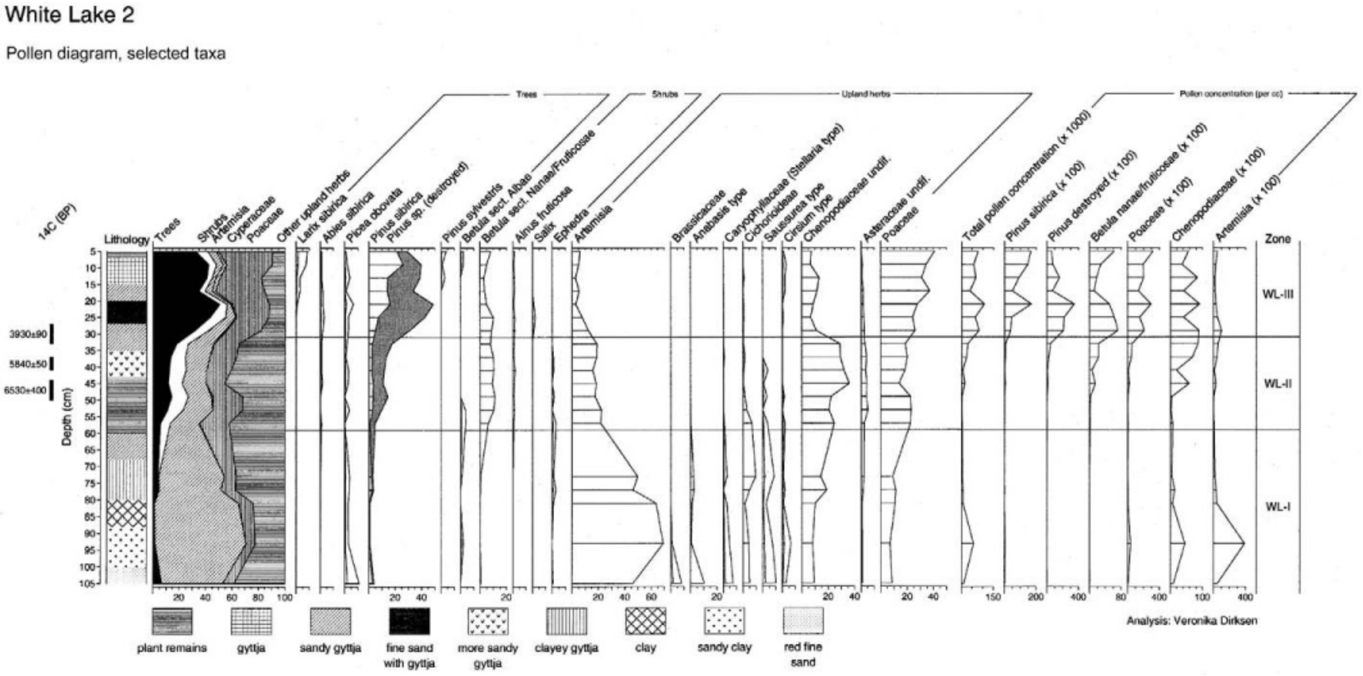

Figure 2. Pollen diagram of the White Lake (WL-2).

production, a persistence of stony steppe within the depression and scarce forest or even tree-less conditions in the mountains under relatively dry and cold climate.

Zone WL-II (60-32 cm; 6530 ± 400 yr BP in the middle of zone, 5840 ± 50 yr BP at the upper part of zone)

An increase of Chenopodiaceae frequency up to 37% and its dominance over *Artemisia* and Poaceae in the second half of zone indicate that desert and semi-desert persisted in the depression and/or halophytic vegetation established around the lake (Rhodes et al., 1996). In both cases, these changes suggest lower moisture availability, when the evaporation prevails over precipitation. Low pollen concentrations denoting poor biomass production at this period also indicate arid conditions. A gradual increase of pine pollen taken together with an appearance of shrub birch pollen suggests an establishment of forest and shrub belts in the mountains. All this evidence indicates dry and warm climate during the mid Holocene.

Zone WL-III (32-5 cm; 3930 ± 90 BP at the beginning of zone)

The most remarkable feature of this zone is a sudden rise of tree pollen values (up to 54%) together with a sharp increase of total pollen concentration. On the other hand, xerophitic taxa, *Artemisia* and Chenopodiaceae, show a distinct decline (up to 3% and 7% respectively) and *Ephedra* disappeared completely, while Poaceae pollen gradually increase towards the top of core reaching their highest value of 41%. Cyperaceae becomes more frequent signaling its establishment in the local wetland. Both grasses and sedges start to colonize the lake shores and replace halophytic wetland communities. This evidence reflects a significant vegetation shift from semi-desert to herbaceous steppe within the depression and a relatively rapid spreading of mountain forest. All these features indicate a strong wet signal due to the sudden onset of moisture conditions. On the other hand, the highest concentration of shrub birch pollen suggests relatively cold climate at the transition between dry and wet periods.

The Kutuzhekovo Lake Pollen Record (KTH)

The record derived from the less arid depression has higher temporal resolution in comparison with the above-mentioned core. However, the deposition rate was not constant and increased gradually towards the top of sediment core. 53 samples including a surface sample from the lacustrine mud were studied and the following zones in the pollen diagram were distinguished (Fig. 3):

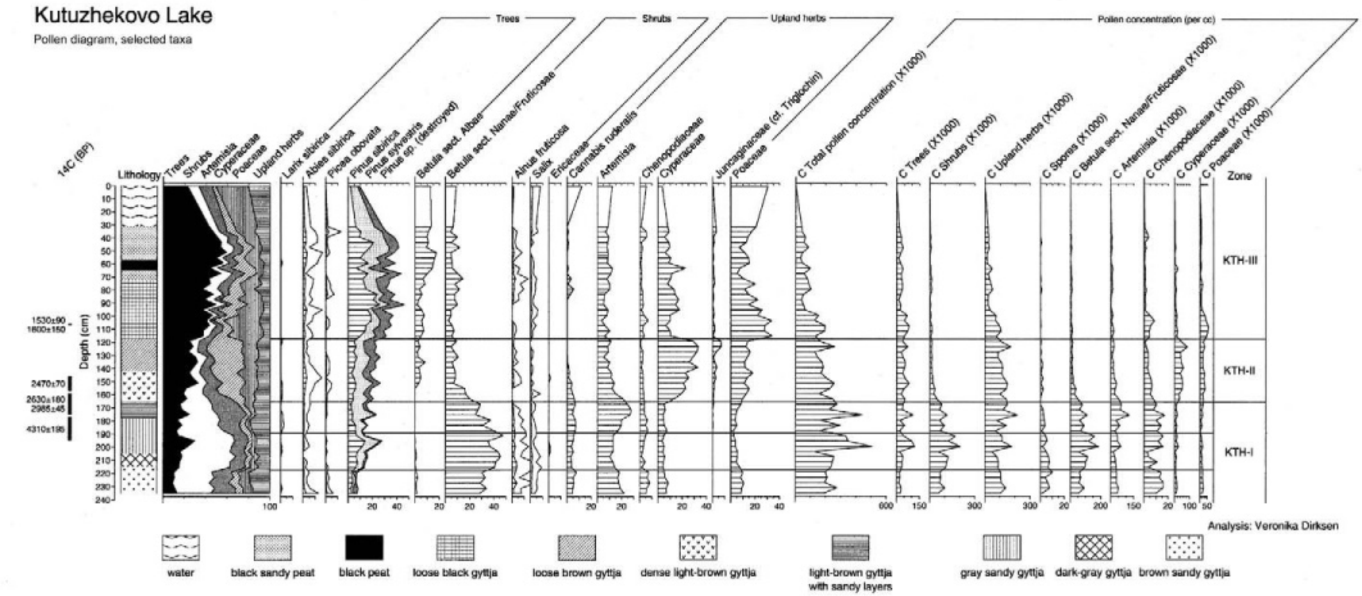

Figure 3. Pollen diagram of the Kutuzhekovo Lake (KTH).

Zone KTH-I (235-165 cm; 4310 ± 195 BP at the upper half of zone)

This zone is characterized by shrub pollen dominance and highest values of xerophitic taxa. In the middle of zone the *Betula sect. Nanae/Fruticosae* pollen reach their greatest percentages (up to 48%) and a sudden rise in pine pollen frequency occurs, while *Artemisia* and Chenopodiaceae show their peaks at the lower and upper parts of zone. The synchronous fluctuations of *Artemisia*, Chenopodiaceae and *Cannabis ruderalis* pollen curves are remarkable. These xerophytic components taken together prevail over the moist-demanding Cyperaceae and Poaceae indicating dry conditions during this time interval, when steppe and desert-steppe persisted at the depression (Dirksen, 2000). All these features suggest a generally arid period interrupted by a minor amelioration just before ca. 4,3 kyr BP. The upper dry interval was obviously less arid than the lower one because of the higher *Artemisia*/Chenopodiaceae ratio (Van Campo and Gasse, 1993). The extremely low values of tree pollen (up to 10%) recorded at the base of core also indicate the maximum aridity of the whole record, when mountain forest was strongly reduced.

