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CHRONOLOGY OF KEY BARROWS BELONGING TO DIFFERENT STAGES OF THE SCYTHIAN PERIOD IN TUVA (ARZHAN-1 AND ARZHAN-2 BARROWS)

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ABSTRACT. This paper focuses on the chronological study of 2 Scythian period monuments that are the key to the chronology of the entire Eurasian Scythian culture. These are the unique monuments of Arzhan-1 and Arzhan-2 in Central Asia (Tuva Republic). The dating of both these monuments began immediately after their discovery, but discussion about their chronological position is still current. Both monuments contained considerable wooden material from their construction suitable for dendrochronology and radiocarbon dating. The first results for the Arzhan-1 barrow were obtained by wiggle-matching in 2004–2005, while the Arzhan-2 barrow was first dated in 2003. It is now possible to compare the chronological position of these barrows using the same methods. As postulated earlier, Arzhan-1 is the oldest Scythian period monument and is dated to the boundary of the 8–9th centuries BC. The position of the Arzhan-2 monument stretches to the middle of the 7th century BC. $\delta^{13}C$ values for annual tree rings in logs from both barrows were also determined to gain a better understanding of the climatic conditions at the time of barrow construction.

INTRODUCTION

The Arzhan-1 and Arzhan-2 barrows are located in Central Asia in the Tuva Republic (Figure 1). In 1970, the famous Arzhan-1 barrow was discovered by Gryaznov (1980). This barrow is considered to be the earliest pre-Scythian or early Scythian monument in Eurasia, and it became the key monument for the study of all Eurasian Scythian cultures.

During 2001, a Russian-German research project discovered the Arzhan-2 monument in the Uyuk hollow, about 9 km from the Arzhan-1 barrow (Chugunov et al. 2002, 2004). This monument is unique because it had not been robbed or otherwise disturbed and appears untouched since its construction. The abundance and variety of well-preserved archaeological material in this monument has no equal among Eurasian Scythian monuments. Consequently, this monument plays an important role in understanding the history of the Eurasian Scythian nomads. Major questions concerning the origin, development, spread, and ways of life of the Scythian cultures still remain unanswered (Alekseev et al. 2001). The distance between these 2 monuments is about 9 km (Figure 1), but the question arises: what is the separation in time between them?

Both barrow complexes form a visual chain of the same type of artificial mounds. However, they differ to some extent in the architectural approaches to their construction. The schemes of their construction are presented in Figures 2A and 2B. There are some similarities in both monuments, notably the construction of the burial chambers. The main burial chamber of the central frame for Arzhan-1 was constructed with double walls filled with different materials outside and inside. Such

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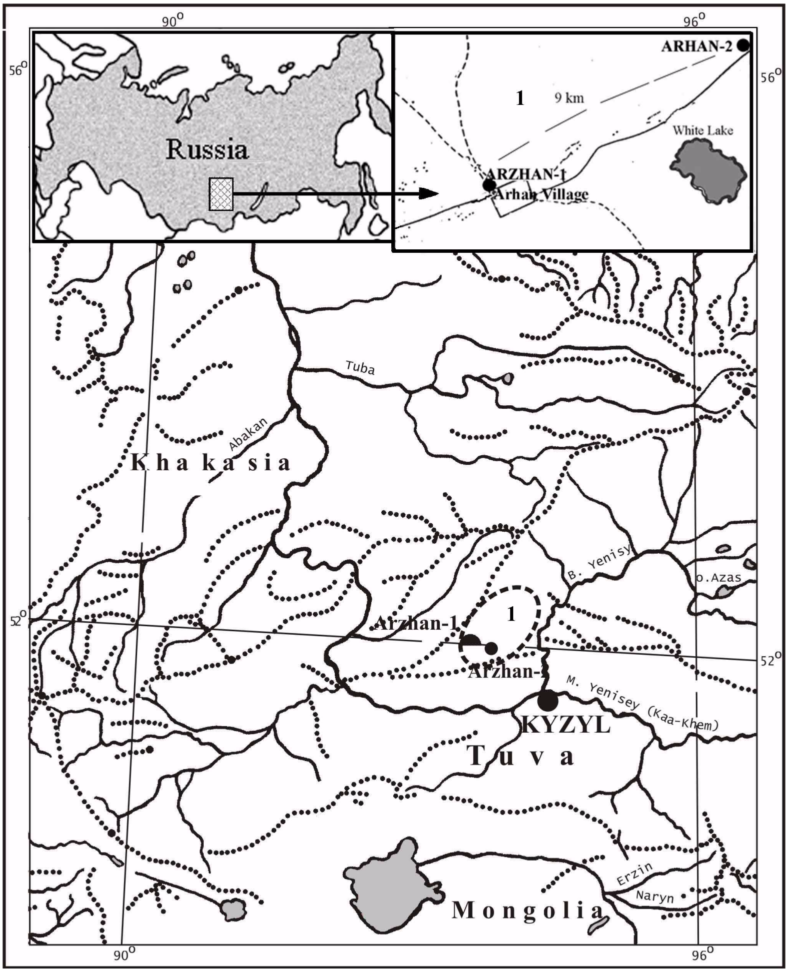

Figure 1 Map of the region under study: 1 - the Uyuk hollow.

a construction type can also be observed in the Arzhan-2 monument. The Arzhan-2 complex consists of 27 graves, but only 12 of them contain the bone remains of 18 people. In the Arzhan-1 monument, the bone remains of 16 people were found. Further, both monuments contain horse remains. In Arzhan-1, about 160 skeletons of horses were found in different chambers. In Arzhan-2, a special group horse burial was found with 14 horse skeletons. In both monuments, the horse skeletons were found with harnesses, which had similarities and differences. According to osteological research, one can assume that the horses of both barrows belong to the same breed group. However, the metapodial index shows evidence of differences in size. The Arzhan-1 horses were smaller than those from Arzhan-2. One reason for these differences could be different environmental conditions (Bourova 2004; Zaitseva et al. 2005); the larger metapodial indices (the Arzhan-2 monument) indicate an arid environment, while the smaller indices suggest a more humid climate (Vitt 1952).

