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CHRONOLOGICAL STUDY OF ARCHAEOLOGICAL SITES AND ENVIRONMENTAL CHANGE AROUND 2600 BP IN THE EURASIAN STEPPE BELT (Uyuk valley, Tuva Republic)

G.I. ZAITSEVA[1], K.V. CHUGUNOV[2], N.A. BOKOVENKO[1], V. I. DERGACHEV[3], V.G. DIRKSEN[4], B. VAN GEEL[5], M.A. KOULKOVA[1], L.M. LEBEDEVA[1], A.A. SEMENTSOV[1], J. VAN DER PLICHT[6], E.M. SCOTT[7], S.S. VASILIEV[3], K.I. LOKHOV[8] and N. BOUROVA[1]

[1]*The Institute for the History of Material Culture of Russian Academy of Sciences, 191186, Dvortsovaya 18, St.Petersburg, Russia (e-mail: ganna@mail.wplus.net)*
[2] *State Hermitage Museum, 191186, Dvortsovaya 34, St.Petersburg, Russia (e-mail: oaves@hermitage.ru)*
[3] *A.F.Ioffe Physical-Technical Institute of Russian Academy of Sciences, 19402 Politekhnicheskaya 26, St.Petersburg, Russia (e-mail: v.dergachev@pop.ioffe.rssi.ru)*
[4] *Institute of Volcanology and Seismology, Far East Branch of Russian Academy of Sciences, 683006 Piipa bvld., 9, Petropavlovsk-Kamchatsky, Russia (e-mail: dirksen@VD3155.spb.edu)*
[5]*Universiteit van Amsterdam, P.O. Box 94062 1090 GB Amsterdam, The Netherlands (e-mail: vangeel@science.uva.nl)*
[6] *Rijksuniversiteit Groningen, 9747 AG Groningen, The Netherlands (e-mail: J.van.der.Plicht@phys.rug.nl)*
[7] *Glasgow University, Glasgow G12 8QW UK (e-mail: marian@stats.gla.ac.uk)*
[8] *Center of Isotopic Research, All-Russian Geological Research Institute (VSEGEI), Basil Island, St.Petersburg, Russia Sredni prospect (e-mail: cirvsg@vsegei.sp.ru)*

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Abstract: The main attention of the article presented focuses on the connection between the development of archaeological cultures and environmental changes during the 9th -4th centuries BC (2700-2400 BP). Environmental changes around 2600 BP can be observed by the character of the radiocarbon calibration curve. The region under study is the Uyuk depression in the Tuva Republic which is the part of the Eurasian steppe belt. To reconstruct environmental changes pollen and geochemical analyses of the lake deposits from the Uyuk depression were used. The main feature that made this territory more attractive for settling, is the humidity that promoted nomadic economy.

The chronology of the archaeological sites corresponds to a period with a complicated shape of the calibration curve, and a special approach (wiggle-matching dating) is required. The famous Scythian time monuments Arzhan-1 and Arzhan-2 are located in this region and the wiggle matching method was used to establish the time of their construction. The Arzhan-1 is the oldest among the Scythian time monuments of all Eurasia. The chronology of other Scythian time monuments located in the western and eastern neighbouring territories of Tuva is considered and compared.

1. INTRODUCTION

There is strong evidence for a global climatic change around 2600-2400 BP (van Geel *et al.,* 1998; Dergachev *et al.,* 2004). It is interesting to know the influence of the climatic changes on the development of archaeological cultures. Just during this period, the Scythian cultures began to exist and to develop and spread into different parts of Eurasia. The region under our study is the Uyuk depression in the Tuva Republic, which forms part of the Eurasian steppe belt. Similarly to the inner continental region surrounded by the Sayan-Altai Mountains, this area is protected against the influence of the Arctic, Atlantic and Indian oceans (**Fig. 1**). Neolithic sites were found in Tuva, mainly in the eastern regions (Todzha depression), including the Neolithic site Azas-2 (Devlet, 1973; Semenov, 1992; Vasiliev and Semenov, 1993; Semenov, 2001) and in the last years in the Upper Yenisey River