Zone KTH-II (165-117 cm; 2985 ± 45 BP and 2630 ± 180 BP at the beginning of zone)

This zone begins with an abrupt pollen change. The most significant features of the zone are the sharp rise of Cyperaceae from 10% at the beginning of the interval up to 32% at the top and the distinct decrease in the frequency of xerophitic taxa. This evidence clearly reflects the rapid vegetation shift under the sudden increase in effective moisture at ca. 3 kyr BP. The shrub birch percentages decrease quite rapidly to 5-10% and tree birch (*Betula sect. Albae*) appears. The frequency of other arboreal pollen, among which *Pinus* taxa are the most abundant, also increases. Based on the differences in ecology of two pine species, we could explain the different behaviour of their pollen curves. *Pinus sylvestris* grows predominantly at the lower part of mountain forest, moreover this species is adapted to grow on sand dunes within the depression. *Pinus sibirica* is common for the highlands spreading up to the upper tree line. Since ca. 3 kyr BP *Pinus sylvestris* pollen frequency increases gradually that suggests a progressive forest shift down-slope as a response to increased moisture availability. On the other hand, the percentages of *Pinus sibirica* are very low and stable, which could be explained by the persistence of relatively cold conditions in highlands preventing the forest from spreading up-slope during ca. 3-2 kyr BP. Furthermore, based on the similar relationship between these two pine taxa observed in the upper part of KTH-I zone, we could suggest the establishment of cold climate much earlier, since ca. 4,3 kyr BP. Summarizing, we suggest that KTH-II period corresponds to maximum humidity occurred in generally cold conditions.

Zone KTH-III (117-30 cm; 1600 ± 150 BP and 1530 ± 90 BP at the lower part of zone)

An abrupt increase in the frequency of *Pinus sibirica* at the beginning of zone reflects the establishment of warmer climate in comparison with the KTH-II interval. The values of xerophitic taxa are rather stable, while Poacea shows a sharp rise from 13% to 33% and reaches the highest values of the whole record. The replacement of sedges dominance by grasses may reflect a drop in water level and a change in trophic conditions, which stimulate the expansion of *Phragmites* vegetation around the lake. However, it is difficult to confirm an exclusively local origin for grasses because some Poaceae pollen grains could also originate from surrounding steppe, rich in *Stipa*, *Festuca*, *Koeleria*, etc., genera. In both cases, we could also assume that the sudden change of Cyperaceae to Poaceae corresponds to the end of maximum humidity period.

DISCUSSION

Comparison of WL-2 and KTH Pollen Records

Pollen records from both lakes represent similar paleoclimatic stories, in spite of the differences in their location. The major pollen types and their climatic significance are similar in the two records originating from generally dry environments. However, the forest changes and the local signals are better represented in KTH pollen record derived from the Minusinsk depression, where the forest-steppe recently exists, while WL-2 diagram from the Uyuk depression, which has never been covered with forest during the Holocene, reflects mainly desert-steppe/steppe fluctuations. Nevertheless, the relationships between the main non-arboreal pollen taxa (Chenopodiaceae, *Artemisia*, Poaceae and Cyperaceae) appear to be the most significant in both records. Despite the fact that KTH record covers a relatively short time period, it has much higher temporal resolution than that of WL-2 record, providing additional paleoclimatic information. It should also be noted, that the fluctuations in temperature are obviously less pronounced and reliable to detect in pollen records from drylands, than those in precipitation because the arid environments are most sensitive to change in moisture availability. However, the temperature controls an effective moisture balance (precipitation minus evaporation), which is in response to a vegetation cover density and a biomass production in arid-semiarid zones (Chen, et al., 2003), so, any possible evaluations of temperature is undoubtedly important.

The period of long-term aridity from presumably the beginning of the Holocene to ca. 4 kyr BP is represented at WL-I and WL-II zones. The undated driest event observed at the base of KTH-I zone could be correlated with the mid-Holocene aridity recorded at WL-II phase. For both diagrams, these periods are characterized by low and stable frequency of arboreal pollen and the prevalence of xerophitic Chenopodiaceae and *Artemisia* over Poaceae and Cyperaceae. The low pollen concentration and the highest Chenopodiaceae value recorded at WL-II zone suggest a negative moisture balance probably due to enhanced evaporation over precipitation under warm climate.

The KTH record shows a minor amelioration upwards, which is not recognized in the WL diagram possibly due to either lower-resolution record or location differences. Nevertheless, the cold pulse, which appears to be registered at ca. 4,3 kyr BP in the upper part of KTH-I zone based on the different behaviour of two pine pollen taxa, could be supported by the highest concentration of shrub birch pollen at the WL-II/WL-III transition dated around 4 kyr BP.

The major change of xerophytic pollen dominance by moist-demanding taxa supported by a steep rise in arboreal pollen frequency is correlated well in both records. The sudden expansion of mountain forest soon after ca. 4 kyr BP represented at WL-III zone is in good agreement with rapid development of wetland sedge vegetation since ca. 3 kyr BP recorded at KTH-II. Both events undoubtedly reflect a strong humid impulse and an establishment of greater-than-today effective moisture balance. Moreover, the WL-III phase shows progressively increased pollen content (in this case we do not take into account the KTH record because of unstable sedimentation rates) denoting conditions optimal to denser vegetation cover. Based on data obtained it is difficult to estimate whether these wet phases began synchronously in both studied areas. Nevertheless, for KTH and WL-2 records, the humid pulse is represented as a sharp climate shift followed by relatively rapid and significant vegetation changes. In addition, on the basis of the above-mentioned indirect pollen evidences we suggest that it seems to be cold in both areas during the period of humidity maximum.

The upper parts of each record, KTH-III zone dated at 1,6 kyr BP and the undated uppermost part of WL-III zone, show the establishment of drier and warmer climate close to the modern conditions at both sites. The progressive rise of Poaceae pollen frequency recorded in two diagrams suggests an expansion of reedy vegetation around the lakes that could be related to decreasing water level at both lakes.

Comparison with Regional Proxy Records

The study of KTH and WL-2 pollen records suggest a persistence of arid conditions during the mid-Holocene up to 4 ka, increased humidity but still generally dry climate between 4 and 3 ka, the sudden onset of more-humid-than-present climate under presumably cold conditions since 3 ka, and the return to drier and warmer conditions after about 1,6 ka. In order to clarify whether these pollen records reflect local signals or regional paleoenvironmental changes, we compare our results with other climate proxies derived from the neighbouring Asian regions (Fig. 4).

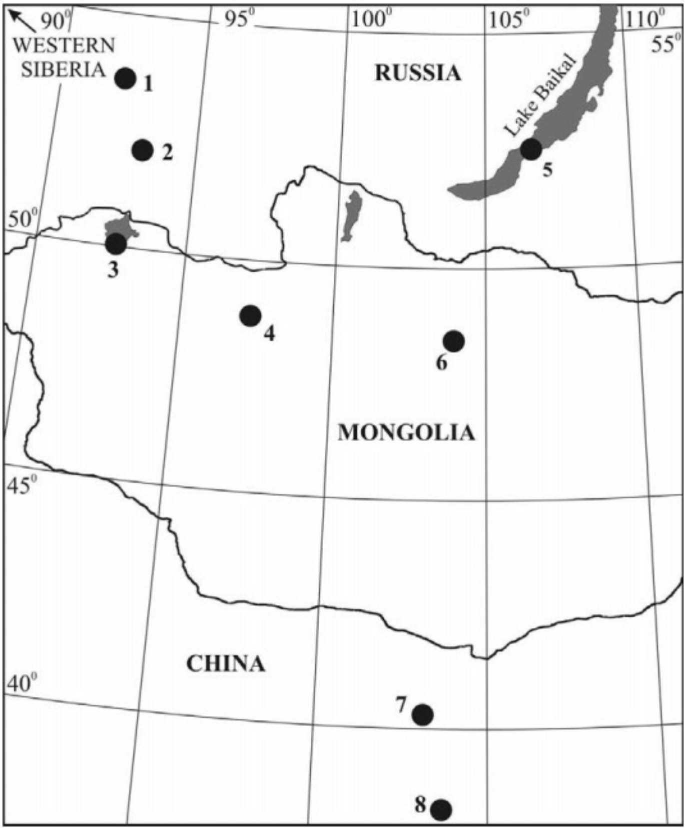

Figure 4. Spatial distribution of proxy records mentioned in the text according to different authors: 1,2 – this paper sites, 3 – Grunert et al., 2000; 4 – Peck et al., 2002; 5 – Karabanov et al., 2000; 6 – Feng, 2001; 7 – Chen et al., 2003; 8 – Xiaoqiang et al., 2003; regional pollen synthesis for Western Siberia – Khotinsky, 1984,1989. Main lakes are indicated as shaded areas.