According to Vitt (1952) and Gromova (1949), the appearance of differences in the size of horses may be determined by the stock management, which in the first instance may depend on forage reserves and ultimately on environmental conditions. Most probably, the climatic conditions during

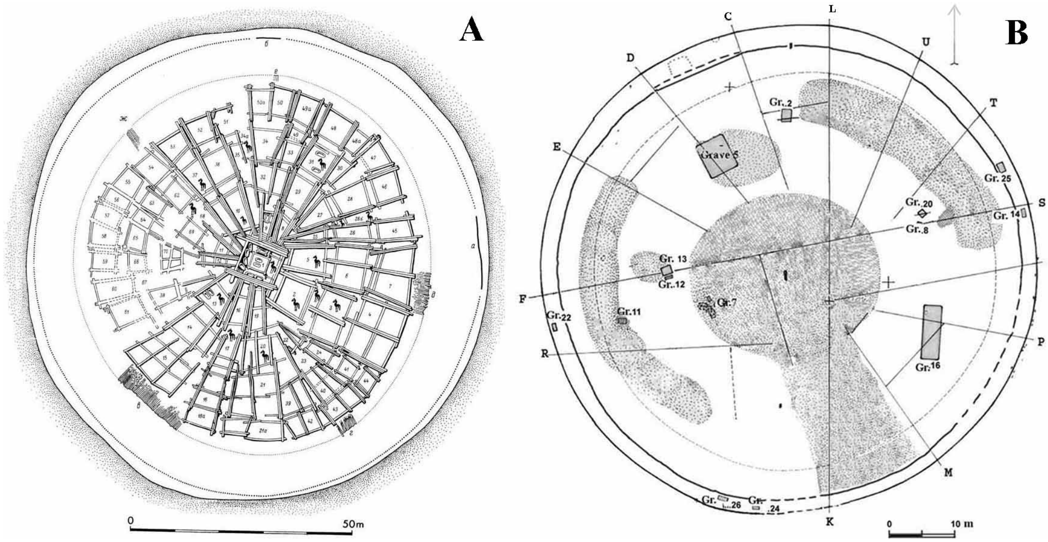

Figure 2 Peculiarities of the architectural style of the Arzhan-1 (A) and the Arzhan-2 (B) barrows

the Arzhan-2 period were more humid than during the Arzhan-1 period and the biomass of the steppe zone was higher, causing increased forage reserves, which thus promoted the increase in horse size.

Some very interesting differences appear in the fine art objects in both monuments. From 27 graves of the Arzhan-2 monument, only one of them, grave 5, is the main grave described as a "royal" grave where 2 skeletons (male and female) are buried, dressed in richly decorated clothes, with gold artifacts made in the typical Scythian animal style. The well-known bronze and horn examples of the animal style from the Arzhan-1 monument were not well represented in the artifacts within the Arzhan-2 monument. The sculptures of horse and sheep are differently presented in Arzhan-2 compared to Arzhan-1. The art of Arzhan-1 has its roots in the traditions of the Bronze Age (Savinov 2002), with the complex of Arzhan-1 representing the earliest stage of the pre-Scythian period.

Early results concerning the radiocarbon chronology of both barrows have been presented previously (Marsadolov 1988, 1997; Marsadolov et al. 1996; Chugunov et al. 2002; Zaitseva et al. 2004, 2005). In spite of these results, questions concerning the calendar date of these monuments remain open. Here, we summarize the results obtained previously and discuss new results produced in the last year.

RESULTS

The dating of both the Arzhan-1 and Arzhan-2 monuments began immediately with their discovery. The first ^{14}C dates for the Arzhan-1 monument were produced in the 1970s from well-preserved wooden remains from the barrow construction. The remarkable preservation state in this area is due to the continental climate; even during summer the interior of the graves can be cool. It is important that practically all the barrows were constructed from wood, and its good preservation means that separate tree rings can be identified. The floating tree-ring chronology for the Sayan-Altai Scythian period monuments was created by Marsadolov (1984). 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, 1988). The first attempts to use the "wiggle-matching" method were made at this time. However, the method had only been recently introduced into chronological studies, and so not all details could be taken into account. Only 4 ^{14}C determinations were produced from 2 different logs (Zaitseva et al. 1996). Using the tree-ring ^{14}C dates, a floating tree-ring chronology, and statistics, Arzhan-1 was dated to the interval 810–745 cal BC (Marsadolov 1984, 1988; Zaitseva et al. 1996, 1998). As the Arzhan-1 barrow is a key monument for the whole Eurasian Scythian chronology, not all archaeologists accepted these dates. Some of them dated this monument to the 8th–7th centuries BC (Chlenova 1972, 1997).

Wiggle-matching is therefore an important tool to resolve this disagreement, because the excavation of the Arzhan-1 barrow took place in 1970 and not all the wooden samples are held in the collection of the Institute for the History of Material Culture. Some logs from the Arzhan-1 barrow construction are stored in the Kyzyl Museum and this museum donated 1 log from their collection for further study. The log had approximately 67 tree rings and was well preserved, including the outer tree rings. It was subdivided into 10-yr sections, which were dated, and the $\delta^{13}C$ ratios were measured. The results are presented in Table 1.