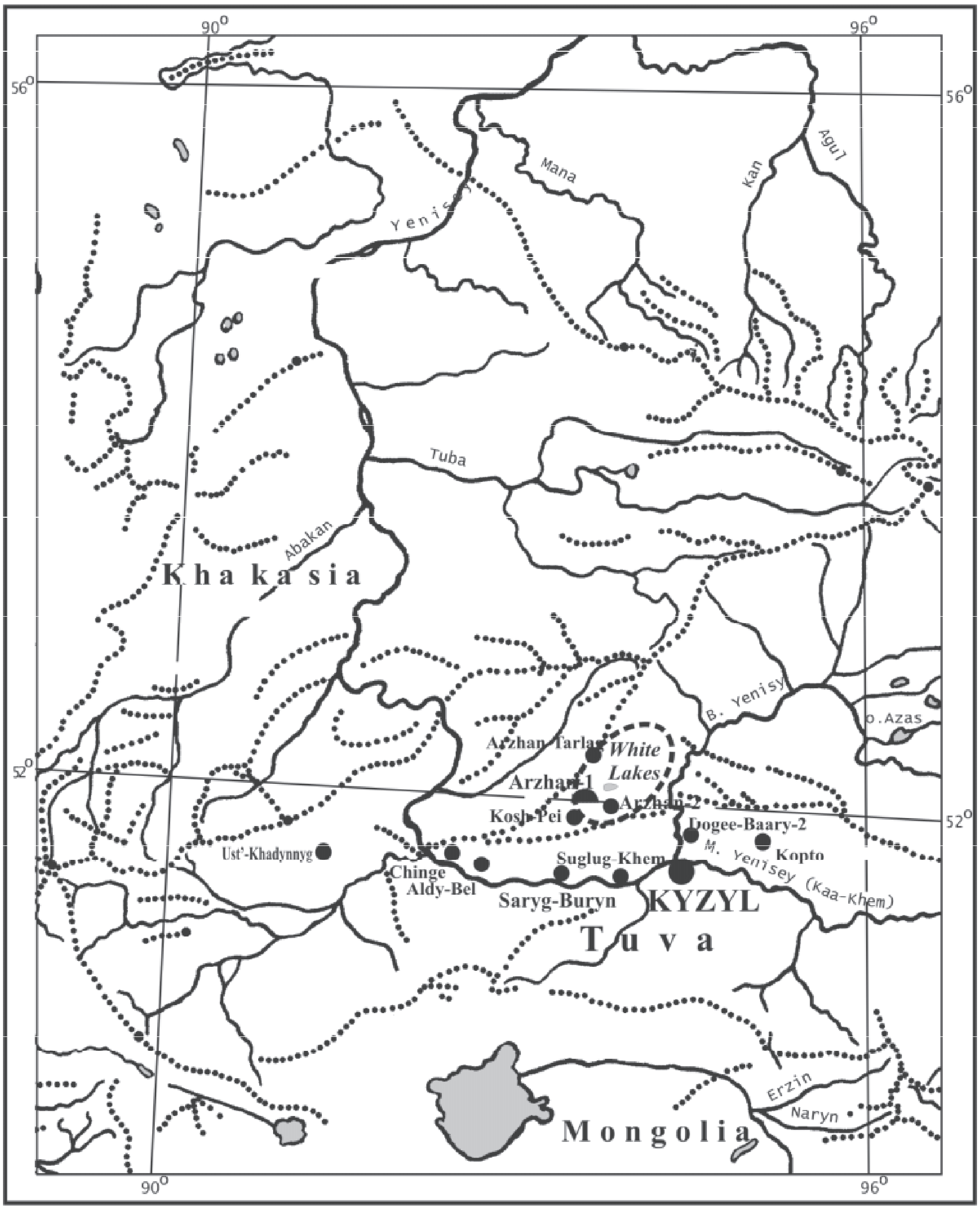

Fig. 1. *The map of the region studied with the Scythian time monuments pointed.*

The schematic border of the Uyuk valley

Sayan mountains ridges

basin the multilayer sites Toora-Dash and Khadynnyg have been discovered (Semenov, 2004). But in spite of the long history of archaeological investigations of the Uyuk valley, no Mesolithic-Neolithic sites were found. Only traces of the Middle-Late Bronze-Age sites (Okunevo culture) were found. One of the reasons for the appearance of the Bronze Age cultures is the arrival of these populations from the Minusinsk valley (neighbouring territory), from where they were forced out by the following Bronze Age culture belonging to the Andronovo population (Bokovenko *et al.*, 1992). The chronology of the Okunevo culture in the Uyuk valley is only just being worked out. Probably this culture existed in the steppe zone (the Uyuk valley) up to the Scythian time, i.e. the 1st millennium BC. The very active settling of the Uyuk depression began during the beginning of the Iron Age, particularly in the Scythian time. Now, one can observe a lot of barrows constructed in that time. But it is very important that in the Uyuk valley the very famous and unique monument Arzhan-1 was discovered by M. Gryaznov (1980). The discovery of this monument played an important role for all Scythian world of Eurasia because it is considered the earliest Scythian (or pre-Scythian) time monument in the whole Eurasia. Recently, in 2001, the unique Scythian monument Arzhan-2 was discovered by a Russian-German expedition (Chugunov *et al.*, 2001a; 2001b and 2004).

Until recently it was not clear which cultural and environmental processes occurred in the Uyuk valley in the Holocene up to the Late Bronze Age and early Iron Age. Beyond doubt, the population which constructed the Arzhan-1 monument came to the Uyuk valley from other territories because there are no local roots for the Scythian cultures. Most probably the answer to this question is related to environmental changes which rapidly made this region attractive for the settling of the Scythian time cultures. This research deals with both the chronology of the Scythian time monuments located in the Uyuk valley and the character of environmental changes.

2. RESULTS

The chronology of the Scythian time monuments

In the Tuva region, in total, a rather large number of Scythian time monuments were discovered (**Fig. 1**). For the most of them the radiocarbon dates were produced (Alekseev *et al.*, 2001). The list of radiocarbon dates of the ordinary Scythian time barrows is presented in **Table 1**. The radiocarbon dates of the Arzhan-1 and Arzhan-2 barrows will be in particular considered bellow.

As one can see from **Table 1**, the radiocarbon dates of practically all of the monuments fall on the so-called Hallstatt plateau in the calibration curve causing uncertainties in the calendar time (from 800 to 400 cal BC). The calendar time of the barrows construction remains open to discussion. The Dogee-Baary-2 group of barrows located in the east of the Uyuk valley (**Fig. 1**) were dated in 1996-99 and now about 20 graves have a ^{14}C date. The majority of the graves are dated to the 5th - 4th centuries BC. For this group of barrows, the wiggle matching method together with the tree-ring chronology was used (Alekseev *et al.*, 2002; Dergachev and Vasiliev, 1999, Dergachev *et al.*, 2001). The radiocarbon dates confirmed the archaeological ideas about the existence of this group of barrows during the 5th -4th centuries BC, practically the same time as the Pazyryk group of barrows in the Altai region (Zaitseva *et al.,* 1996). In 1989-1991 the Kosh-Pei-2 group of barrows was discovered by Vladimir Semeno in an area not far from the Arzhan-1 and 2 barrows (**Fig. 1**). These barrows are archaeologically dated to the second half of the 6th century BC (Semenov, 2000) but individual ^{14}C dates produced for this monument do not allow its chronology to be determined more precisely and the chronological position is under debate.

As one can see from **Fig. 1**, in the Uyuk valley, which is a very small area, several Scythian time monuments have been discovered, among them are the Arzhan-1 and Arzhan-2, Arzhan-Tarlag, Kosh-Pei. Thus, between Arzhan-1 and Arzhan-2 barrow one can observe a chain of barrows which have not been investigated so far.

