A TREE-RING AND ^{14}C CHRONOLOGY OF THE KEY SAYAN-ALTAI MONUMENTS

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ABSTRACT. We present a radiocarbon chronology of key Sayan-Altai monuments from the Scythian period, based on a statistical analysis of dates produced in the 1980s and now supplemented with new dates. These new ^{14}C dates were produced for samples from the Tuekta-1 barrows (burial mounds) and were measured both in St. Petersburg and Groningen. These tree-ring samples were fitted to the calibration curve. Chronologies were established for the Arzhan, Tuekta-1 and Pazyryk-5 barrows. The time of the construction of the Arzhan and Pazyryk-5 barrows is the 9th and late 5th–4th centuries BC, respectively, and agrees with archaeology. According to new data obtained, the time of the Tuekta-1 barrow construction is some years older than has been accepted thus far by archaeologists.

INTRODUCTION

Since their discovery, the well-known great barrows (burial mounds) of the Sayan-Altai have been the focus of researchers from several disciplines. The finds from these barrows allow us to solve important problems relating to the origin, development and spreading of Scythian-Sarmathian cultures in Eurasia. Figure 1 shows the locations of the barrows. The Pazyryk group and the Tuekta-1 barrow are located in the Gornyi Altai region of Southern Siberia, and the Arzhan barrow is located in Tuva (Central Asia).

Investigation of the barrows started in the mid-19th century and results have been published by several researchers (Gryaznov 1950, 1992; Mandelshtam 1992; Marsadolov 1996). Chronological problems have been discussed for more than 50 years. Rudenko (1953, 1970) and Kiselev (1951) believed that the Pazyryk barrows dated between the 5th and 3rd centuries BC. However, this position has been controversial.

Some archaeologists supported Rudenko's view that the Pazyryk barrows date from the Scythian period (5th century BC). Others believed that these barrows dated from Hun-Sarmathian time (3rd century BC), following Kiselev. Later, others reconsidered and agreed with Rudenko's opinion that the Pazyryk barrows dated from the 5th–4th centuries BC (Smirnov 1964). Up to the present, others have believed that these barrows date from the 4th, 3rd or even the 2nd century BC (Moshkova 1992).

Thus, the chronological periods suggested by researchers range from the 6th to the 2nd centuries BC, a span of *ca.* 500 yr. According to dendrochronological data, 5 Pazyryk great barrows were erected over a 50-yr period (Marsadolov 1984, 1996). The discussion of the barrows' chronology was revived at meeting ("Transformed and Transferred Images in East and West Asia") held in the United States in 1990 (Schneider 1991). Based on the similarity of these barrows with finds from Chinese monuments (the textile decoration and the animal styles from different objects), the Pazyryk barrows were believed to be from the end of the 4th to the beginning of the 3rd century BC (Chugunov 1993).