Table 1 ^{14}C dates for tree rings from a log used in the construction of the Arzhan-1 monument used for wiggle-matching.

Nr	Lab nr	Nr of tree rings, counting from the center	$\delta^{13}C$ (‰)	^{14}C (BP)	Calibrated age intervals, cal BC 1 σ	2 σ
1	Le-6918	0–6	–22.60	2778 ± 16	975–900	1000–845
2	Le-6919	10–19	–23.05	2710 ± 20	895–820	905–810
3	Le-6920	20–29	–22.08	2717 ± 20	895–830	905–815
4	Le-6921	30–39	–22.60	2658 ± 20	825–800	840–790
5	Le-6922	40–49	–22.23	2659 ± 20	825–800	840–795
6	Le-6923	50–59	–23.11	2641 ± 20	815–795	830–790

To match the ^{14}C determinations for the tree-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 samples from the log. The results are presented in Figure 3. The reliability of these results has been checked mathematically using a χ^2 criterion (Figure 4). The results from the wiggle-matching showed the best estimate of the construction date of the Arzhan-1 barrow to be 795 cal BC (787–801 cal BC). We then decided to reconsider the analyses of the ^{14}C determinations made in the 1970s. Two logs were used for these determinations: D38 (80 tree rings) and D36 (126 tree rings). The ^{14}C results were published in Zaitseva et al. (1997). We assumed that these tree-ring samples had the same age and most probably that sample D36 corresponded to dendroseries 90042 and sample D38 to 90040 from the collection of I Slusarenko. Taking into account isotopic fractionation, wiggle-matching was performed, the results of which are shown in Figure 5. According to the results obtained, the most probable time of the barrow construction is 788 cal BC. The discrepancy between the 2 results (795 and 788 BC) is within the statistical error.

Thus, the Arzhan-1 monument construction can be practically dated to the boundary of the 8th to 9th centuries BC as earlier assumed; it remains the earliest Scythian (perhaps pre-Scythian) period monument in all Eurasia and assumes the key chronological position for the entire Scythian world.

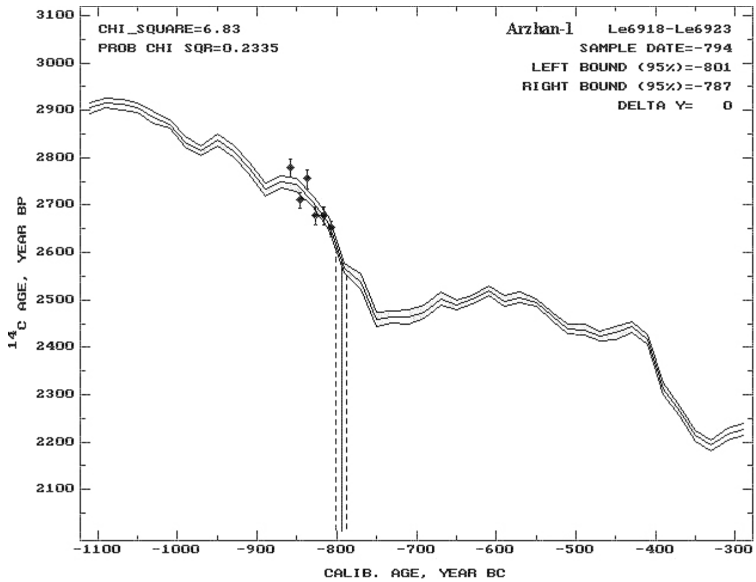

Figure 3 Correlation of the ^{14}C data produced in 2004–2005 with the calibration curve. The ^{14}C dates lie on the linear part of the curve.

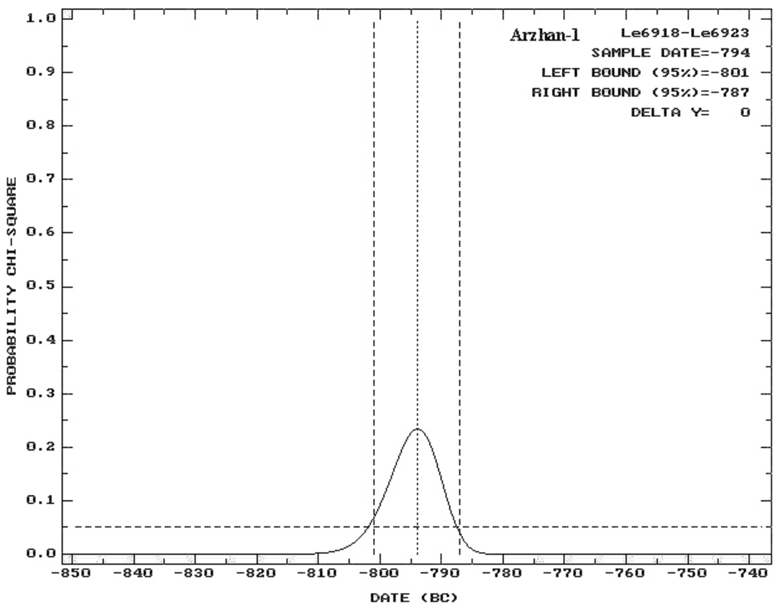

Figure 4 The reliability of the estimated date of the Arzhan-1 barrow construction. The dotted vertical lines are the position of the most probable data; the right and left confidence limits are 787 and 801 BC; and the dashed horizontal line corresponds to a probability of 0.05.