The main focus of this study was to establish the precise chronological position of the Arzhan-1 monument. The dating of the Arzhan-1 monument began immediately with its discovery. The remarkable fact is that the organic materials are well preserved in this area due to the continental climate. Even during the summer, the interior of

Table 1. *Radiocarbon dates of the Scythian time monuments in Tuva.*

No.	Lab. index	Monument	Dated material	Position in the monument	^{14}C Age (BP)	Calibrated time intervals (cal BC)	
						1σ	2σ
1.	Gu-9181	Arzhan-Tarlag	wood	20 outside tree-rings	2310±60	410-200	800-150
2.	Gu-8354	Arzhan-Tarlag	wood	20 outside tree-rings	2360±50	540-380	800-200
3.	Gu-8352	Arzhan-Tarlag	wood	20 outside tree-rings	2410±70	760-390	770-380
4.	Gu-8353	Arzhan-Tarlag	wood	20 outside tree-rings	2470±60	770-410	780-400
5.	Le-5450	Arzhan-Tarlag	wood	The upper level of the construction	2455±25	760-410	770-400
6.	Le-5399	Kosh-Pey-2	wood	Barrow 2	2570±35	810-590	820-540
7.	Le-5217	Kopto	charcoal	Barrow 3, grave 1	2380±25	520-390	760-390
8.	Le-5218	Kopto	charcoal	The base of the upper chamber	2420±25	540-400	760-400
9.	Le-5221	Kopto	wood	Barrow 3, grave 3	2430±40	760-400	770-400
10.	Le-5222	Kopto	charcoal	Barrow 2, grave 4	2440±30	760-410	770-400
11.	Le-5219	Kopto	charcoal	Barrow 4, grave1	2460±25	760-410	770-400
12.	Le-5216	Kopto	wood	Barrow 2, grave 1, low part	2480±60	770-510	790-410
13.	Le-5220	Kopto	wood	Barrow 2, grave 1,	2500±60	790-520	800-410
14.	Le-5224	Kopto	wood	Barrow 2, grave 5	2500±60	790-520	800-410
15.	Le-5225	Kopto	wood	Barrow 3, grave 4	2525±20	790-560	800-540
16.	Le-5566	Saryg-Bulun	wood	Barrow 1, grave 5	2300±50	410-210	510-200
17.	Le-5603	Suglug-Khem-1	wood	Part of wood plate	2800±200	1290-790	1500-400
18.	Le-5553	Suglug-Khem-1	wood	Object 35, covering of felling	2490±25	770-520	790-410
19.	Le-5554	Suglug-Khem-1	wood	Object 35, covering of felling	2495±20	770-540	790-520
20.	Le-5556	Suglug-Khem-1	wood	Object 35, covering of felling	2500±20	770-540	790-520
21.	Le-5551	Suglug-Khem-1	wood	Object 35, covering of felling	2515±20	790-540	800-540
22.	Le-5557	Suglug-Khem-1	wood	Object 35, covering of felling	2540±25	800-560	800-540
23.	Le-5555	Suglug-Khem-1	wood	Object 35, covering of felling	2560±18	795-764	810-590
24.	Le-5552	Suglug-Khem-1	wood	Object 35, covering of felling	2575±20	799-766	810-660
25.	Ua-15270	Ust'-Khadynnyg-1	bone	barrow 37	2190±70	370-160	400-50
26.	Ua-15229	Ust'-Khadynnyg-1	Wood from arrow point	Cultural layer	2635±70	900-670	980-520
27.	Ua-12973	Chinge	textile	Barrow 22, grave 2	2360±45	320-380	800-250
28.	Le-5847	Aldy-Bel	wood	Barrow 1, low wood of felling	2335±20	402-391	407-380
29.	Le-5848	Aldy-Bel	wood	Lateral burial	2440±30	760-410	770-401
30.	Gu-9181	Aldy-Bel	wood	Lateral burial	2470±50	770-410	770-400

the graves can have low temperatures. The environmental condition promoted good preservation of the organic materials in the monuments so that they can be used for radiocarbon dating. It is important that practically all the barrows were constructed from wood and their good preservation means that separate tree-rings can be identified. The floating tree-ring scale for the Sayan-Altai Scythian time monuments was created by Dr. L. Marasadolov in the eighties (Marsadolov, 1984 and 1988). This scale included the Pazyryk groups, the Tuekta barrow in the Altai, and Arzhan-1 in Tuva. But there was a gap between the Altai group of barrows and Arzhan-1 (Marsadolov, 1984 and 1988). At that time, first attempts to use the "wiggle matching" method were made. In total, only four radiocarbon determinations were produced from two different logs (Zaitseva *et al.,* 1996). Using the tree-ring radiocarbon dates, floating tree-ring chronology, and mathematical statistics Arzhan-1 was dated to the interval between 810 calBC and 745 calBC (Marsadolov, 1988; Zaitseva *et al.*, 1996; Zaitseva *et al.,* 1998); that is this barrow can be dated to the end of the 9th century BC. As the Arzhan-1 barrow is a key monument for all Eurasian Scythian chronology, not all archaeologists accepted these dates. Some of them dated this monument to the 8th-7th centuries BC (Chlenova, 1972 and 1996).

Now, we decided to reconsider these earliest dates and to produce new dates from a single log using the wiggle matching method.

The radiocarbon dates for the Arzhan-1 monument from remains of a single wooden piece produced earlier (Zaitseva, *et al.,* 1998) are presented in **Table 2**.

Table 2. *The list of ^{14}C dates for the Arzhan barrow produced from single wooden remains.*

N	Lab Index	^{14}C age (BP)	Material for dating
1.	Le-5194	2570±50	wood, single stick
2.	Le-5144	2590±90	wood,
3.	GIN-8619	2600±40	wood, single stick
4.	Le-4769	2610±40	wood
5.	GIN-8425	2610±30	wood, single stick
6.	GIN-8618	2620±40	wood, single stick
7.	Le-5143	2660±50	wood
8.	Le-4772	2680±50	wood

The combined radiocarbon date obtained from the OxCal calibration program (Ramsey B., 1994; 2001) is 2617± 15 BP which corresponds to the calendar time intervals of 806-794 cal BC (68% probability) and 822-791 CalBC (95% probability). This radiocarbon date falls on a rather accurate part of the calibration curve causing the tight calendar time intervals (**Fig. 2**). This result is in agreement with the results obtained earlier which dated this monument to the end of the 9th century BC. Recently, in the collection of the Institute for the History of Material Culture, a log from the Arzhan-1 construction was found. The log with about 67 tree-rings with rather well preserved outside tree rings was subdivided into 10-year parts that were dated. The $^{13}C/^{12}C$ ratios were determined too, in order to obtain more precise dates. The results are presented in **Table 3**.