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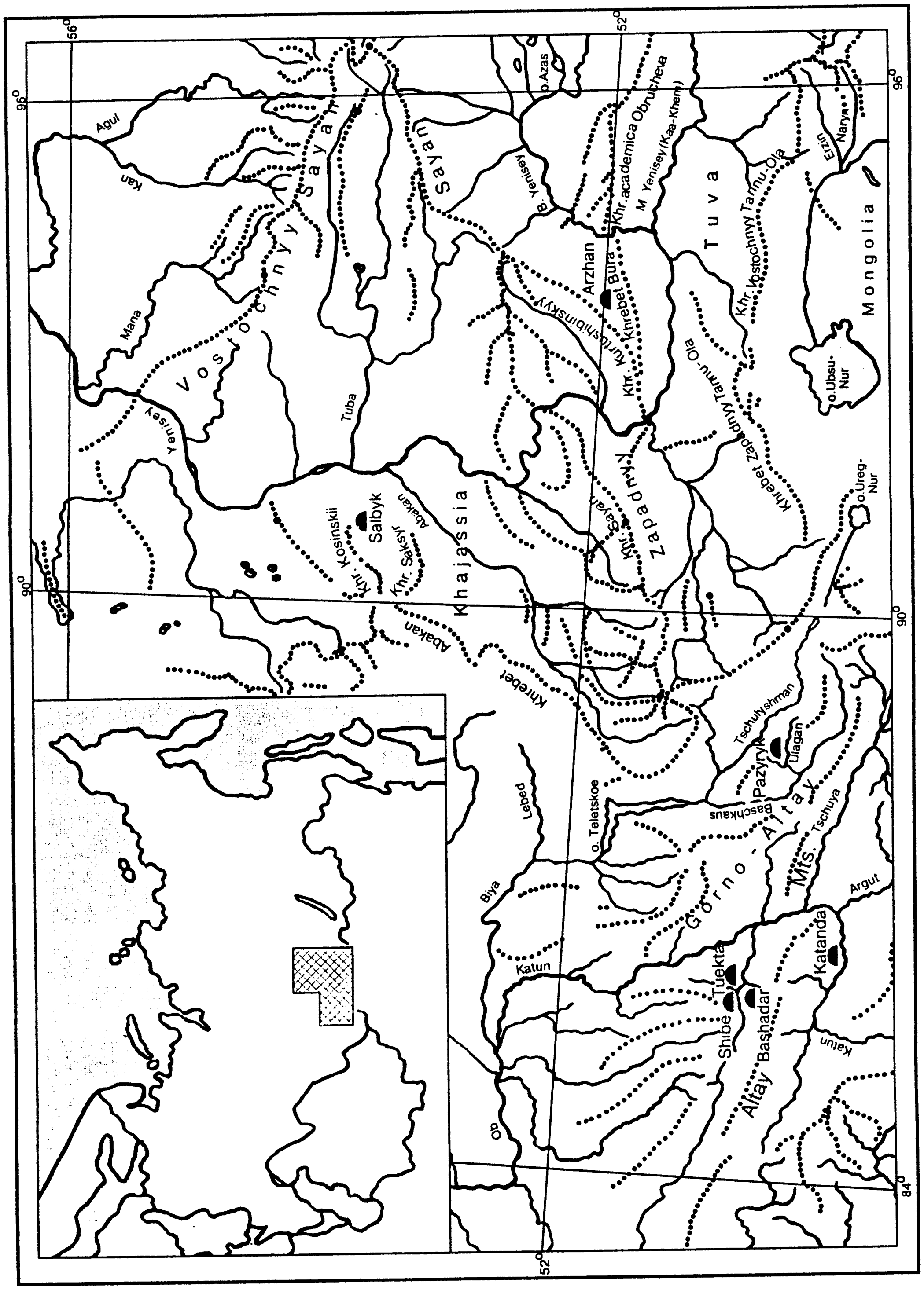

Fig. 1. Location of the investigated barrows in Southern Siberia

A similar controversy involved the chronology of the tsar barrow Arzhan, excavated in 1971–74 by M. Kh. Mannay-oola and M. P. Gryaznov (Gryaznov 1980). These archaeologists dated the Arzhan to between the 9th and 6th centuries BC. Although most researchers believe that the barrow was constructed in the 8th century BC, recent publications established a date of the 7th century BC (Chugunov 1993; Chlenova 1996), but there is no convincing proof. Dating by dendrochronology and/or radiocarbon should resolve these problems with the chronologies.