The main grave (nr 5) of the Arzhan-2 monument also contains wooden construction materials: the covering, the double walls, and the well-preserved floor. In 2001, before the reconstruction of the chamber, one of these logs (D3) containing 133 rings from the covering was used for ^{14}C dating and dendrochronology. The results of the ^{14}C dating are presented in the Table 2.

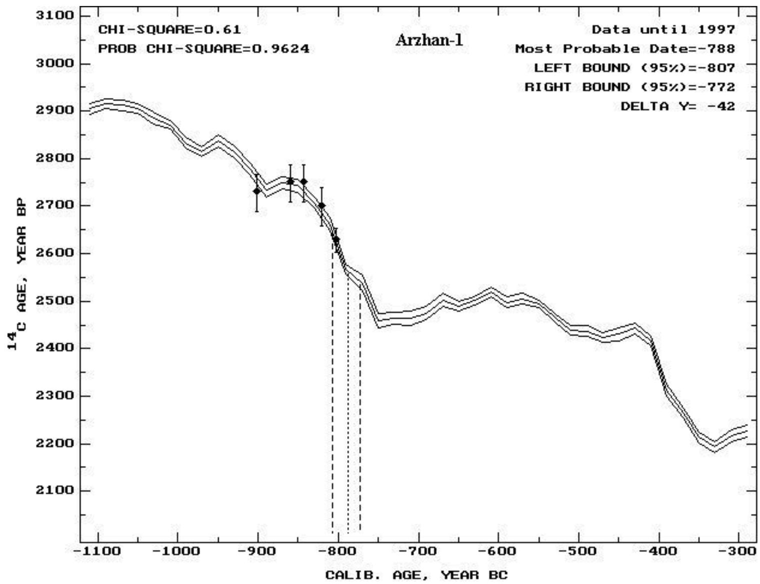

Figure 5 Correlation of the ^{14}C data produced in 1970 with the calibration curve

Table 2 ^{14}C age for the tree-rings samples for the covering log (D3) produced in 2001.

Nr	Lab nr	Tree rings, counting from the center	^{14}C age (BP)	Corrected ^{14}C age[a] (BP)	Calibrated age intervals, cal BC 1 σ	Calibrated age intervals, cal BC 2 σ
1	Le-6260	0–20	2635 ± 60	not used for the study		
2	Le-6261	21–30	2444 ± 50	2515 ± 50	800–540	800–410
3	Le-6262	31–40	2421 ± 24	2492 ± 24	770–540	790–510
4	Le-6263	41–50	2359 ± 18	2430 ± 18	540–400	760–400
5	Le-6264	51–60	2390 ± 18	2461 ± 18	760–410	770–410
6	Le-6265	61–70	2400 ± 18	2471 ± 18	770–510	770–410
7	Le-6266	71–80	2391 ± 18	2462 ± 18	760–410	770–410
8	Le-6267	81–90	2420 ± 18	2491 ± 18	770–540	780–510
9	Le-6268	91–100	2327 ± 18	2398 ± 18	520–400	760–390
10	Le-6269	101–127	2437 ± 21	2508 ± 21	770–540	790–520

[a]We used a specially calculated coefficient to correct the ^{14}C age because the $^{13}C/^{12}C$ ratio could be not measured in the lab at that time.

The first chronology for this monument was obtained using wiggle-matching, and showed that its construction could be dated to the calendar interval 670–625 cal BC at 2 σ (Chugunov et al. 2004). After reconstruction of the chamber, logs from the walls could then be used. Log C3 from the internal wall with 150 rings was used for this new study. This log was subdivided into sections of 10–20 tree rings, which were dated in the ^{14}C laboratory of the Institute for the History of Material Culture (St. Petersburg) using liquid scintillation spectrometry (Zaitseva et al. 1999). The results are presented in Table 3.

Table 3 ^{14}C dates for the tree-ring samples for log C3 from the internal wall.

Nr	Lab nr	Tree rings, counting from the center	^{14}C age (BP)	Corrected ^{14}C age (BP)[a]	Calibrated age intervals, cal BC	
					1 σ	2 σ
1	Le-6561	1–10	2435 ± 20	2518 ± 20	790–550	800–540
2	Le-6562	11–30	2408 ± 20	2505 ± 20	770–540	790–520
3	Le-6563	31–50	2409 ± 18	2475 ± 18	770–520	770–410
4	Le-6564	51–70	2354 ± 16	2462 ± 16	760–410	770–410
5	Le-6565	71–90	2419 ± 16	2485 ± 16	770–540	770–510
6	Le-6566	91–100	2391 ± 16	2506 ± 16	770–540	790–540
7	Le-6567	101–110	2458 ± 20	2503 ± 20	770–540	790–520
8	Le-6568	111–120	2377 ± 16	2488 ± 16	770–540	770–510
9	Le-6569	121–130	2374 ± 16	2473 ± 16	770–510	770–410
10	Le-6570	131–140	2408 ± 20	2471 ± 20	770–510	770–410
11	Le-6571	141–150	2401 ± 15	2495 ± 15	770–540	780–520

[a]We used a specially calculated coefficient to correct the ^{14}C age because the $^{13}C/^{12}C$ ratio could be not measured in the lab at that time.