To correlate the radiocarbon determinations for three ring samples with the calibration curve, a statistical approach was applied (Dergachev and Vasiliev, 1999; Dergachev *et al.,* 2001). The ^{14}C dates are matched to the calibration curve by minimizing the statistical parameter χ^2_{n-1}, where n is the number of the samples from the log.

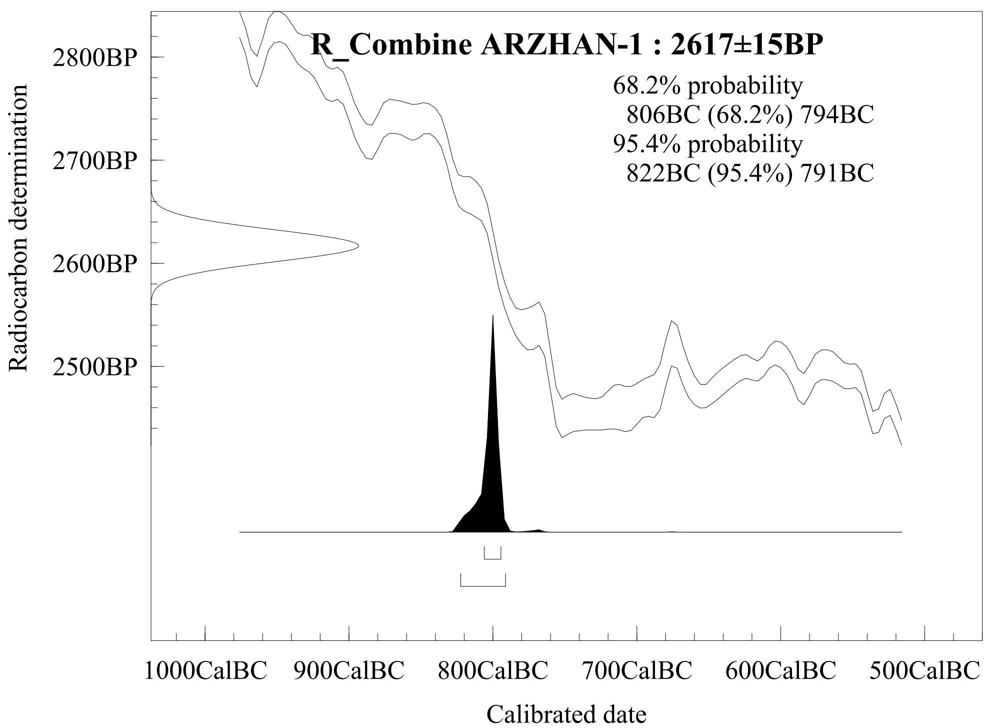

Fig. 2. *Part of the calibration curve and the combined radiocarbon date from 8 radiocarbon determinations for the Arzhan-1 barrow.*

Table 3. *The radiocarbon dates of tree-rings from a log of the construction of the Arzhan-1 monument used for the wiggle matching method.*

No.	Laboratory index	Amount of tree-rings counting from the centre	^{14}C Age (BP)	δ^{13}C ($^0/_{00}$)	Calibrated time intervals (cal BC)	
					1σ	2σ
1.	Le-6918	0-6	2778±19	-22.60	980-860	1000-830
2.	Le-6919	10-19	2710±17	-23.05	900-825	900-810
3.	Le-6920	20-29	2754±20	-22.08	920-835	970-830
4.	Le-6921	30-39	2677±19	-22.6	831-806	900-800
5.	Le-6922	40-49	2766±19	-22.23	831-806	900-800
6.	Le-6923	50-59	2650±17	-23.11	820-802	828-799

The results are presented in **Fig. 3**. The reliability of these results have been checked mathematically by using the χ^2 test (**Fig. 4**). Thus, according to the results obtained, the Arzhan-1 monument construction can be dated to the boundary of the 8th to the 9th centuries BC as earlier assumed. As earlier postulated, the Arzhan-1 monument is the earliest Scythian (maybe, pre-Scythian) time monument in all Eurasia and takes up the key chronological position for the entire Scythian world.

As mentioned above, in the Uyuk valley a second unique Scythian time monument Arzhan-2 was discovered in 2001 (Chugunov *et al.*, 2001a; 2001b and 2004). The distance between the two monuments is about 9 km. The results of radiocarbon dating using the wiggle matching method showed that this monument could be constructed in the second half of the 7th century BC (Zaitseva *et al.,* 2004). The chronological gap between these barrows is about 150 years. The archaeological materials of the Arzhan-1 monument have a more archaic character compared to the Arzhan-2 monument (Chugunov *et al.,* 2004). The architectural elements of the burial chamber construction of Arzhan-1 differ from the Arzhan-2, but the wooden burial chamber in both cases was constructed with double walls. The artefacts from both monuments have an analogous animal style. The horse equipment (bridles) from Arzhan-1 have the preceding typology compared to those of the Arzhan-2 (Chugunov *et al.*, 2004). In both monuments the remains of horses have been found. In the Arzhan-1 monument which consists of different graves, over 160 horse skeletons were found. Also in Arzhan-2, a collective horse burial was found (grave 16 with 14 complete horse skeletons).

Not far from the Arzhan-1 monument, there are other Scythian time monuments; among them are the Arzhan-Tarlag barrow discovered in 1997 by K.Chugunov, and the Kosh-Pei-2 barrow discovered by Vlad Semenov in 1989 (Semenov, 2000). These barrows are archaeologically dated to the 5th - 4th centuries BC. The ^{14}C date for the burial mound No.2 from this monument is 2570±35 BP and is corresponded to the calibration time interval