Based on pollen, organic carbon content and $\delta^{13}C$ data from a peat section at the Midiwan in Northern China, Xiaoqiang et al. (2003) found a long-term dryness from 7,5 kyr BP to the present, which was interrupted by the cool humid interval between 4,5 and 3,0 kyr BP. The paleoclimatic record of the sediment core from Lake Yanhaizi in Inner Mongolia reported relatively arid (dry and warm) climate between 8,0 and 4,3 kyr BP, and two humid phases, 6,4-5,8 and 4,3-3,2 kyr BP, among which the second one was the wettest (Chen et al., 2003). The soil/loess sequences from Northern Mongolia also recorded a dry and possible warm period from ca. 8,3 to 4 kyr BP, which has been followed by wetter conditions since 4070 yr BP (Feng, 2001). The sedimentologic and geomorphic data obtained from Lake Telmen in North Central Mongolia (Peck et al., 2002), approximately 400 km southeast of White Lake, indicated hyperarid conditions between 7110 and 6260 cal yr BP, which have been followed by a less arid interval from 6260 to 4390 cal yr BP, when the lake level began to rise. Since 4390 yr ago generally humid conditions prevailed and the highest water level of Lake Telmen occurred between 2710 and 1260 cal yr BP. These results correlate well with those inferred from Lake Uvs Nuur in Northwestern Mongolia (Grunert et al., 2000), about 175 km south of White Lake. The period of long-term aridity from 10 to 5 ka has been indicated by the lake level dropping by about 45 m. Since 2,8 kyr BP the water level of Lake Uvs Nuur started to rise in response to enhanced effective moisture balance. The Kutuzhekovo and White Lake records are in a rather good agreement with these results.

Summarizing, we can conclude that the mid-Holocene was dry and warm in arid-semiarid zones of the Central Asia. However, this is opposite to the widely perceived humid and warm mid-Holocene optimum reported in Europe, China (Van Campo et al., 1996; An et al., 2000) and even in closer regions, such as Baikal and Western Siberia (Fig. 4). Thus, the climate proxies obtained from last two regions indicate that the humidity maximum and the thermal maximum for the Holocene occurred rather synchronously between ca.8,0 and 4,6 kyr BP (Khotinsky, 1987, 1989; Mats, 1993; Horiuchi et al., 2000).

Further, the evidences of increased effective moisture and the maximum humidity phenomena in arid-semiarid areas of Asia occurred since ca. 4,5-4 up to 2-1,3 ka. As reported in a regional synthesis (Lehmkuhl and Haselein, 2000), this period correlates well with the 4-3 ka cold pulse attributed to Neoglacial and can be compared with the 3-2 ka interval of high lake stands in Central Asia. It is in complete agreement with our data, which suggests a sharp climate shift to wetter-than-today conditions since 3 ka during the cold phase started earlier, at 4,3 ka. On the other hand, these contradict the data from Baikal and Western Siberia. Indeed, the diatoms and chrysophyte cysts record obtained from Lake Baikal (Karabanov et al., 2000) shown warm/humid maximum during the Subboreal period (2,5-4,5 ka), while the same time interval, according to the paleoenvironmental synthesis of pollen data from Western Siberia (Khotinsky, 1987, 1989), was reported to have been generally dry and cold.

These discrepancies may signal two contrasting climate scenarios in the arid-semiarid zones of Central Asia (and neighboring Southern Siberia) and the temperate zone of Eurasia. The mid-Holocene was the arid period in Central Asia possibly due to the greatly enhanced evaporation, which prevailed over increased precipitation that reduced the effective moisture balance (Chen et al., 2003). In contrast, during the late Holocene cold period (4-2 ka), when evaporation decreased as temperature dropped, increased effective humidity might have been expressed as a sharp climate shift.

MAIN ENVIRONMENTAL CHANGES AND CULTURAL DEVELOPMENT

According to archaeological data, the Mesolithic and Neolithic cultures, which were represented over Eurasia, have not been found in the intermountain steppe depressions of Southern Siberia and Tuva (Zaitseva, this volume). During the long-term period between ca.10 and 5 kyr BP these areas have been almost uninhabited with the exception of some sites located within the recently forested mountains. The Mesolithic-Neolithic period corresponds to the mid-Holocene aridity, when stony steppe and desert-steppe persisted in depressions and mountain forest was strongly reduced. A scarce vegetation cover and unfavorable climate did not provide attractive living conditions and prevented the ancient tribes from spreading there. This assumption could explain the scarcity of Mesolithic-Neolithic finds in the studied areas.

Since the beginning of the Bronze Age the occupation history of both areas became dissimilar. Indeed, there was no gap to be found in the cultural development from early to late Bronze Age (ca. 5-3 kyr BP) in the Minusinsk depression, where *Afanasievo*, *Okunevo*, *Andronovo* and *Karasuk* cultures have followed each other, while the Bronze Age archaeological evidence from Tuva is practically absent. Only a few traces of the middle Bronze Age *Okunevo* and of the late Bronze Age *Karasuk* cultures were recorded in Tuva, whereas during the same time the Minusinsk depression was quite well inhabited. We could suppose that the climate change at the beginning of Neoglacial (4-3 ka) may have launched the Bronze Age cultures expansion with large differences in the occupation of both areas. In response to the cold climate shift, the effective humidity has increased earlier in the northerly-located Minusinsk depression, than in arid Tuva, where a temperature drop may have resulted firstly in greater seasonal contrast and enhanced climate continentality.

The most intensive occupation of both areas occurred at the transition from the late Bronze to the early Iron Ages (ca. 3-2,7 kyr BP), when the *Scythian* cultures appeared (*Tagar* culture in the Minusinsk depression and *Aldy-Bel* culture in the Uyuk depression). Since the 9th century BC the human population density increased sharply and the Scythian nomads expansion to the Asian steppe zone occurred. We suggest that the reason for this cultural phenomenon was the strong late Holocene humid pulse, which changed initially arid depressions into an attractive living area for the stockbreeding nomads. This 3-2 ka period of more-humid-than-today climate can be regarded as optimal for steppe vegetation growth that provided the much higher biomass production and, consequently, triggered the increase in human population density and the blooming of impressive Scythian cultures.

CONCLUSION

The pollen data of two sediment cores collected from the Kutuzhekovo Lake in the Minusinsk depression (Southern Siberia) and the White Lake in the Uyuk depression (Tuva) both indicate a strong humid pulse, which occurred in the late Holocene (since ca. 3 kyr BP) after a long-term aridity during the mid-Holocene. This is contrary to the findings noted in the temperate zone of neighboring regions, such as Baikal and Western Siberia, but is consistent with proxy records reported for the arid-semiarid zones of Central Asia. Moreover, the paleoclimatic changes are in good agreement with cultural changes recorded for both depressions. Almost no evidences of the Mesolithic-Neolithic cultures (10-5 ka) have been reported for these areas which could be explained by generally arid conditions persisting there during the mid-Holocene. The sudden onset of more-humid-than-present climate correlates well with the beginning of the Scythian cultures expansion to Asian steppe and forest-steppe in the 9th century BC. Increased effective humidity balance in initially arid areas has provided a higher biomass production of steppe vegetation and more favorable living conditions for the stockbreeding nomads and thus, triggered the blooming of the Scythian cultures.

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Chapter 23

ARCHAEOLOGICAL CULTURES ON THE BACKGROUND OF CLIMATIC CHANGES IN THE HOLOCENE, POLAND

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ABSTRACT

Frequency distributions of calibrated radiocarbon dates for some of the archaeological sites from the Holocene are compared with climatic records shown in frequency distributions of ^{14}C data sets from speleothems, tufas and peat, laminae thickness, temperature and lake water changes for Poland, Central Europe. All archaeological and environmental events presented using the calendar time scale [BC/AD] are based on ^{14}C dating performed in the Gliwice Radiocarbon Laboratory and come from "RoSE" database.

Keywords: ^{14}C dating, statistical analysis, chronostratigraphy, Mesolithic, Neolithic cultures, Poland

INTRODUCTION

Some number of dates (^{14}C, U/Th, etc.) for individual archaeological sites and for palaeoclimatic events are presented using the Cumulative Probability Density Function (CPDF). A CPDF is constructed by summing up the probability distributions of individual ^{14}C calibrated dates (Geyh and Streif 1970, Geyh 1980, Michczyńska and Pazdur 2003). The presentation of a CPDF on calendar time scale gives information about time periods with relatively high and low density probability value and also indicates high or low intensity of settlement and environmental processes. Comparison of archaeological evidence and statistical analysis of ^{14}C calibrated data sets for individual archaeological sites (Pazdur et al. 1998) gives information about the time period of the settlements or indicates a rebuilding time or dates the construction (Michczyński et al. 2003) and can be correlated with the duration of separate archaeological cultures. Construction of a CPDF for the same archaeological material from different sites in a geographical

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region my be interesting to find time periods when the same tools are being used (Pazdur et al. 2001).

A CPDF can be constructed for environmental data sets using ^{14}C dates on speleothems (Geyh 1970, Pazdur et al. 1995a), tufas (Pazdur 1987), peat (Michczyńska and Pazdur 2003) or other sediments with well defined sedimentary conditions (Pazdur and Pazdur 1986, Go dzik and Pazdur 1987). The methodology and limitations of the statistical analysis in relation to the number of dates and their uncertainties was presented in Geyh (1970), Hercman (2000) and Michczyńska and Pazdur (2003). High and low CPDF values in different periods reflect on climatic conditions mainly temperature and humidity.
Comparison of settlement periods, duration and phases of archaeological cultures and palaeoenvironmental evidence can be used for determination of climatic impact on development and migration of human society. The Probability Density Distribution Functions (CPDF) of calibrated radiocarbon dates for some archaeological sites from the Holocene period are compared with climatic records shown in the frequency distributions of ^{14}C data from speleothems, tufas, peat and laminae thickness, temperature and lake water changes for Poland, Central Europe. The locality of the sites is shown in the Fig. 1.