Comparing the dating results of the 2 logs (Tables 2 and 3), one can see that the ^{14}C ages lie practically in the same interval, but the range of the ^{14}C dates falls on a plateau of the calibration curve, making it difficult to determine the position of this monument on the calendar timescale. Because the period around 2700–2500 BP is characterized by global climatic changes caused by variations in solar activity and consequently cosmic-ray intensity (van Geel et al. 1998), the effects of these are reflected in both the shape of the calibration curve and in isotopic fractionation. $\delta^{13}C$ is not measured in the Laboratory of the Institute for the History of Material Culture and so is not included in the calculation of the ^{14}C age. Therefore, a correction factor, taking systematic errors into account, was calculated. The systematic errors in our case result from instrumental error and isotopic fractionation. Therefore, to correct the ^{14}C ages we used a method of low-frequency filtering to exclude the high-frequency noise, which can be linked with the influence of sharp climatic changes in this period (Dergachev et al. 2001). A similar approach was used for the dates of both logs (D3 and C3). The corrected ages are presented in both Tables 1 and 2. These corrected values of the ^{14}C ages were used in the assessment of the concordance of the dates with the calibration curve using a statistical approach. The dates of the ^{14}C ages are located on the calibration curve in order to minimize the statistic χ^2_{n-1}, where n is the number of samples from the log. The results are presented in Figures 6 and 7. The mathematical estimation of the reliability of this match is presented in Figure 8.

In 2005, another log from the burial chamber of grave 5 was used for wiggle-matching. In this case, the $\delta^{13}C$ values were measured in the University of Helsinki on individual rings and used for correcting the ^{14}C dates. The results are presented in Table 4.

The correlation of the dates obtained with the calibration curve and the coincidence probability of the results are presented in Figures 9 and 10. In this case, the calendar age range is 693–464 cal BC, much wider than for the D3 and C3 logs (Figure 8). Such a difference could be explained by the following: the ^{14}C dates lie on the plateau and, more importantly, the number of tree rings from M5 is not sufficient for a precise determination (~93 tree rings). A summary of both earlier and new results for the calendar age intervals for grave 5 of the Arzhan-2 monument is presented in Table 5.

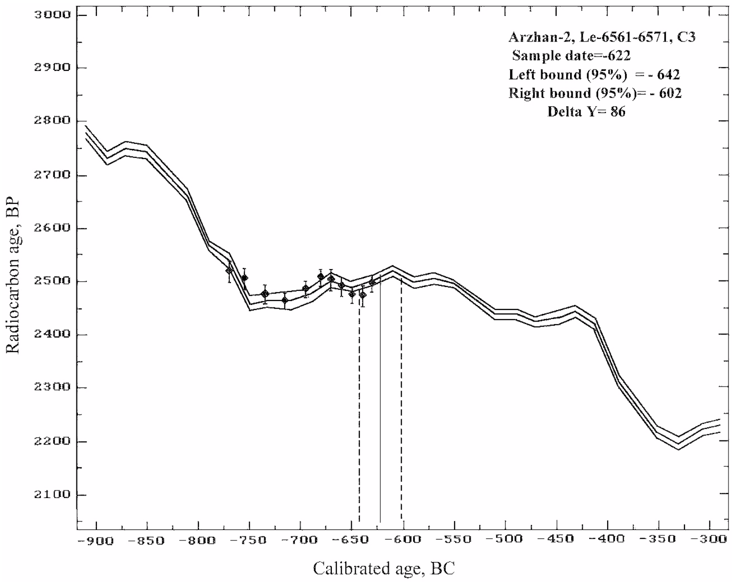

Figure 6 Correlation of the ^{14}C data produced for log C3 of the Arzhan-2 barrow, grave 5, with the calibration curve. The ^{14}C dates lie on a plateau of the calibration curve. The age is 622 BC with confidence limits of 642–602 BC.

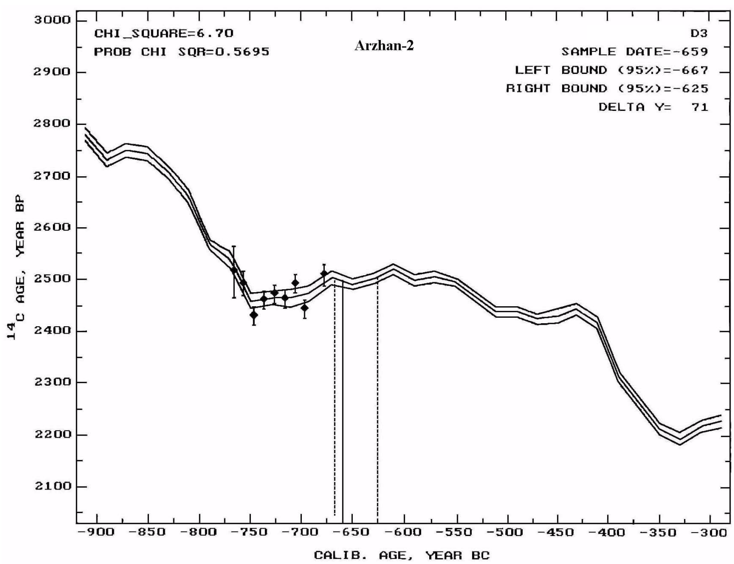

Figure 7 Correlation of the ^{14}C data produced for log D3 of the Arzhan-2 barrow, grave 5, with the calibration curve. The age is 659 BC with confidence limits of 667–625 BC.

According to all the results obtained, one can conclude that the construction of grave 5 of the Arzhan-2 monument occurred in the middle to the end of the 7th century BC (the most probable ages are 622, 659, and 634 cal BC).