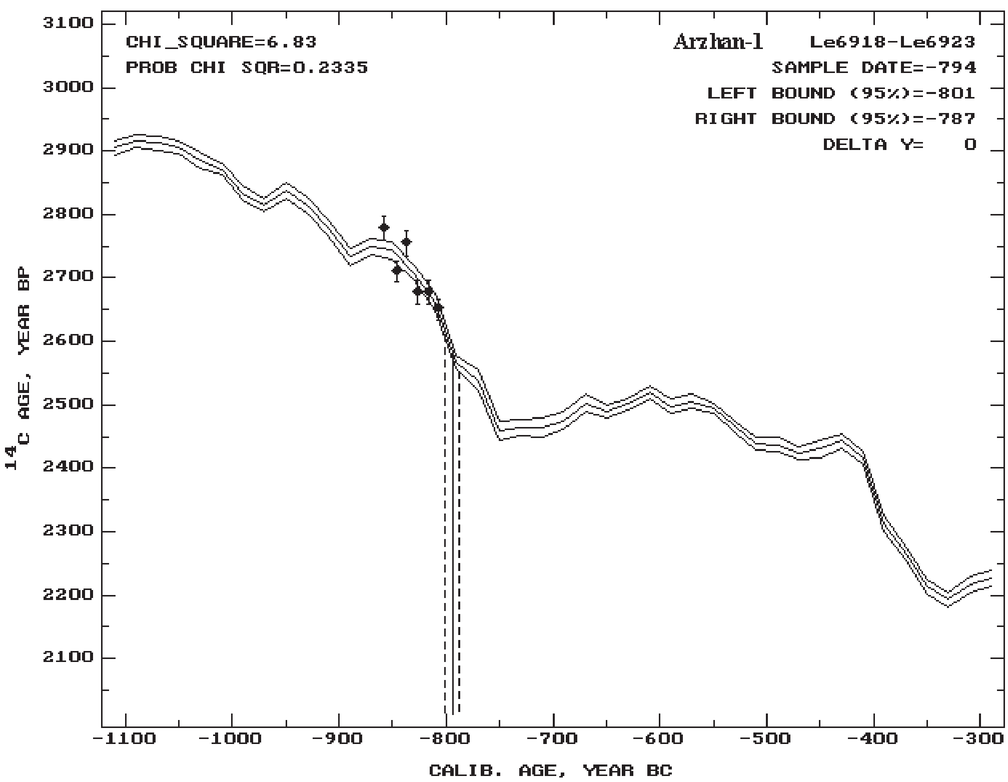

Fig. 3. *The position of the radiocarbon dates from the tree-rings on the calibration curve.*

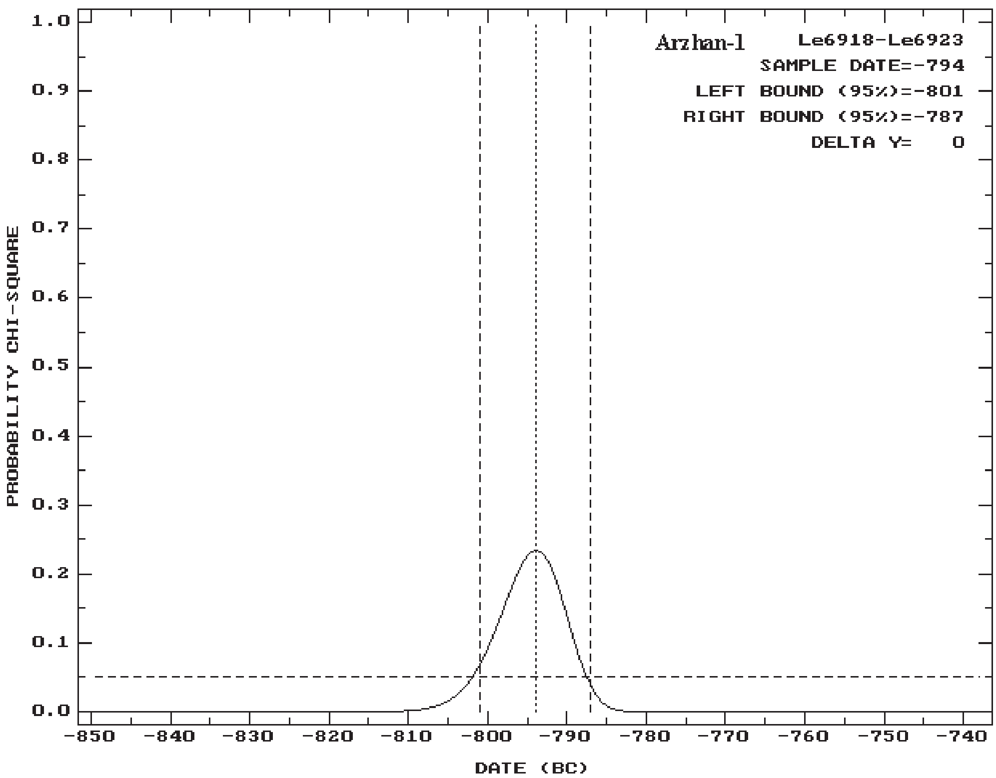

Fig. 4*. The reliability of the age obtained by ^{14}C dates for the Arzhan-1 barrow.*
The dotted vertical lines are the position of the most probable date, the right and left confidence limits are 787 and 801 BC, the dashed horizontal line corresponds to a probability of 0.05.

810-590 calBC (68% probability) and 820-540 calBC (95% probability) (**Table 1**).These time intervals are older than the archaeological estimation (Semenov, 2000). This discrepancy can be explained by the fact that the wooden sample used for radiocarbon dating consists of the sum of tree-rings and the ^{14}C date presents the average age of the whole wooden log. Most likely, the outside tree rings were lost. It means that it is impossible to estimate the correct time of the monument construction according to a single ^{14}C date, particularly if this date falls into the Hallstatt-plateau. Thus, if we look at the calibration curve on **Figs 2 and 3** and the ^{14}C dates from **Table 1**, one can see that practically all these dates of the Scythian monuments located in the Uyuk valley have a ^{14}C age corresponding to the Hallstatt-plateau. However, the ^{14}C dates for the Arzhan-1 barrow correspond to the steep part of the calibration curve before the plateau, and therefore the Arzhan-1 construction can be dated to the 8th -9th centuries BC. The ^{14}C dates of the tree-rings from the Arzhan-2 monument are situated at the beginning of the plateau and this monument can be dated to the 7th century BC. Other monuments are more difficult to date more accurately using only separated ^{14}C dates, but archaeologically most of them can be dated to the 5th- 4th centuries BC. The main question that arises is whether these monuments represent different stages in the development of one culture originating from the oldest Arzhan-1 monument, or whether the ancient population came from other territories to the Uyuk valley and accepted the same cultural traditions. This problem is still unsolved.