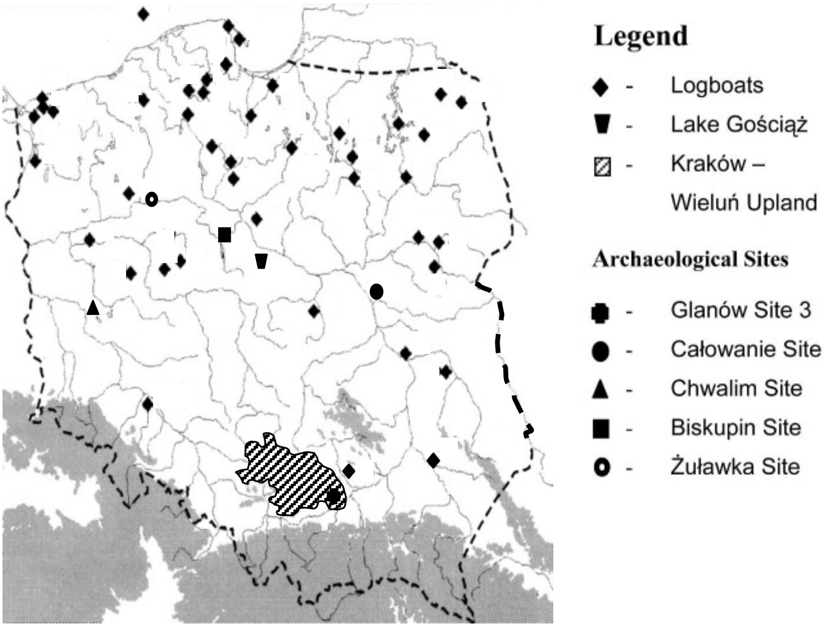

Figure 1. Map of Poland

All archaeological and environmental events are presented using the calendar time scale [BC/AD]. All ^{14}C dates were made in Gliwice Radiocarbon Laboratory and come from the "RoSE" data base (Piotrowska et al. 2004). Calibration of conventional ^{14}C ages was done using the OXCAL (Ramsey 1995) and GdCALIB (Pazdur and Michczyńska 1989) programmes.

PALAEOENVIRONMENTAL DATA SETS FOR CPDF ANALYSIS

Analysis of ^{14}C dates for different sediments may show some systematic errors connected with the nature of the material, especially for carbonate sediments (speleothems and tufas). Before transforming the ^{14}C conventional ages to CPDF calendar ages, ^{14}C dates should be corrected for reservoir effects. These errors are different for different kind of sediments and sites because the carbon in dated samples can come from different sources (Pazdur 1987). On the basis of the CPDF shapes (Fig. 2) the correlation of climatic conditions for some time periods with independent chronostratigraphic divisions can be made (Table 1).

Table 1. Chronostratigraphy division of the Holocene with borders given in conventional ^{14}C (Starkel 1999) and calendar years and climatic conditions according to time records of different climatic evidence (see Fig. 2).

Period		**^{14}C age, BP**	**Calibration calendar intervals, AD/BC**	**Warmth**	**Humidity**
Bölling			13,300 – 12,100 BC	warm	humid
Older Dryas	OD		12,100 - 11,800 BC	Cold	dry
Alleröd	AL.	11,800 – 10,900	11,800 – 10,700 BC	warm	humid
Younger Dryas	YD	10,900 – 10,250	10,700 – 9550 BC	Cold	dry
Pre-Boreal	PB	10,250 – 9300	9550 – 8350 BC	Cold	dry
Boreal	BO	9300 – 8400	8350 – 7500 BC	warm	dry
Atlantic	AT1 AT2 AT3 AT4	8400 – 7700 7700 – 6600 6600 – 6000 6000 – 5000	7500 – 6480 BC 6480 – 5550 BC 5550 – 4900 BC 4900 – 3800 BC	Cold warm warm Cold	dry humid humid humid
Sub-Boreal	SB1 SB2	5000 – 4200 4200 – 2800	3800 – 2850 BC 2850 – 950 BC	warm warm	dry humid
Sub-Atlantic	SA1 SA2 SA3	2800 – 2000 2000 – 500 500 –	950 BC – 150 AD 150 AD – 1430 AD 1430 AD –	warm warm Cold	humid dry dry

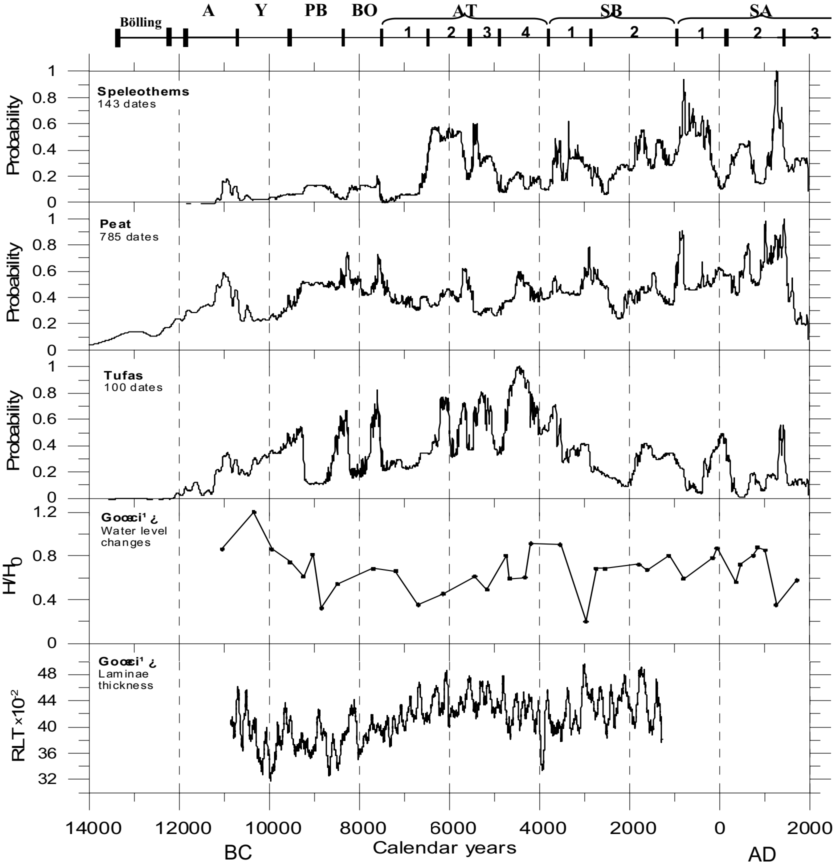

Figure 2. Evidences of the climatic changes fixed in the different deposits

Peat

Peat have very well defined carbon sources (plants) and their ^{14}C age is free from systematic error. For statistical analysis, 785 dates of peat from Poland were selected (Michczyńska and Pazdur 2003). The dates encompassed the Holocene and Late Glacial period. The analysis was based on the following assumptions: the amount of organic matter in sediments depends on palaeogeographical conditions and the number of ^{14}C dated samples is proportional to the amount of organic matter deposited in sediments in the considered time intervals. ^{14}C dates from peat do not need any correction for a reservoir effect. A high value of a CPDF in some time periods indicate climatic conditions with relatively high values of precipitation and temperature.

Speleothems

On the basis of the CPDF of 143 calibrated ^{14}C dates for speleothems from Cracow – Wieluń Upland caves, warm or cold and dry or wet climatic periods can be indicated in the Late Glacial and Holocene. To transform conventional radiocarbon dates to the calibrated data set, all conventional dates for carbonates (T_C) were corrected for the reservoir age (T_R) to give the "true" value for conventional age (T_{CONV}), (Holmgren et al. 1994, Pazdur et al. 1995a and 1999)

$$T_{CONV} = T_C - T_R$$

using a constant T_R = 1650 years value (Hercman 2000).

Calcareous tufa

The observed T_R values for these sediments range from several hundreds to several thousands years and greater (Pazdur 1988, Pazdur et al. 2002a, b). The magnitude of the reservoir age can be determined experimentally by measuring the age of organic matter T_{ORG} dispersed in carbonate with age $T_{C'}$. In this case for pure carbonate levels in the tufa profile.

$$T_{CONV} = T_C - T_R$$
$$T_R = T_{C'} - T_{ORG}$$
$$T_R - changing$$

A CPDF for 100 calcareous tufa samples from South and South – East Polish sites was calculated. Sedimentary conditions are determined by precipitation and temperature.

PALAEOCLIMATIC EVIDENCE IN LAKE SEDIMENTS

Relative laminae thickness of annualy laminated lake sediments

The most accurate chronostratigraphy of lake sediment may be obtained on profiles of laminated sediments with annual lamination as for Lake Gościąż (Goslar et al. 1998a, b). Sediments of Lake Gościąż, containing ca. 12,500 couplets is the longest known sequence, covering a significant part of the Late Glacial and whole Holocene, and offers therefore the unique opportunity for palaeoclimatic and palaeoecologic reconstruction (Pazdur et al. 1995b). The ordered varve numbers N determine the calendar time scale for sedimentary processes. The relative Laminae Thickness (RTL, Fig. 2) is correlated with sedimentary temperature.

$$RLT = \frac{white}{black + white}$$

where “white” and “black” mean thickness of white and black laminae respectively.