The first ^{14}C dates for these barrows were produced in the 1960s (Butomo 1965; Rudenko 1970; Dolukhanov 1970). A tree-ring chronology, spanning *ca.* 600 yr, was established between 1950 and 1980 (Zamotorin 1959; Zakharieva 1976; Marsadolov 1988, 1987). It is a floating chronology that was connected with the calendar time scale by a series of ^{14}C dates produced from different parts of this tree-ring scale (Markov 1987). In addition, Marsadolov attempted to correlate the tree-ring and ^{14}C data from the Sayan-Altai monuments with one of the first calibration curves constructed by Ralf *et al.* (1973). The zero position (starting point) of the floating tree-ring scale was determined to be 360 ± 40 yr BC (Marsadolov 1987, 1988). Later, the recommended calibration curves (Stuiver and Pearson 1986) resulted in a more accurate date: 400 ± 40 yr BC (Marsadolov 1994, 1996). Confidence levels based on a statistical analysis were obtained by Zaitseva *et al.* (1996, 1997). Here we present new and more precise results, measured in 1996, for samples from the floating tree-ring scale for the Arzhan and Tuekta-1 barrows. These data are used to construct the best chronology possible thus far.

Results and discussion

Figure 2 shows the floating tree-ring chronology of the great barrows of Sayan-Altai. The tree-ring samples for which ^{14}C dates were obtained are indicated as black bars. The zero position of the floating tree-ring scale is placed here at 360 BC, being the youngest possibility (Marsadolov 1988, 1994, 1996; Zaitseva 1996). Table 1 presents the complete set of ^{14}C dates measured for the barrows. In the table, the tree-ring numbers correspond with those shown in Figure 2. Also listed are calibrated results that we obtained with the Groningen calibration program (van der Plicht 1993). The ^{14}C measurements made in the 1980s are now supplemented with measurements produced in 1996: the Tuekta-1 barrow was dated both in Groningen (conventional) and St. Petersburg (LSC). The samples dated in Groningen were single tree rings; samples dated in St. Petersburg generally contained five tree rings.

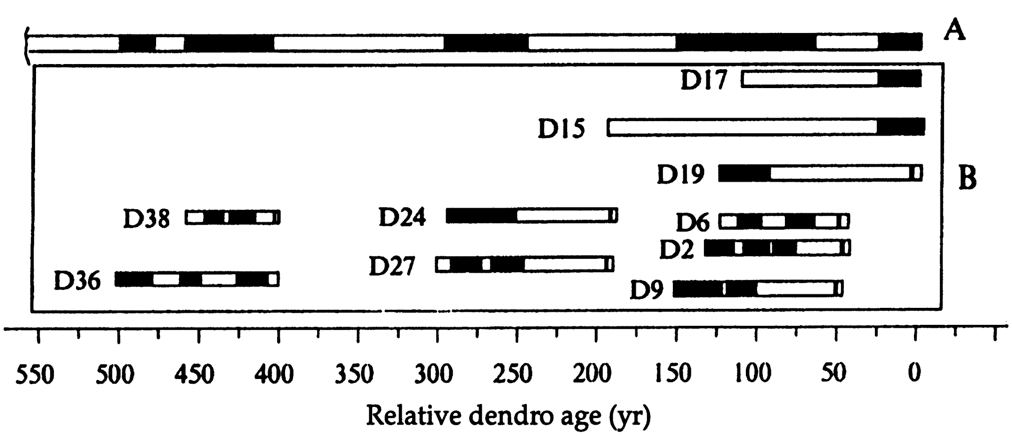

Fig. 2. Outline of the floating tree-ring scale for the great barrows of the Sayan-Altai. A = master floating chronology; B = trees ^{14}C dated in this study; D = number of log from tree-ring scale (Table 1); ▬ = the span of ^{14}C-dated samples.

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TABLE 1. ^{14}C Dates for the Great Barrows of Sayan-Altai Using the Mathematical Statistical Method