Environmental study

As mentioned above the settling of the territory under study begun only in the Middle Bronze Age and only traces of the Okunevo culture were found under the bottom of only buried soil discovered there, and the Arzhan-2 monument was constructed directly on the surface of that soil. During the Scythian time a lot of barrows appeared, which one can see even now. The arrival of the ancient nomads in this territory might be connected with environmental changes which probably made this place more attractive and favourable for their economy.

Evidence for climate change around 800 cal BC is evident; the change is probably related to a decline of solar activity (increase of cosmic ray intensity and therefore a sharp rise in atmospheric radiocarbon concentration (van Geel *et al.,* 1998; Dergachev *et al.,* 1999; Dergachev *et al.,* 2004).

To determine the character of the possible climate change in the Uyuk valley, sediment cores from two brackish lakes were collected in 2001-2002 at a short distance from the Arzhan monuments. The White Lake-1 and White Lake-2 (WL1 and WL2) are located respectively at 52°05'11" N; 93°42'18" E and 52°03'59" N; 93°43'40" E (**Fig. 1**). The deposits were collected with Russian and Dakhnovski samplers. A pollen diagram was produced (**Fig. 5**), the samples were analysed geochemically (**Fig. 7**), and ^{14}C dates were obtained. The dating results are presented in **Table 4**.

Unfortunately, two different White Lake-2 cores were used for the study: the first was used for pollen and geochemical analyses, and the second one was used for radiocarbon dating. The main reason is that the deposits of one core had a poor organic content. To correlate the results obtained, we studied pollen assemblages directly from the core used for radiocarbon dating between 20 and 50 cm. Comparing pollen data from both cores, we had to shift the date Le-6499 (3930±90) from the depth of 21-26 cm up to the depth of 28-33 cm.

In addition, in 2001 several profiles inside the Arzhan-2 monument were analysed (**Fig. 6**) and some ^{14}C dates were produced from organic materials.

The radiocarbon dates of the deposits from the Arzhan-2 monument are in **Table 5**.

From 33 samples of the longest core White Lake-2 (WL2), only 19 samples contained enough pollen for percentage calculations. Pollen preparation was processed in the University of Amsterdam following a standard method (Faegri and Iversen, 1989). An average of 507 pollen grains were counted in each sample. The results are given as a percentage diagram of selected taxa (**Fig. 5**). The percentages are based on a total pollen sum, excluding local aquatic taxa and spores.

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. This phase is characterized by a low frequency of tree pollen and the prevalence of xe-

Table 4. *The radiocarbon dates from humic acids of deposits from White Lakes (one and two).*

No.	Laboratory number	Material	Depth (cm)	^{14}C Age (BP)	Calibrated time intelvals (cal BC/AD)	
					1σ	2σ
WL1 1	Le-6195	humic acid	20-40	2090±100	360 BC- 20 AD	390 BC- 80 AD
WL2 2	Le-6499	humic acid	21-26	3930±90	2580-2290 BC	2900-2100 BC
WL2 3	Le-6501	humic acid	36-41	5840±50	4790-4670 BC	4850-4580 BC
WL2 4	Le-6502	humic acid	41-44	4670±400	3900-2900 BC	—
WL2 5	Le-6503	humic acid	44-49	6530±400	5800-5000 BC	—
WL2* 6	Le-6623	humic acid	22-35	2460±120	770-480 BC	850-200 BC
WL2* 7	Le-6624	humic acid	35-50	4360±150	3650-3100 BC	3700-2900 BC

Table 5. *The radiocarbon results for the deposits from Arzhan-2 monument*

No.	Laboratory number	Material	Location	^{14}C Age (BP)	Calibrated time intelvals (cal BC)	
					1σ	2σ
1.	Le-6219	charcoal	Outside the royal grave 5	3000±20	1300-1130	1370-1120
2.	GrA-18938	soil	Inside the royal grave 5	2530±70	800-520	810-410