Lake Gościąż water level changes

In the case of lake sediments with a calendar time scale N = Cal [AD/BC], the reservoir age T_R of the carbonate fraction can be determined by the difference between T_C and varve number N and a respective dilution factor q_L for ^{14}C. The q_L value determines the content of radiocarbon in lake water at the moment of sedimentation and from the total carbon and ^{14}C mass balance model in steady state (Broecker and Walton 1959), the relative ratio of the lake volume to its surface H/H_0 may be estimated at the moment of sedimentation. H_0 is the ratio of lake volume to its surface in the present (Pazdur et al. 1995b). Changes of relative mean water depth of lake H/H_0 describe the precipitation record in time period of interest.

CLIMATE AND CHRONOSTRATIGRAPHY DIVISION OF THE HOLOCENE

A comparison of chronostratigraphic division of the Late Glacial and Holocene for the Polish area according to Starkel (1999) and climatic condition records is presented in Fig. 2 and Table 1. The borders of stratigraphic units in calendar AD/BC years were determined using OxCal for calibration of ^{14}C, conventional ages have been used by Starkel (1999) for determination of the borders of chronostratigraphy units. The values for the border sequences were taken as the median of the calendar years range with the highest probability value, atn the 68 % confidence level.

Detailed analysis of CPDFs for different sediment and climatic records for Lake Gosciąż allow us to find strong correlation between borders of chronostratigraphic units and rapid changes in CPDFs and lake records. It is worth adding that the Starkel chronostratigraphic division was done mainly on the basis of palynological records for lakes, mires and peat sites from the Polish area.

ARCHAEOLOGICAL SITES AND CULTURES

Archaeological data sets for CPDF analysis

Organic samples from archaeological sites (wood, charcoal, peat) were dated by radiocarbon using gas proportional counting (Pazdur and Pazdur 1986, Pazdur et al. 2003). The laboratory standard errors are in the range of 30 to 100 or even more years and depend on sample ages and carbon amount used for dating. Some wooden construction samples from Biskupin and uławka Mała sites (Pazdur et al. 1998) and logboats (Pazdur et al. 2001) were also dendrochronologically dated, but these results are not presented in this paper.

Cumulative probability density functions of the calibrated ^{14}C dates with connection to archaeological evidence can be divided into phases corresponding to different cultures (Fig. 3 and 4)

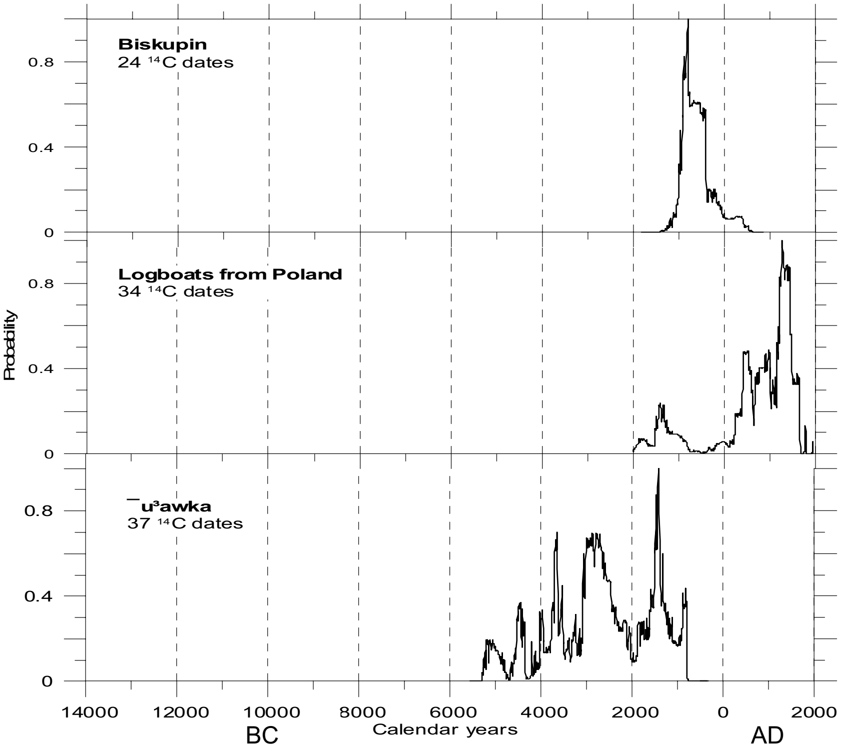

Figure 3. Density function of ^{14}C dates for the archaeological sites of the Neolithic and Bronze Age: Biskupin, Longboats and Żuławka

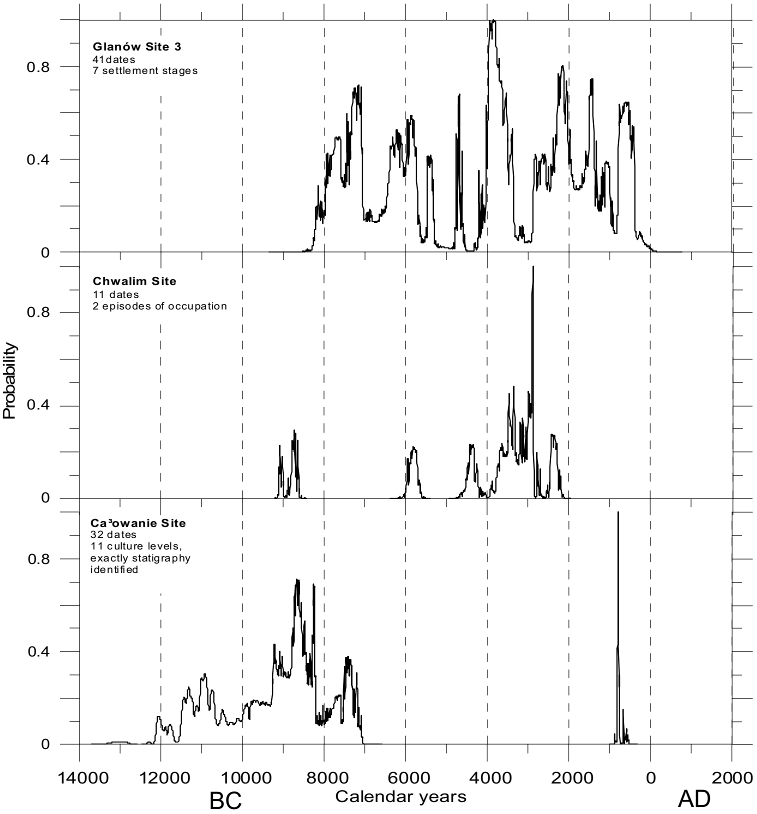

Figure 4. . Density function of ^{14}C dates for the archaeological sites of the Mesolithic: Glanow-3, Chwalim, Całowanie

Mesolithic sites

The Mesolithic Sites in Poland are mainly concentrated in the southern part of country (Fig. 1) although the most important are in Glanów, Całowanie and Chwalim (Zając, 2001). The dating of materials (mostly charcoals, woods and peats) may allow us to explain the human activity in these regions (Pazdur *et al.* 2003, Fig. 3).

Całowanie. The correlations between ages of dated materials with the period of archaeological cultures are relatively simple because of very distinct geological stratigraphy at the site. In addition archaeological levels have been recognized within which many elements of flint tools and others materials (e.g. wood) are located. 32 radiocarbon dates were obtained and their correlations with archaeological levels was described by (Schild *et al.* 1999).

Glanów 3. Site located on Cracow – Wieluń Upland, near Cracow. Currently 42 radiocarbon dates have been obtained (Pazdur et al. 2003). Here, mainly charcoal samples were investigated but also archaeological forms (e.g. flints tools, pottery) corresponding to Lendzielska's, Mierzanowicka's Culture and Roman Period. Charcoals were dated to the Early and Late Mesolith, however some dates fall outwith the above mentioned archaeological cultures. Additionally in Glanow 3 the dates can be divided into aggregations, which are recognized according to the flint pattern (Zając 2001). However, such a division is valid only for dates over 8000 BP, which corresponds well to the Polish Mesolith.

Chwalim. This site is situated on Gnila Obra river with partial geological stratigraphy (Kobusiewicz and Kabaciński 1993). 11 samples were taken for analysis from a peat bog. Many flint monuments, burnt stones and pottery were found without stratigraphy. On the other hand, where there was distinct stratigraphy several flints and deer, elk and bison bones occurred. Most of these excavations fall on the Early Mesolith and Komornicka Culture.

Neolithic and Bronze Age periods

Complex interdisciplinary analyses of material collected in systematic excavations on Site 1 in Żuławka Mała and Biskupin, Central Poland, allow us to distinguish several phases of occupation from the Neolithic and Bronze periods (Pazdur *et al.* 1998, Fig. 4).