Lab no.	^{14}C age (BP)	Dendro sample no., total tree rings	Ring(s) dated, counting from center of log	Age intervals (cal BC) 1 σ	Age intervals (cal BC) 2 σ
Arzhan					
Le-2449	2740 ± 40	D-38, 80 tree rings	36–60	904–834	982–966 934–810
Le-2444	2790 ± 40	D-38, 80 tree rings	15–35	990–954 942–898 874–852	1008–834
Le-2452	2790 ± 40	D-36, 126 tree rings	48–60	990–954 942–898 874–852	1008–834
Le-1698	2770 ± 40	D-36, 126 tree rings	1–25	974–972 930–840	992–826
Le-5184*	2670 ± 25	D-36, 126 tree rings	97–126	826–806	890–888 844–798
Le-5195a*	2700 ± 20	50 tree rings	39–50	840–814	898–875 852–808
Le-5195b*	2750 ± 30	50 tree rings	21–38	906–890 888–844	928–818
Le-5195v*	2680 ± 40	50 tree rings	1–20	892–884 844–802	900–798
Tuekta-1					
Le-2450	2490 ± 40	D-27, 1 19 tree rings	31–60	764–752 730–710 708–618 606–528	778–478 452–414
Le-2447	2540 ± 40	D-24, 113 tree rings	31–50	794–760 678–658 634–552	802–750 734–526
Le-5177*	2510 ± 60	D-24, 113 tree rings	1–10	782–752 728–714 704–530	796–476 456–414
Le-5178*	2490 ± 50	D-24, 113 tree rings	11–15	766–750 734–612 610–528	782–474 458–412
Le-5179*	2420 ± 50	D-24, 113 tree rings	16–20	752–726 722–702 530–402	762–628 598–570 562–394
Le-5180*	2420 ± 35	D-24, 113 tree rings	21–25	746–742 524–404	760–678 656–638 548–396
Le-5181*	2440 ± 35	D-24, 113 tree rings	26–30	752–728 718–702 530–410	762–670 666–630 594–576 558–402

TABLE 1. (Continued)

Lab no.	^{14}C age (BP)	Dendro sample no., total tree rings	Ring(s) dated, counting from center of log	Intervals of calibrated age, BC 1 σ	2 σ
Le-5182*	2460 ± 50	D-24, 113 tree rings	31–35	760–678	764–616
				658–636	608–406
				550–472	
				460–412	
GrN-22497*	2454 ± 16	D-24, 113 tree rings	15	753–699	756–687
GrN-22504*	2463 ± 16	D-24, 113 tree rings	22	531–508	539–471
GrN-22511*	2452 ± 15	D-24, 113 tree rings	29	496–493	459–413
				443–418	
Pazyryk-1					
Le-1694	2440 ± 40	D-2, 86 tree rings	1–20	752–698	762–628
				532–420	598–572
					562–402
Le- 1695	2390 ± 40	D-2, 86 tree rings	21–40	516–436	758–686
				424–396	540–386
Le-2456	2340 ± 40	D-2, 86 tree rings	41–55	468–462	744–742
				412–366	522–356
				272–266	290–246
					228–210
Pazyryk-2					
Le-1692	2470 ± 40	D-9, 108 tree rings	1–30	762–670	764–616
				668–630	606–412
				594–576	
				558–508	
				442–418	
Le-1693	2450 ± 40	D-9, 108 tree rings	31–50	756–688	762–626
				538–412	600–406
Le-2446	2430 ± 40	D-6, 70 tree rings	15–30	752–728	762–670
				714–704	666–628
				530–406	594–576
					558–398
Le-2453	2380 ± 40	D-6, 70 tree rings	41–60	512–440	754–692
				420–392	534–382
Pazyryk-5					
Le-2448	2360 ± 40	D-15, 186 tree rings	161–186	488–444	752–728
				418–380	720–706
					530–366
					274–266
Le-2455	2290 ± 40	D-17, 102 tree rings	81–102	398–358	402–348
				286–252	316–204
				222–214	
Le-1700	2410 ± 40	D-19, 120 tree rings	1–40	746–742	760–676
				524–400	660–634
					552–392

*^{14}C dates were produced in 1996–1997.