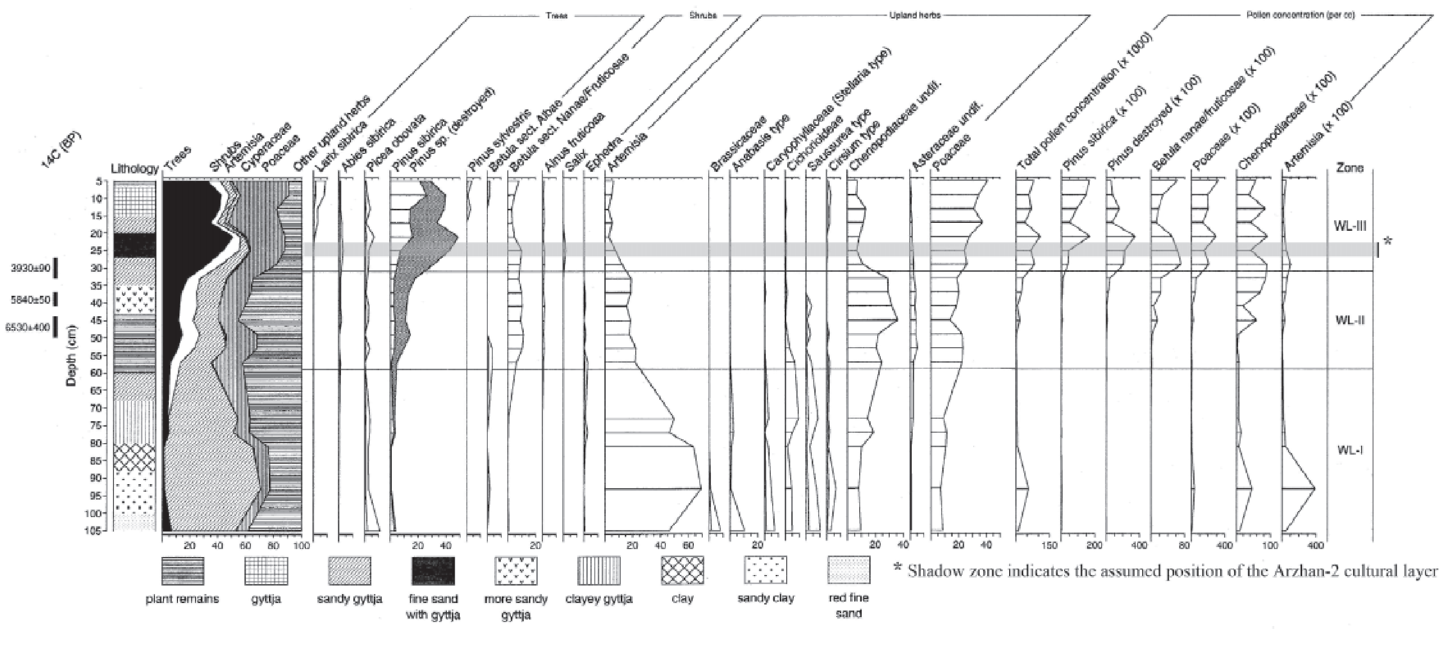

Fig. 5. *Pollen diagram of White Lake-2.*

rophytic taxa (*Chenopodiaceae* and *Artemisia*). 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. All these features indicate a persistence of stony steppe and desert-steppe within the valley and scarce forest or even tree-less conditions in the mountains under arid climate.

The remarkable change of xerophytic pollen dominance by moist-demanding taxa supported by a sudden rise in tree pollen frequency after *ca* 4 kyr BP is represented at WL-III zone. This evidence indicates a significant vegetation shift from semi-desert to herbaceous steppe within the valley, and a relatively rapid expansion of mountain forest. Both events undoubtedly reflect a strong humid impulse and an establishment of wetter climate. Moreover, the WL-III phase shows progressively increased pollen content indicating conditions optimal to denser vegetation cover. The highest concentration of shrub birch pollen at the WL-II/WL-III transition indicates that it seems to have been cold at the start of the wet period.

To determine the position of the Arzhan-2 cultural layer on the pollen diagram, we used the results obtained from the profiles that were sampled directly inside the monument. The pollen diagram (**Fig. 6**) is composed of 4 sets of samples representing the following stratigraphical levels:

1. A buried cultural level (1 sample) belonging to the Okunevo culture dated to 3000±20 BP (Le-6219);
2. The bottom of buried soil below the Arzhan-2 monument (2 samples);
3. The surface of buried soil (5 samples) directly connected with the Arzhan-2 barrow construction dated to 2530±70 BP (GrA-18938);
4. The modern surface (2 samples).

The low temporal resolution of the WL-2 sediment core did not allow us to make a direct correlation between the WL-2 pollen record (**Fig. 5**) and pollen data from the Arzhan-2 monument (**Fig. 6**). To determine a possible stratigraphical position of the monument on the WL-2 pollen record, we used the changes in tree-pollen curves taking into account the location of differences of both sites. These long-distance transported taxa have a regional significance, while the values of non-arboreal taxa are more variable and depending on the local environments. According to the Arzhan-2 pollen data, the total tree-pollen sum from the surface of the buried soil is higher than that from the Okunevo cultural level and lower than that from the modern surface. Based on these data, we suppose that the Scythian cultural layer corresponds stratigraphically to the lower part of the WL-III zone in the WL-2 pollen diagram which is characterized by the steep rise in tree pollen frequency and reflects increasing moisture.

The onset of a more humid than present climate correlates well with the beginning of Scythian cultures expansion to Asian steppe and forest-steppe at 9th century BC. An increased humidity in initially arid areas has provided a higher biomass production of steppe vegetation and more favourable living conditions for the stockbreeding nomads.

To reconstruct the environmental changes, geochemical analyses were also applied. The following methods were used:

The chemical composition of samples was obtained by means of ICP-OES, CNS analysis. The concentrations of following elements - Na, Ca, Mg, Al, Fe, Mn, P, Ti, Zn, Cu, Ni, Cr, Ba, Sr, S were determined by ICP-OES (PerkinElmer 5000) in ppm (mg/kg). The concentrations of sulphur, nitrogen and total carbon were determined by CNS analysis. The van Wesemael (1955) method was used for determination of carbon dioxide concentrations. A concentration of organic carbon in the samples was calculated according to the equation:

$$C_{org} = C_{tot} - C_{min} \quad (2.1)$$

where:

$$C_{min} = CO_2 \times 12/44 \quad (2.2)$$

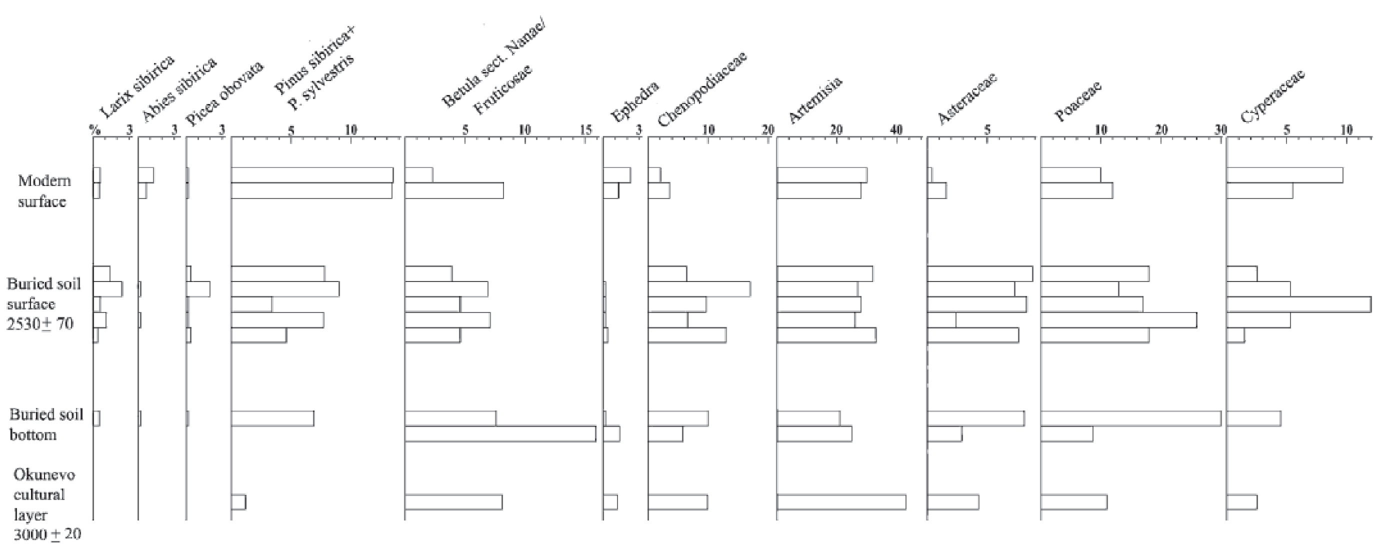

Fig.6. *Pollen diagram for the deposits under the Arzha-2 monument.*

For the determination of clay composition in the deposits an X-ray diffraction method was applied. Mineral composition was determined by IRS method. The granulometric composition of some samples was defined by means of grain-size analysis.