Biskupin. The fortified settlement with wooden buildings on the peninsula of Lake Biskupin, at present it is the best explored site in the system of 18 fortified settlements of the Lusatian Culture (Bronze Age) in the Great Poland Lowland (Miklaszewska-Balcer 1991a,b). Precise dating of the site is of crucial importance for studies related to the Late Bronze Age and Early Iron Age. The most frequently accepted opinion is that which locates the Biskupin settlement in the Halstatt C/D period. The results of conventional radiocarbon dating of series of wood and charcoal samples (25 dates) collected from archaeological trenches show some scatter and locate the Biskupin settlement between 850 and 400 cal BC (Pazdur et al. 1998). Dendrochronological studies gave the date of 747 BC for the building of the older settlement (Ważny 1993). Late autumn or winter 738/737 BC was when most of the trees were cut down

This date is supported by results from wiggle matching, which was applied to a series of ^{14}C dates of an oak chronology spanning ca 160 years, leading to the estimate of 730 ± 30 cal BC.

The opinion of different archaeologists concerning the age of the settlement is also highly diverse. One opinion is based on analysis of certain features of the pottery from Site 4, and some authors claim this date is confirmed by the alleged Scythian invasion, which led to devastation of the settlement. However, the origin of a fragment of horse harness, the only artefact discovered at Biskupin which could be attributed to the Scythians, is highly problematic (Miklaszewska-Balcer 1991a,b).

Site 1 in □uławka Mała. The materials, which were identified in the course of excavations enabled eight occupation phases for Neolithic and Bronze Periods (Krąpiec et al. 1996) to be distinguished. Several tens of samples of wood and charcoal have been analysed with radiocarbon and dendrochronology. The limits of particular occupation phases (5130-1410 BC, 4530-4420 BC, 3890-3570 BC, 2950-2570 BC, 2190-2040 BC, 1560-1410 BC, 1200-1410 BC) have been established from the cumulative probability distributions of calendar ages of 37 radiocarbon dates (Pazdur et al. 1998). Dendrochronological analysis of 70 samples of oak wood from an uncovered construction resulted in the establishment of 4 floating chronologies. The analysis showed that most of examined samples are of the same age (ca 3100 BC) and there is reasonably good agreement between archaeological, radiocarbon and dendrochronological analysis.

Logboats

Logboats are a relatively recent source of archaeological knowledge in Poland (Ossowski 2000). It was only when natural methods of absolute dating became widespread that it became possible to establish the age of these boats and to examine their cultural and historical connections. Until the present day, following a query conducted in Polish museums, it was possible to determine the number of logboats in Polish museums to be about 200, 30 of which are ethnographic artefacts, the builder of which is known. In addition, we have numerous archival data on accidental discoveries of such craft. At the present time we can estimate that the number of Polish logboats is over 300. 132 logboats have been subjected to ^{14}C dating and dendrochronological studies so far. Most of the logboats on display in museums stem from the late Middle Ages and modern times. So although quite a large number of such boats from various regions of Poland have been accumulated in the country's museums, not a lot can be said about the utilisation of logboats in times earlier than the late Roman period. The results of ^{14}C dating (51 dates) were the subject of discussion and probabilistic interpretation of the calendar age of the dated boats (Pazdur *et al.* 2001).

Most of the analysed logboats were made of oak (*Quercus robur/petraea*). Tree-ring analyses were carried out on 60 oak logboats and 46 logboats were absolutely dated. Logboats from earlier periods, i.e. Middle Ages and Modern Times predominate. The frequency distribution pattern is in agreement with the distribution pattern from ^{14}C dating.

SETTLEMENT PERIODS AND LOGBOATS EXPLOITATION ON THE CLIMATIC BACKGROUND

Cumulative probability density functions of ^{14}C calibrated dates for some archaeological sites from the Holocene (and older, Fig. 3 and 4) are compared with climatic records shown in the CPDF of ^{14}C calibrated data sets from speleothems, tufas and peat, relative lake laminae thickness and lake water-level changes for Poland (Fig. 2).

The CPDF of calibrated ^{14}C ages from speleothems and tufas were made on the basis of 143 and 100 data sets respectively. These dates were obtained from samples that come from caves and tufa sites in the south and east of Poland. The dated peat comes from all Poland (630 radiocarbon dates, Michczyńska and Pazdur 2003). The distribution from these formations gives information that the climate was warm /cold and humid/dry. Comparison of climatic statistical records was made with water level changes and laminae thickness for Lake Gościąż (Pazdur *et al.* 1995, Goslar *et al.* 1998).

The comparison between the CPDF of calibrated ^{14}C ages from Krakowsko – Wielunska Upland speleothems and tufas and Glanów Site 3 shows that when climatic conditions were improving (maximum in the CPDF from speleothems), the settlement from Glanów Site 3 was increasing too. In the case of Chwalim, Całowanie, Biskupin and uławka Sites, similar comparisons can be made. However, here the indicator of climatic changes is related to peat formations and Lake Gościąż laminae thickness and water level changes.

With the climatic records, some correlation with the CPDF for logboats is also found. In the distribution of calibrated dates we find a lack of samples between *ca.* 800 BC and *ca.* 300 AD. This result is surprising and different from the results observed for Central Europe. The remaining ranges of age, with a high frequency of dates, are in good agreement with similar periods obtained for Central Europe.

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Chapter 24

HORSE REMAINS FROM THE ARZHAN-1 AND ARZHAN-2 SCYTHIAN MONUMENTS

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ABSTRACT

This paper presents the first osteological study and comparison of horse remains from the two famous Arzhan-1 and Arzhan-2 Scythian monument in Tuva. In spite of the fact that the horses from both monuments belong to the same breed groups, one can observe some differences in the sizes of the horses caused probably by differences in the local environmental conditions.

Keywords: Scythian time, horse remains, osteology, Tuva region

INTRODUCTION

The investigation reported here focuses on the study of horse remains from the two famous Scythian barrows Arzhan-1 and Arzhan-2.

The Scythian barrow Arzhan-1 was discovered by M. Gryaznov in 1971-1974 in the Uyuk hollow in Tuva. Arzhan-1 is a very complicated monument consisting of 29 different archaeological burials and graves dated to the same time. As well as the tsar burial ground and graves of nobility, over 160 horse skeletons were found in this monument. All of them were stallions older than 12-15 years (Gryaznov, 1980:49, 52). According to the archaeological point of view, graves 2 and 3 with the horse remains belonged to the Arzhan culture originating from the Tuva region. This barrow is the oldest Scythian monument and is dated to the 9th century BC.

The Arzhan-2 monument is located in the Uyuk hollow not far from the famous barrow Arzhan -1. It was discovered in 2001 by the Central Asiatic archaeological expedition (Chugunov K.V.2000) and the Eurasian Department of the German Archaeological Institute (Prof. G.Parzinger and Dr. A.Nagler). The construction of this monument differs from Arzhan-1. Arzhan-2 contains a variety of archaeological materials reflecting both the

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mode of life and the burial tradition of the ancient nomads. A collective horse burial was also found here (grave 16, 14 complete horse skeletons). The burial mound is dated to the 7th century BC.

MATERIALS AND METHODS

The horse remains from Arzhan-2 and the Arzhan-1 form the basis of the study presented.

All 14 skeletons from Arzhan-2 are in the State Hermitage Museum collection. Only stallions about 12-16 years old were found in the grave. Some horses showed pathological symptoms of disease.

Unfortunately, only a small part of collection from Arzhan-1 was kept in the collection of the Institute for the History of Material Culture RAS. According to Gryaznov (1980) 13 horse burials were found from which the remains from burials 2, 3 have been analyzed.

The methodological approaches of von den Driesch (1976), Eisenmann and Beckouche (1986) were generally used for the cranial and postcranial measurements. For each group of measurements, the range of variation and average value have been calculated. All long bones have epiphyses which are firmly fused to their diaphyses.

Skull

Unfortunately, the material from Arzhan-1 contains only one complete skull and a few pieces. In Table 1 the measurements of the horse skulls from Arzhan-2 and Arzhan-1 are presented

Table 1. Skull measurements of the horses from the Arzhan-1 and Arzhan-2 monuments

	Measures	**Arzhan-2**			**Arzhan-1**		
		n	lim	M	n	lim	M
	Skull						
1	basilar length	7	448,4-502,8	489,2	1	468	
2	palatal length	10	266,2-277,3	269,4	2	261-262,5	261,7
3	distance from palate to hormion	6	103,5-110	107,6	1	107	
4	distance from hormion to basin	5	120,7-132,8	128,4	1	116	
5	muzzle length	12	129-143,2	134,8	1	128	
8	occlusal length of the upper cheekteeth	13	154-173	166,4	3	160-161,5	160,6
9	choanal length	8	61,5-69,6	65,4	1	65	
10b	choanal breadth between the pterygoid processes	8	40,2-47,5	43,6	1	41,5	
11	breadth between the foremost points of the facial crests	9	152,6-172,3	163,3	2	155-156	155,5
13	frontal breadth	4	207,5-215	211,7	1	202	
16	breadth of the supra-orbital crest	8	49,2-63,5	56,4	1	54	