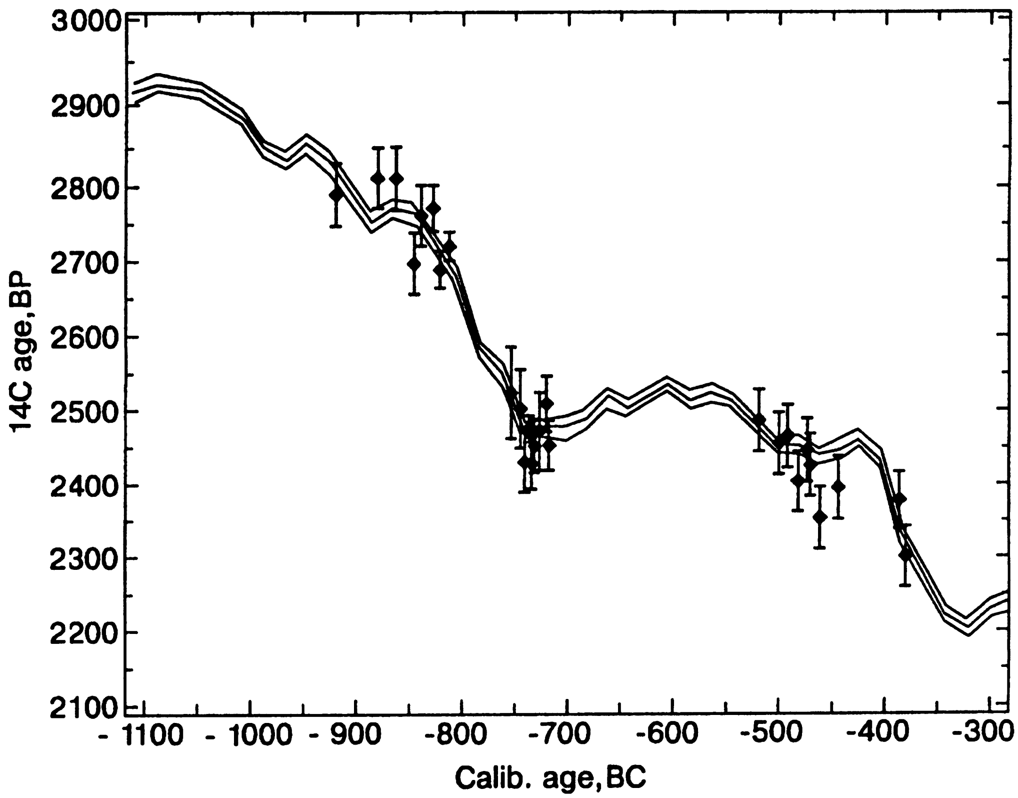

Fig. 3. The part of the Stuiver and Pearson (1986) calibration curve and location of the ^{14}C dates according to model "C"

The results (Table 1), plotted in Figure 3 with the calibration curve (Stuiver and Pearson 1986), clearly show the three groups of dates corresponding to Arzhan (*ca.* 2750 BP/850 BC), Tuekta (*ca.* 2450 BP / 750 BC) and Pazyryk (*ca.* 2400 BP / 450 BC). Here the position of the ^{14}C dates is not connected with the floating tree-ring scale (model "C", see below). The set of data can be analyzed by minimizing the quantity χ^2, defined as

$$\chi^2 = \sum_k^L \sum_i^{N_k} \frac{(Y_i - C(\tau_i + \delta\tau_k))^2}{\sigma^2_{y,i} + \sigma^2_{c,i}} \tag{1}$$

where L = number of groups of experimental points, N_k = number of points in the group, Y_i = ^{14}C age of the sample "i" in group "k", C = calibration curve dependence, τ_i = relative calendar age "i" in group "k", $\delta\tau_k$ = variation parameter determining the position of the groups on the calendar axis of the calibration curve, σ_y = error ^{14}C age and σ_c = error of calibration dependence.

For the minimizing procedure, we varied the several free parameters using these assumptions:

"A": The relative position of the age of the barrows is fixed on the floating tree-ring scale. The variable parameter is the zero position of the tree-ring scale.