Statistical analysis was used to interpret 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 in parallel with the factor analysis data were applied as paleoclimatic markers.

We take into account that increasing of carbonate concentration in the lake deposits can be the result of photosynthesis and indicate the warm climatic condition (Peck *et al.*, 2002).

Besides, the carbonate/halide ratio in the alkaline lake deposits can be used as one of indicators of climatic humidity for arid zone (Volkova, 1998).

Three groups of elements were determined in the deposits of White Lake 2 (Koulkova, 2004):

1. A detrital (alumosilicate) element group, consisting of K, Al, Ti, Ba, Fe.
2. Sr, Ca, S, CO_2, N, C_{org} - a group consisting of carbonates, sulphates and organic complexes. Since all CO_2 is bounded by Ca into carbonate; the calcium excess combined with strontium constitutes sulphate complexes.
3. Sodium shows minor correlation with all elements; Na probably combines into halogen minerals. The halite evidence in the samples confirms this.

The results of the climatic reconstructions based on geochemistry display the following major fluctuations:

1. The period when the lower layers (135 - 95 cm) were deposited was characterized by a cool, dry climate and, based on the data of the granulometric analysis, the depth of the lake basin was rather low.
2. During the next period (95 - 58 cm), the climate was even colder but according to the granulometric composition, the lake level was relatively high. Some amount of organic material appears. The increase of carbonate amount, absence of halide minerals, and appearance of the clay minerals of smectit group testifies some increase of humidity.
3. During the following period (57-30 cm), one can observe a temperature rise and relatively dry conditions (shallow lake).
4. From the depth of 30 cm after 3900 BP the climate conditions were remarkably changed. Local organic production in the lake was increased about 10-20 times what indicates sufficient increase of humidity; the lake began to fill up. All these features did not allow us to estimate the level of temperature during this period.

One can see some discrepancies between geochemical and pollen data, especially on the upper part of WL-I pollen zone. Both analyses undoubtedly indicate a cold climate during this time. Nevertheless, the evaluations of precipitation are contrary to each other. This can be caused by the conditions that occurred at that time which have no modern analogies for the studied area. Indeed, according to pollen data a cold stony semi-desert and even a desert with scarce vegetation cover persisted there. The presence of such taxa as *Ephedra,* and first of all, *Anabasis* (**Fig. 5**) could confirm our assumption. Thus, the *Anabasi* species indicating an extremely continental condition are almost absent in the vegetation of Tuva now but were very common in the Mongolian stony deserts (Volkova, 1994). Therefore any geochemical markers of precipitation for these conditions could have another meaning. This requires additional research taking into account the results obtained.

For the steppe area, the most important role that the humidity played was influencing the biomass productivity which in turn was positively reflected in the nomad's economy based on cattle breading. According to the date obtained, one can conclude that only in the first millennium BC the climatic conditions in the Uyuk valley began to be more humid which promoted an increase of the density of population.

The Arzhan-1 barrow located in this region was constructed during the boundary of the 9th and the 8th century BC, and shortly after the Arzhan-2 monument dated to the 7th century BC was constructed. Later, the other Scythian barrows began to appear in different parts of Tuva, including the Uyuk valley.

One can suppose that the climate played a major role in the settlement history of Tuva. The Uyuk valley began to be more attractive for settling of the ancient nomadic communities. The nomads arrived in the Uyuk valley from other regions because the cultures belonged to the Neolithic-Beginning of Bronze Age cultures were not found here. In the Uyuk valley only single traces of the Middle Bronze Age (Okunevo) culture existence have been found but now it is impossible to determine regions from which the Scythian cultures came to the Uyuk valley and created the very impressive monuments as the Arzhan-1 and Arzhan-2.

Other interesting results concerning the environmental conditions were further explored by the osteological study of horse bones. These analyses showed that the lengths of such bones as femur, tibia, metacarpus and metatarsus from Arzhan-2 are rather greater than those from Arzhan-1 (Bourova, 2004). There are differences in the length of the long bones which can be reflected in the values of shoulder heights. The horses from Arzhan-2 were larger-bodied animals. The horses from Arzhan-1 were considerably smaller. There were even very small individuals of a shoulder height below 120 cm among them. First of all, probably, the differences in size are linked with the different environmental conditions. The larger metapodial indices indicate arid environments; the smaller indices characterize a more humid climate (Vitt, 1952). The decrease of the horse indices between the 9th – 7th centuries BC probably shows a climatic shift to more humid conditions. The climate condition can influence the vegetational system (biomass production), which could also be reflected by the animal size.

Based on the different analyses related to the study of the environmental conditions one can conclude that the main factor influencing the attractiveness of the Uyuk valley for settlement is an increased humidity. Most probably this process became more intense at the end of the 2nd and the beginning of the 1st millennium BC and the population who constructed the Arzhan-1 came to the Uyuk valley in that time. Later, the humidity continued to increase and the occupation of the Uyuk valley and neighbouring territories continued to spread.

3. CONCLUSIONS

During the Neolithic-Bronze Age the Uyuk valley in Tuva was predominantly unoccupied by ancient cultures. The oldest Scythian time monument in all Eurasia appeared in the Uyuk valley at the boundary of the 9th and the 8th century BC and probably stimulated the appearance of other Scythian monuments, among them the unique Arzhan-2 monument, dated to the middle of the 7th century BC, and Scythian time monuments dated to the 5th-4th centuries BC. It is impossible to say now anything about the interaction between them, although there are many analogies and similarities in the different artefacts and traditions. Increased humidity and the related biomass production as well as carrying capacity are likely to have been the main factors influencing the start of the early Iron Age occupation of the Uyuk valley in Tuva.

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