17	muzzle breadth at the posterior borders of the I^3	12	70-77,2	73	1	68	
17b	least muzzle breadth between the interalveolar borders	12	45,3-58	51,2	2	45,5	45,5
18	vertex length	7	540.5-556,7	546,7	1	558	
20	height of the external auditory meatus	6	12,7-21	16,1	-	-	
23	anterior ocular line	11	369,5-398,7	387,6	2	373-382	377,5
25	facial height in front of P^2	10	95,5-115	104,2	1		
	occlusal length of P^2	12	33,4-40	36,6	2	35,9	35,9
	breadth of P^2	12	22,5-26,7	23,2	3	20-22,5	21,5
	occlusal length of the protocone P^2	-	-	-	3	9-9,6	9,2
	occlusal length of P^3	13	23,6-27,3	26	3	26,5-27	26,8
	breadth of P^3	13	24,3-28	26,6	3	25,2	25,2
	occlusal length of the protocone P^3	12	9,3-13,6	11,4	3	10-11,2	10
	occlusal length of P4	12	22,5-27	25,2	3	24,5-25,5	25,1
	breadth of P4	12	25,5-29,7	27,5	3	25,5-27,8	26,6
	occlusal length of the protocone P4	11	10-14,8	12,3	3	11-11,8	11,3
	occlusal length of M^1	13	20,2-25,4	23	3	21,5-23	22,2
	breadth of M^1	13	25,4-28,8	27	3	26-27	26,5
	occlusal length of the protocone M^1	12	10,3-14,3	12,2	3	11-11,3	11,1
	occlusal length of M^2	13	21-25,2	23,5	3	22,8-23	22,9
	breadth of M^2	13	24-27,6	26,1	3	23,9-25,6	24,5
	occlusal length of the protocone M^2	12	11,3-15	13,4	3	12-13	12,6
	occlusal length of M^3	13	25,5-31,5	27,8	3	28,3-30	29,1
	breadth of M^3	13	21,5-26,2	24,3	3	21,8-24,5	23,1
	occlusal length of the protocone M^3	12	12,4-16,5	14,4	3	12,9-14,5	13,7
	Lower jaw						
	greatest length	11	432-463	413,4	4	388,3-443	417
	greatest length of the angular part	13	123,5-142	131,4	4	118-133	127,3
	length of the diastema	12	77,5-109,2	95,4	3	75-101	91
	occlusal length of the lower cheekteeth	14	72-84	79,1	3	70-77	72,4
	height of the vertical ramus	12	212,8-238	221,5	3	206,1-230	205,7
	occlusal length of P2	13	29,5-35	32,2	2	30-33	31,5
	breadth of P2	13	13,5-19,5	16,4	2	16-18,2	17,1
	postflexid length of P2	13	8,8-16,7	14,3	2	11,2-12,8	12
	occlusal length of P3	14	25-28,4	26,8	3	25-27	26
	breadth of P3	14	16-20,8	18,1	3	16,2-17	16,5
	postflexid length of P3	14	3,5-14,7	11,4	3	9-11	10,1
	occlusal length of P4	14	21,7-27,2	25,3	3	24,2-26,1	24,9
	breadth of P4	14	15,8-21	18,7	3	16-18,8	17,6
	postflexid length of P4	14	6-13,6	11,1	3	8,8-9	8,9
	occlusal length of M1	14	22,3-25,6	24,1	4	22-23	22,6

	breadth of M1	14	15-20	17,5	4	16-17,1	16,4
	postflexid length of M1	14	4,4-13,6	8,3	4	4,5-8	6,8
	occlusal length of M2	14	22,8-26,3	24,6	4	23-25	23,8
	breadth of M2	14	14,4-18,6	15,5	4	16-17	16,4
	postflexid length of M2	14	5-11	8,5	4	6-8,3	7,6
	occlusal length of M3	14	29,6-34	31,7	4	31-34,5	32,1
	breadth of M3	14	13,1-16,5	15,1	4	13,5-15	14,1
	postflexid length of M3	14	7,2-10,4	9,2	4	7,2-10	8,5

n - number of specimens; lim- minimum and maximum observed value; M - mean

One can see the similarities in the range of variations. Following V. Eisenmann (1986) differences between the logarithms (base 10) of the standard (E.hemionus oager) and the logarithms of the other form were calculated and plotted. Figure.1 compares the means of the horse crania from the two Scythian monuments. The horses from two monuments seem to have very similar crania.

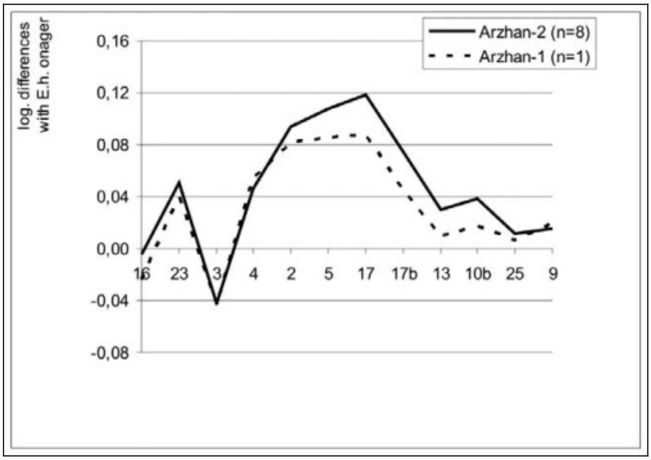

Figure 1. Ratio diagrams of the cranial measurements (means) of horses from Arzhan-2 and Arzhan-1 compared to E. hemionus onager

Teeth

Measurements of upper teeth included occlusal length (OL) and breadth for each tooth and occlusal length of the protocone (PL) (Table 1). The protocone index (PL×100/OL) was also calculated for each tooth. Measurements of lower jaw teeth included occlusal length (OL) and breadth and postflexid length. (Table 1).

The comparative diagrams of mean occlusal length of upper jaw teeth, protocone lengths, protocone index and occlusal length of lower jaw teeth plotted in Fig.2,3,4,5 show that there are no significant differences in the size of teeth.

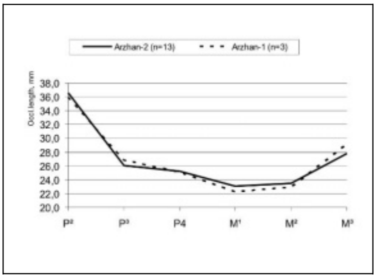

Figure 2. Mean occlusul lengths in mm of the upper cheekteeth of horses from the Arzhan-2 and the Arzhan-1

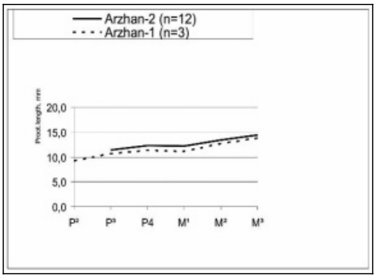

Figure 3 Mean protocone lengths in mm of the upper cheekteeth of horses from the Arzhan-2 and the Arzhan-1

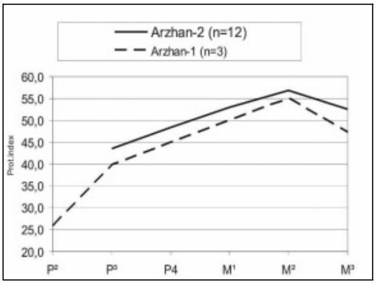

Figure 4 Mean protocone indices for the upper cheekteeth of horses from the Arzhan-2 and the Arzhan-1

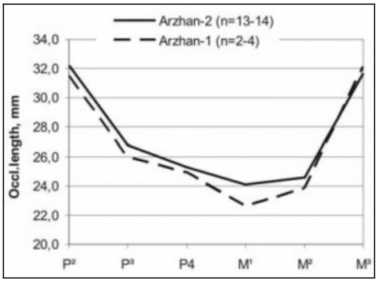

Figure 5 Mean occlusal lengths in mm of the lower cheekteeth of horses from the Arzhan-2 and the Arzhan-1

Post-cranial skeleton

Another situation can be observed when we compare the postcranial elements. (Table 2). The lengths of bones such as the femur, tibia, metacarpus and metatarsus from Arzhan-2 are greater than those from Arzhan-1 (Table 2). Among the extremity bones, the main focus was given to metacarpals and metatarsals.

Table 2 Comparison of the measurements of postcranial elements

Measurement	Arzhan-2			Arzhan-1		
	n	lim	M	n	Lim	M
Humerus, length	6	277-300	293	1	274	
breadth of diaphysis	6	35-37,2	36,2	1	34,2	
Radius,lenght	14	324-350	336,4	-	-	-
breadth of diaphysis	6	38-41	39,5	-	-	-
Femur,lenght	14	386-412	398,7	21	345,2-383	367,5
breadth of diaphysis	6	40-47	43,8	21	34,9-46	36,3
Tibia,lenght	14	342-372	354,8	1	332,4	
breadth of diaphysis	6	39-43	41,5	1	39	
Metacarpus,lenght	14	218-240	227,4	6	219-229,6	223,7
breadth of diaphysis	6	33-41	35	6	31,5-33,5	32,3
Metatarsus	14	262-281	268,8	4	256,6-263	260,9
breadth of diaphysis	6	31-33	31,5	4	28,9-31,2	29,5

n - number of specimens; lim- minimum and maximum observed value; M – meaning

First there are some differences in the measurements. The greatest length of the metacarpals from Arzhan-2 is between 218 mm and 240 mm, the average is 227.4 mm, whereas 219 mm to 229.6 mm with an average of 223,7 mm is more characteristic for the horses from Arzhan-1 (Table 2). The greatest length of metatarsals from Arzhan-2 is 262 – 281 mm with an average of 268,8 mm and for Arzhan-1 it is 256,6 – 263 mm with an average of 260,9 mm.