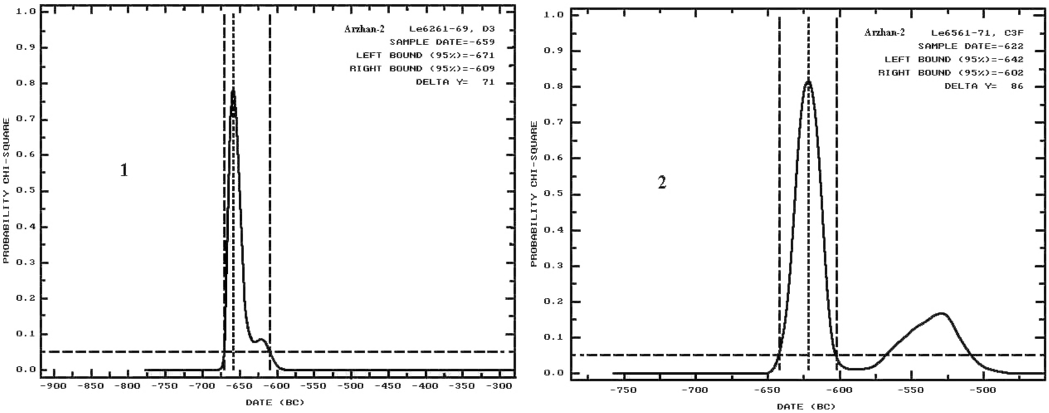

Figure 8 Reliability of the estimated date of the Arzhan-2 barrow construction: 1 - log C3; 2 - log D3.

Table 4 The ^{14}C dating results for the log (M5) from the inner part of the chamber, grave 5, Arzhan-2 monument.

Nr	Lab nr	Nr of rings, counting from the center	δ^{13}C (‰)[a]	^{14}C age (BP)	Calibrated age intervals, cal BC 1 σ	2 σ
1	Le-7114	1–10	–23.7	2440 ± 30	760–410	770–400
2	Le-7415	11–20	–23.5	2437 ± 50	760–400	770–400
3	Le-7416	21–30	–22.5	2444 ± 25	760–410	770–400
4	Le-7417	31–40	–22.9	2574 ± 30	810–670	820–540
5	Le-7418	41–50	–22.2	2444 ± 30	760–410	770–400
6	Le-7419	51–60	–22.0	2472 ± 30	770–510	770–410
7	Le-7420	61–70	–22.1	2462 ± 25	760–410	770–410
8	Le-7421	71–80	–22.3	2456 ± 40	760–410	770–400
9	Le-7422	81–90	–22.5	2408 ± 35	760–400	760–390

[a]δ^{13}C was calculated as an average of the results for the individual tree rings.

The calendar interval for the construction of Arzhan-1 is 795–788 cal BC (Figures 4, 5). Thus, summarizing the results obtained, the time separation between the construction of Arzhan-1 and Arzhan-2 is >130 yr. The ^{14}C dates for the Arzhan-1 monument lie on a linear (proportional) part of the calibration curve (Figures 4, 5), while the ^{14}C dates for the Arzhan-2 monument fall on the so-called Hallstatt plateau (Figures 7–10). The end of the linear part of the calibration curve is ~750 cal BC, suggesting that the construction of Arzhan-1 cannot be younger than this age.

δ^{13}C VALUES IN ANNUAL TREE RINGS OF THE ARZHAN-1 AND ARZHAN-2 MONUMENTS

The period of the plateau in ^{14}C around 2700–2500 BP is characterized by global climatic changes caused by both solar and cosmic-ray activity (van Geel et al. 1998), and the effects of these are reflected in both the shape of the ^{14}C calibration curve and in the stable isotope values. δ^{13}C measurements made on single tree rings from the logs of Arzhan-1 and for log M5 of Arzhan-2 produced interesting results. In spite of the fact that δ^{18}O is mostly used for the determination of relative temperature, some information about temperature and humidity can also be obtained from the δ^{13}C values in living organisms (Helle and Schleser 2004). The results presented in Figure 11 reflect the dependence of the δ^{13}C value on the number of annual rings from the center of the log. From this

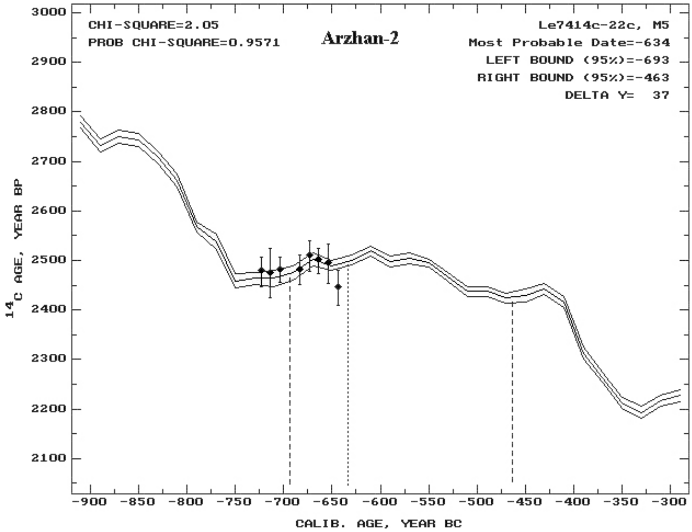

Figure 9 Correlation of the ^{14}C data produced for log M5 from Arzhan-2 barrow, grave 5, with the calibration curve. The age is 643 BC with confidence limits of 693–467 BC.