"B": The age of the Arzhan barrow is determined by minimizing χ^2, independent of the floating tree-ring scale. The relative ages of Tuekta-1 and Pazyryk-5 are fixed by the floating tree-ring scale. The (variable) parameters are the ages of the Arzhan and Pazyryk-5 barrows. We selected here Pazyryk-5 from the total data set available for the Pazyryk group because it is the youngest barrow in this group, the age corresponding to the beginning of the floating tree-ring scale.

"C": The calibrated ages of all barrows are determined independently of the floating tree-ring scale by minimizing χ^2. This model has three independent variables: the construction dates of the Arzhan, Tuekta-1, and Pazyryk-5 barrows. We assume that one cannot rule out the possibility of errors in the floating tree-ring scale, which was constructed in 1960–1970 from different logs found in different regions (Altai and Tuva). We assume that the only cause of deviation of the measurements from the calibration curve is the measurement error (null hypothesis). The probability of this hypothesis is determined by χ^2 and the number of degrees of freedom N_f (= difference the between number of measured points and the number of variable parameters).

$$P = \int_{x^2}^{\infty} F(N_f, x)dx \tag{2}$$

This probability was calculated for the three "models" A, B and C as defined above, with results shown in Table 2.

TABLE 2. Base Characteristics of Theoretical Models and Investigated Barrows

Model	Age of Arzhan	Age of Tuekta-1	Age of Pazyryk-5	N_{df}	χ^2	P	P_{min}	Status
A	810	605	425	28	49.56	0.007	0.035	–
B	810	560	380	27	37.77	0.08	0.035	?
C	810	655	380	26	20.03	0.79	0.035	+

We also calculated the probability of the χ^2 deviations corresponding to 2 σ (P_{min}). From our calculations as shown in Table 2, we conclude that model "A" cannot be accepted because $P<P_{min}$. For model "B", $P>P_{min}$, although not significantly. We consider this solution possible but improbable. Model "C" appears to be acceptable, based on values of both χ^2 and P.

As for the models "B" and "C", the ages of the Arzhan and Pazyryk-5 barrows remain the same, 810 and 380 BC, respectively. These values are in agreement with earlier results (Zamotorin 1959; Rudenko 1970; Zacharieva 1976; Marsadolov 1988, 1994, 1996; Zaitseva 1996). The result obtained with model "C" is new: the age of the Tuekta-1 barrow, which is *ca.* 80–100 yr older than previously believed. This is made possible by the increased number of ^{14}C determinations and their high precision (in particular the Groningen measurements) (Table 1). Earlier conclusions were based on only 2 to 3 ^{14}C dates. The traditional chronology for this barrow, therefore, has to be revised.

The chronology of the Arzhan barrow remains the same in our investigation. This barrow was constructed in the 9th century BC. This is in agreement with recent measurements made in St. Petersburg and Moscow: 2610 ± 30 BP (GIN-8425), 2620 ± 40 BP (GIN-8618) and 2600 ± 40 BP (GIN-8619) (Chlenova 1996). After calibration, the results are 9th to 8th centuries BC.

The age of the Pazyryk-5 barrow remains at 380 BC. The acceptable values from our analysis for the age of the barrow's construction are shown in Figure 4 (Arzhan and Pazyryk-5) and Figure 5 (Tuekta-1 and Pazyryk-5).