DISCUSSION AND CONCLUSIONS

Thus, from the data presented, it is clear that the horses from Arzhan-2 differ somewhat from Arzhan-1 mainly in some larger dimensions. However, there are differences in the length of the long bones which may reflect the values of shoulder heights. According to Vitt's classification the horse could be divided into following groups (Table 3).

Table. 3 Comparison of a shoulder height

Height in cm	112-120	120-128	128-136	136-144	144-152
	very small	small	< average	average	> average
Arzhan-1	9,60%	47,60%	42,80%		
Arzhan-2			7,10%	85,80%	7,10%

The horses from Arzhan-2 were larger-bodied animals. The horses from Arzhan-1 were considerably smaller. There were even very small individuals (shoulder height below 120 cm) among them.

The question naturally arises as to whether the horses were of the same breed group.

Based on the basal length of the skull Vitt V. (1952) classified four groups of horses from the Pazyryk and the Sibe monuments. Inside these groups he created the skeleton profiles for each group calculating the average dimensions of the post-cranial elements. The diagrams of the skeleton profiles were used as one of the pieces of evidence that all the animals belonged to the same breed group and that the differences between groups I and IV can perhaps be the result of the different ways in which horses were kept (Vitt, 1952).

In agreement with the reasoning of V. Vitt, the comparative skeleton profiles were created (Fig. 6).

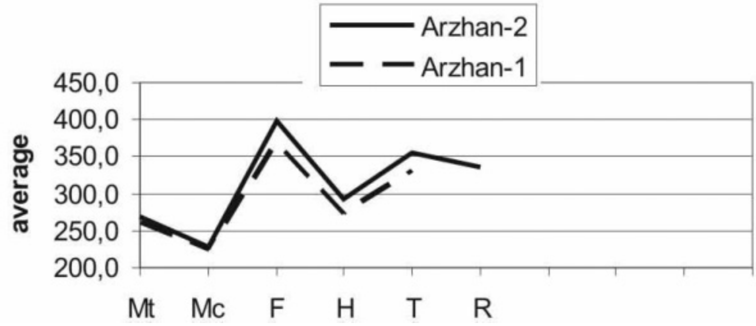

Fig.6 Skeleton profile

On the whole, one can see that diagrams obtained have more or less equal values and look very similar. Thus, in spite of the range of variation a general resemblance between horse skulls, teeth and extremity bones from both barrows can be observed.

Analyzing the data presented here it is possible to propose that the same breed group of horses existed in Arzhan-2 and Arzhan-1. If this view is correct, one can suggest some reasons for the observed size differences.

First of all, probably, the differences in size can be linked with different environmental conditions.

Considering this suggestion the metapodial indices ((Mt/F)*100) were examined which can be used as one of the indicators of changes in paleoenvironments. The larger metapodial indices indicate an arid environment; the smaller indices characterize a more humid climate (Vitt, 1952).

Here the lowest value of metapodial index of the horses from Arzhan-2 is 64.5, the highest – 69.6, the average being 67.3, while the values for the horses from Arzhan-1 are the following: 68.5, 73.2 and 71.6 respectively. The difference in metapodial indices is in accordance with our suggestion.

The decrease of horse metapodial indices between the 9th – 7th centuries BC probably shows the effect of climatic shifts to more humid conditions. The climate state will influence the vegetational system which also could be reflected in the animal size.

Of course, it is necessary take into consideration, that differences in the horses' constitution and in size could be as a result of husbandry, of feeding and of harnessing (e.g. the different ways in which they were put to use and were kept).

The question of the time, the place and the ancestor of the domestic horse is still open to discussion. There is an opinion that the domestic horse's ancestor was the tarpan , a wild horse that became extinct in the late 19^{th} century (Heptner et al., 1961; **Bökö**nyi,1978). N. Spasssov and N. Iliev (1997) proposed the hypothesis of a polyphyletic origin of the domestic horse, which existed in coexistence with the tarpan (*Equus gmelini*) and the broad-hoofed horse (*Equus germanicus transilvanicus* (=*E. latipes*)). These two species can be simultaneously regarded as ancestors of the domestic horse. Here the comparison of the horse skulls from Arzhan-2, Arzhan-1, *E,gmelini*, *E.przewalskii* and *E.caballus cf. germanicus* are presented (Fig. 7, 8, 9).

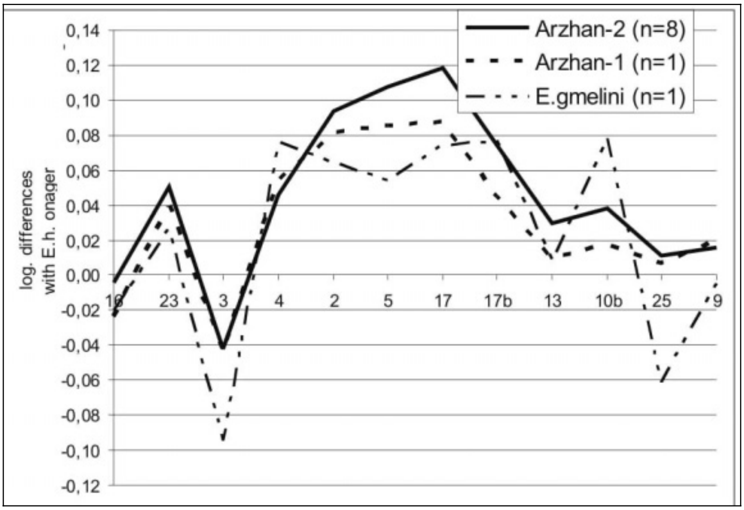

Figure 7 Ratio diagrams of the cranial measurements (means) of horses from the Arzhan-2 and the Arzhan-1 and E. gmelini compared to E. hemionus onager

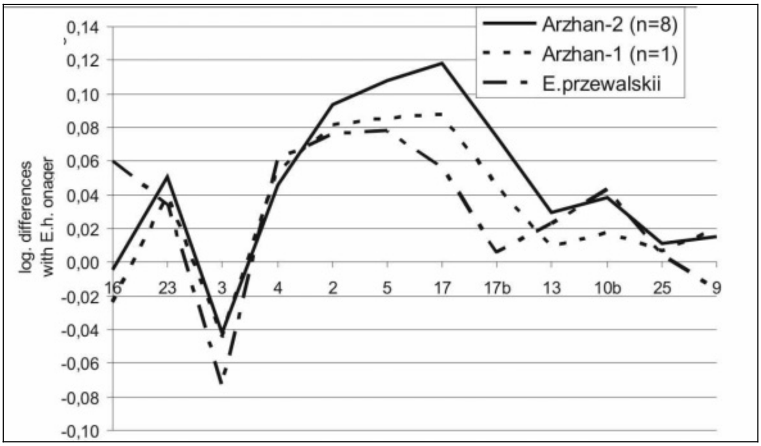

Figure 8 Ratio diagrams of the cranial measurements (means) of horses from the Arzhan-2 and the Arzhan-1 and E.przewalskii (Eisenmann V.,1986) compared to E. hemionus onager

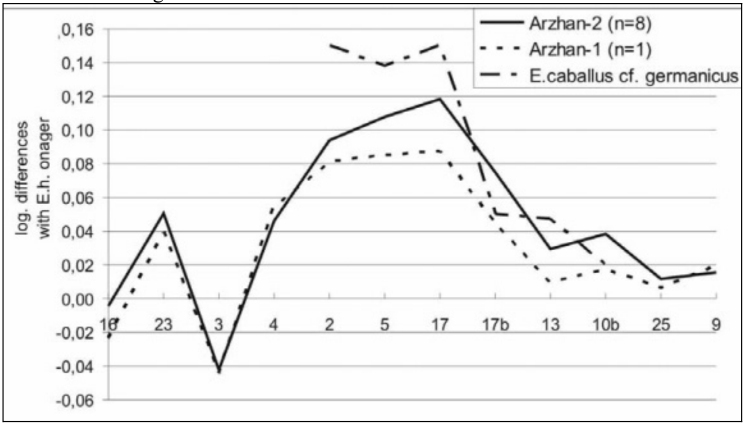

Figure 9 Ratio diagrams of the cranial measurements (means) of horses from the Arzhan-2 and the Arzhan-1 and E. caballus cf. germanicus (Eisenmann V.,1986) compared to E. hemionus onager

The figures show that these horses differ both in proportion and in size. The present study is preliminary and based on a limited amount of material thus we are unable to conclude anything definite about the ancestor of the Arzhan' horses. We can conclude that the horses from Arzhan-2 and Arzhan-1 could belong to the same breed group. It seems to be highly probable that the differences between the horses from Arzhan-1 and Arzhan-2 were due both to climatic changes and to an improvement in forage, and also as a result of the different ways in which they were put to use and were kept. The question about the ancestor of the Arzhan' horses is still open to debate.

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