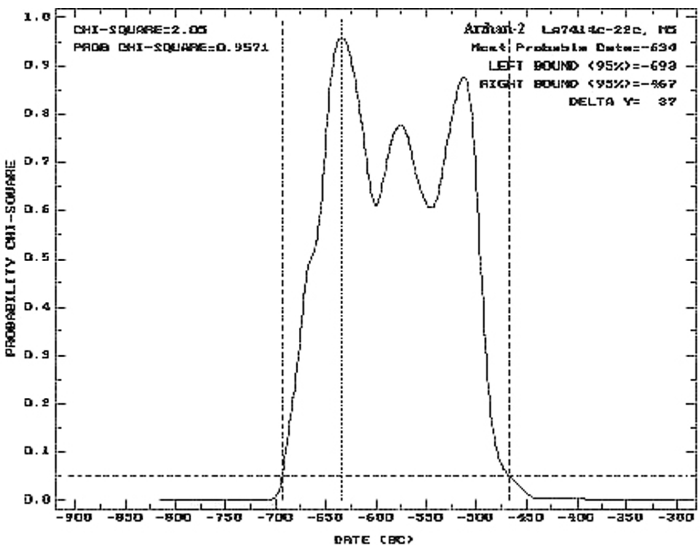

Figure 10 The reliability of the estimated construction date of the Arzhan-2 barrow (log M5).

Table 5 Calendar time intervals (cal BC, 2 σ) for the construction of grave 5 of the Arzhan-2 monument.

Log C3			Log D3			Log M5		
Left-bound	Most probable age	Right-bound	Left-bound	Most probable age	Right-bound	Left-bound	Most probable age	Right-bound
642	622	602	667	659	625	693	634	464

figure, one can see a difference between Arzhan-1 and Arzhan-2: the $\delta^{13}C$ values in the log from Arzhan-2 fluctuate more than in the log from Arzhan-1. Further analysis was then undertaken, assuming first that the logs were felled and prepared close to the time of the barrow construction and that the wooden materials were taken from similar places in spite of the time separation (~130 yr) between the 2 monuments. First, a global trend was subtracted from the data. The residuals of the series obtained after trend removal are shown in Figure 12. Detrended data were then used for the calculation of the power spectrum (Figure 13). A long-term component changing on the timescale of 100 yr or so is observed. The variance of the residual data of Arzhan-2 is 0.52‰, which is twice that for Arzhan-1. The standard deviation for Arzhan-1 is 0.51‰ compared to 0.72‰ for Arzhan-2. The power spectrum of the data is characterized by the presence of spectral lines with periods of several years up to 22–24 yr. In the power spectrum of Arzhan-1, one line with a period of ~24 yr is predominant. In the power spectrum of Arzhan-2, one can observe several lines with periods: 21.7, 8.54, 4.95, 3.56, and 2.78 yr. The frequencies of the lines selected from the power spectrum of Arzhan-2 follow an equidistant succession determined by the formula $\omega = 0.046 + k \times 0.08$, $k = 0...4$, where k is number of harmonics, and all parameters have the dimension *cycles per year* (Figure 14).

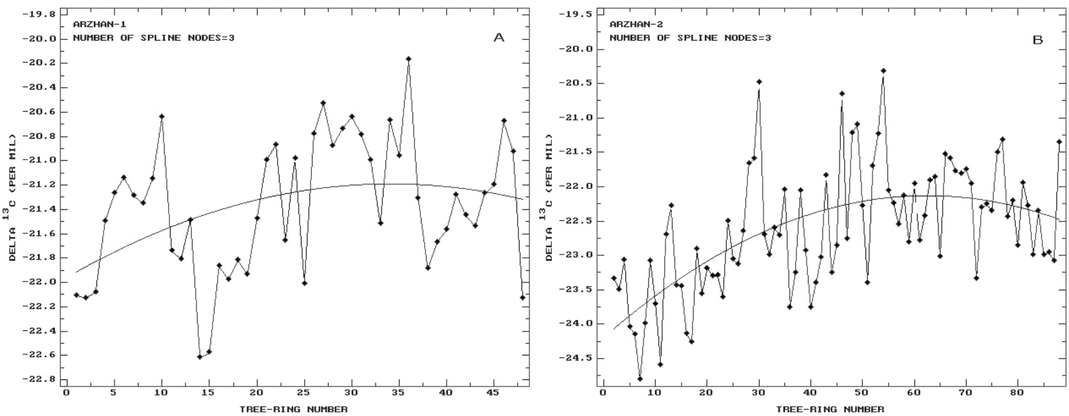

Figure 11 Dependence of the $\delta^{13}C$ values on the ring number counting from the center of the log. The smooth curve is the long-term component of the ratio. This is a cubic spline drawn through 3 nodes by the least-squares technique: A - Arzhan-1; B - Arzhan-2.

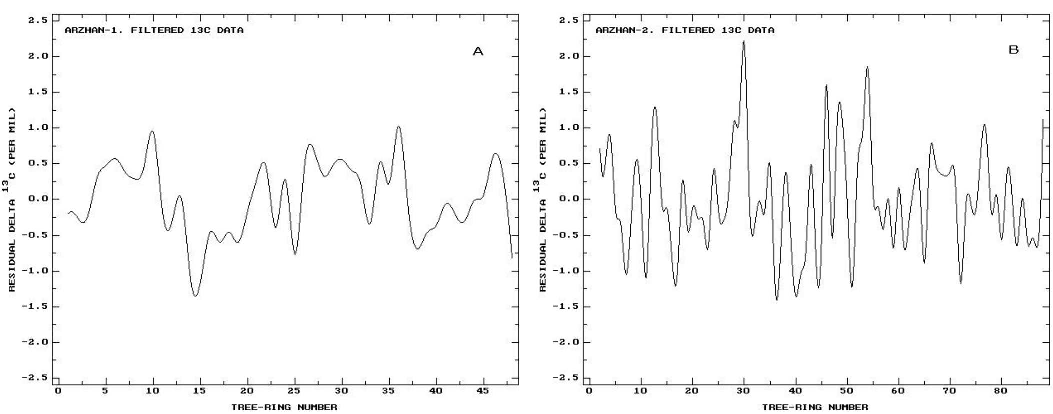

Figure 12 Detrended $\delta^{13}C$ data. Residual series for $\delta^{13}C$ after trend removal: A - Arzhan-1; B - Arzhan-2.