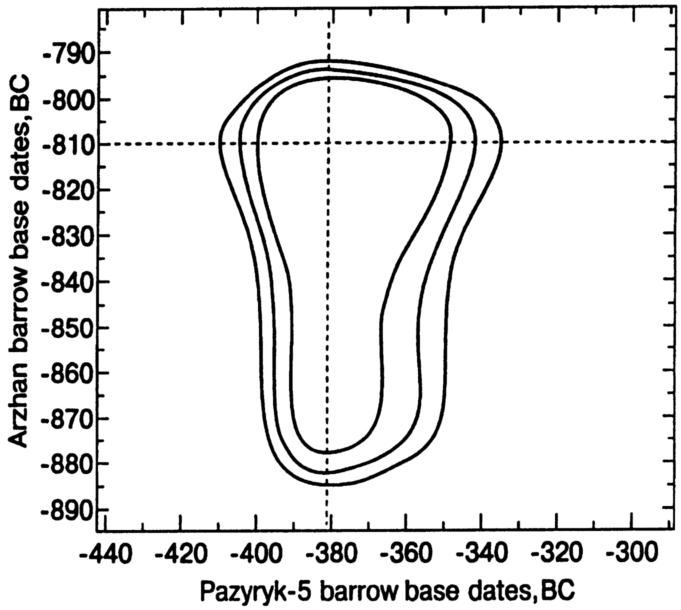

Fig. 4. The intervals of the permissible calendar time of the Arzhan and Pazyryk-5 barrow construction for probabilities 0.80, 0.90 and 0.95

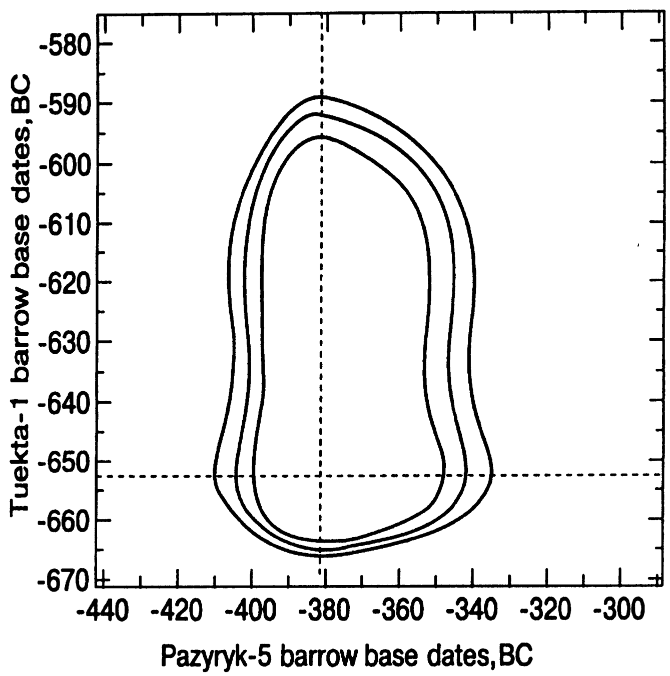

Fig. 5. The intervals of the permissible calendar time of the Tuekta-1 and Pazyryk-5 barrow construction for probabilities 0.80, 0.90 and 0.95

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The three lines correspond to confidence intervals of 80, 90 and 95%. The most reliable dates of the barrow's construction are indicated by dotted lines. Based on these values, the possible chronological intervals of the barrow's construction are shown in Table 3.

TABLE 3. Chronological Intervals for Barrow Construction (95% probability)

	Chronological limit (BC)		
Barrow	Low	Probable	Upper
Arzhan	885	810	790
Tuekta-1	665	655	590
Pazyryk-5	410	380	335

CONCLUSION

Statistical analysis of a series of ^{14}C dates for wood from a floating tree-ring scale yields chronologies for the construction of the famous Arzhan, Tuekta-1 and Pazyryk-5 barrows. Our results for the Arzhan and Pazyryk-5 barrows are in agreement with archaeological information. For the Pazyryk-5 barrow, the possible dates are 410–335 BC, but the most probable age is 380 BC. The Arzhan barrow dates from the end of the 9th to the beginning of the 8th century BC, as earlier established. New ^{14}C dates obtained (Table 1) for the Tuekta-1 barrow, based on ^{14}C measurements made in 1996–1997, are older than previously accepted. Therefore, the floating tree-ring chronology, or the placement of the wood samples from the three barrows investigated on the floating chronology, may need to be re-examined. Alternatively, additional ^{14}C dating may be needed to confirm the results derived from model "C", in light of the disagreement with the tree-ring chronology.

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