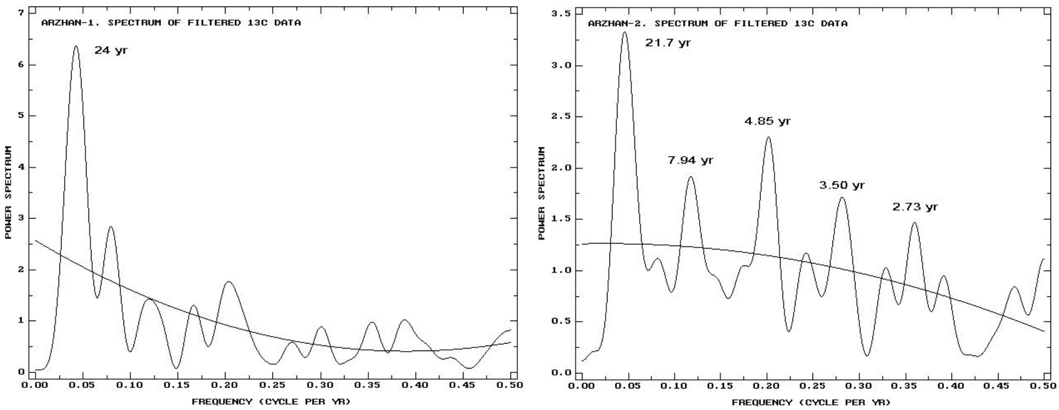

Figure 13 Power spectrum for the $\delta^{13}C$ data after trend removal. The smoothing curve is the average level of the spectrum. This curve is a cubic spline drawn through 3 nodes by the least-squares technique: A - Arzhan-1; B - Arzhan-2.

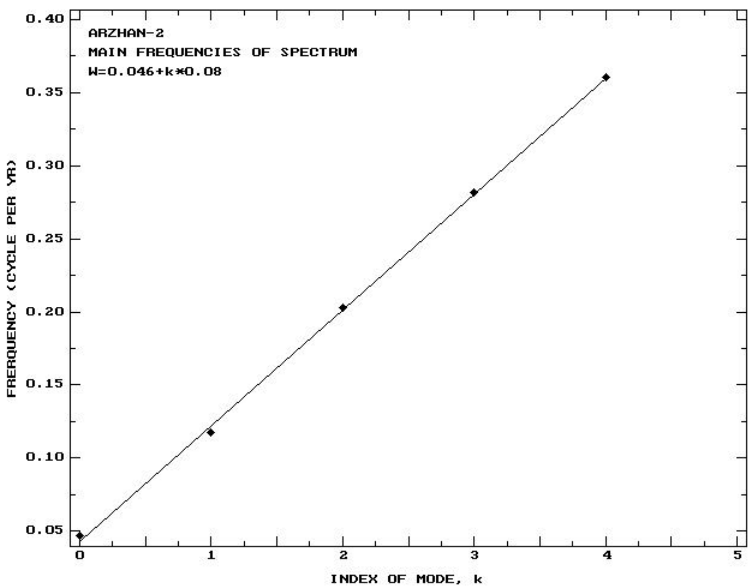

Figure 14 Frequency of selected lines from the power spectrum for the Arzhan-2 data. They form an equidistant succession determined by the formula $\omega = 0.046 + k \times 0.08$, $k = 0...4$, where k is the number of harmonics and all parameters have the dimension *cycles per year.*

The power spectrum for Arzhan-2 has fluctuations with several frequencies, and the dispersion of the data is relatively high. According to the frequency values in the spectrum (0.46^{-1} = 21.7 yr and 0.08^{-1} = 12.5 yr), these correspond to cycles of solar activity (22 and 11 yr). Thus, the time period covered by the samples from Arzhan-2 (~7th century BC) could be characterized as showing an impact of solar factors, influencing the ^{13}C fractionation. Together, the spectra obtained suggest that the conditions under which the trees grew for Arzhan-1 and Arzhan-2 differed, providing further confirmation that ^{14}C dates for Arzhan-1 and Arzhan-2 would lie on different sections of the calibration curve. We can identify the differences in the environmental conditions, but not the cause of these differences (e.g. temperature, humidity). This latter analysis requires other methods, including pollen analysis (Zaitseva et al. 2004).

CONCLUSIONS

The positions of the Arzhan-1 and Arzhan-2 monuments were determined on the calendar timescale using wiggle-matching of ^{14}C dates. New data for these monuments were obtained and led to a reconsideration of the data produced in the 1970s. Now, it appears highly likely that the Arzhan-1 barrow was constructed on the boundary of the 8th–9th centuries BC, while the Arzhan-2 barrow, main grave 5, was erected in the middle to end of the 7th century BC.

For the first time, the $\delta^{13}C$ values in individual tree rings were measured for logs from the Arzhan-1 and Arzhan-2 barrows. These data confirmed that different environmental conditions prevailed in the 2 periods of barrow construction, with a suggestion that the climate was more stable during the Arzhan-1 construction period compared with Arzhan-2. This is confirmed by their positions on different sections of the calibration curve.

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