CALIBRATION CURVES AND THE CHRONOLOGY OF KEY MONUMENTS AT SAYAN-ALTAI

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Abstract

Studies of the chronology of the elite barrows at Sayan-Altai are of a great importance for the determination of the origin and development of the cultures of the Scythian period. In this work dendrochronology and radiocarbon dating have been combined. Statistical calculations were used to obtain the best fit of the radiocarbon dates for the tree-ring series to the bidecadal calibration curve and thus to determine the zero point of the floating tree-ring chronology on the calendar time scale. The results obtained position the zero point of the floating tree-ring series in the calendar time period 380–420 BC with the confidence probability of 0.95. The goodness of fit can be improved by shifting the Arzhan tree-ring dates relative to the other tree-ring scale by 40 years. For all cases the age of the Arzhan barrow lies in the limit of 800 years BC. The results from chronological investigations of the constructions at the elite barrows of Sayan-Altai are summarised.

Introduction

The elite barrows at Sayan-Altai represent the peculiar and striking cultures of the Scythian period and are related to cultures which, existed from Ordos (China) to Danube and are connected by the well-known "Scythian triad" (harness, weapon and art objects of animals). The history of the investigations starting from the last century is widely elucidated in the literature (Bokovenko 1992, Rolle 1980). These barrows are located in the mountain regions of central Asia (Fig. 1). The barrows Pazyryk, Bashadar, Tuekta and Katanda presented in this paper are located in Gorno-Altai in Southern Siberia and the barrow Arzhan in Uyuk Hollow of Tuva. Best known are the "King's mounds" Arzhan and Pazyryk excavated by Gryaznov (1984) and Rudenko (1970). Archaeological material found in these barrows have been well preserved because of the frozen conditions due to the special construction of the barrow's. The excavated material provides good possibilities for different typological comparisons with finds from other regions and forms the basis for archaeological periodisation. Nevertheless, the chronology for the Sayan-Altai barrows remains a controversial question. Several chronological models have been discussed by different authors (Gryaznov 1984, Kyzlasov 1977). Thus, the material of Pazyryk barrows have been dated from the 6th to 3rd century BC and artefacts from the Arzhan barrows have been attributed to the 9th-6th century BC. A discussion on the chronological problems of the Sayan-Altai barrows was published in a special volume of "Archaeology of the USSR" in 1992. The importance of the problems of the origin, forming and development of the Scythian

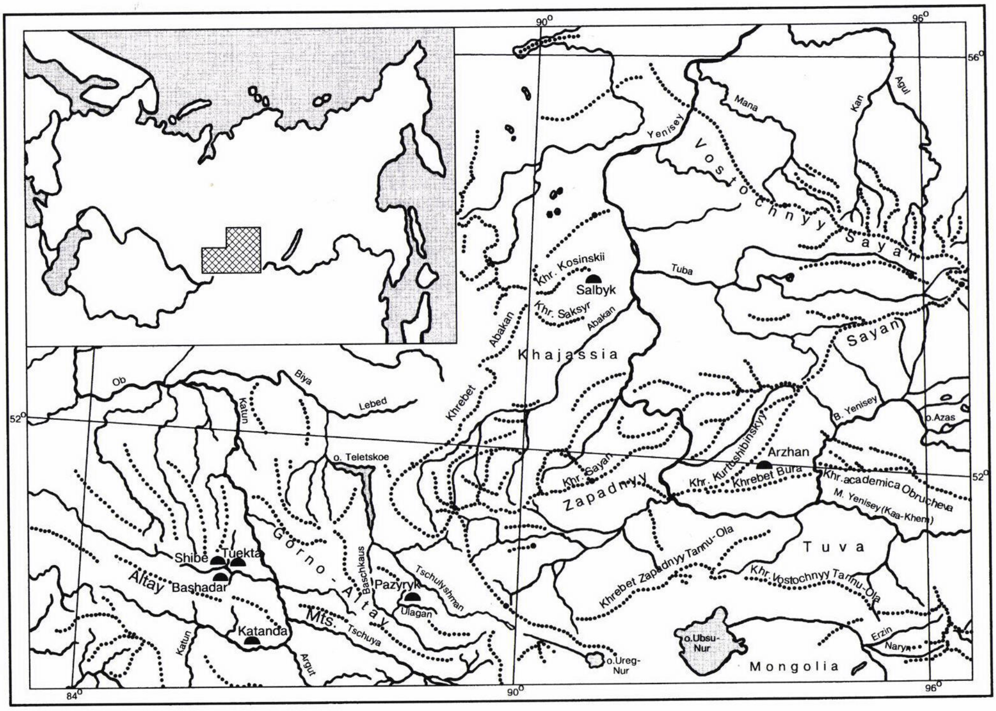

Fig. 1. The geographical location of the great barrows at Sayan-Altai.

cultures, which have been known in the northern Pontic area since the 7th century BC justifies the repeated return to the chronology of the Sayan-Altai barrows.

Scientific methods, which have been actively used in archaeological research since the 1960s provide a possibility to obtain data, which are independent of archaeological typology, and to make more accurate conclusions in comparison with data previously accepted. Radiocarbon dating and dendrochronology are important methods in chronological research, particularly in the cases, where the two methods can be combined. In addition the use of statistical methods for interpretation of numerical experimental results gives the possibility to make more reliable conclusions. This approach is presented in this paper.

Results

The first single radiocarbon dates for the Sayan-Altai barrows were obtained in the 1960s when the radiocarbon method was first put into practice. In 1970s and 80s the first tree-ring research on material from the barrows were carried out by Zakharieva and Marsadolov (Zakhrieva1976, Marsadolov 1984, 1988). These investigations have formed the basis in the construction of a floating tree-ring chronology with a length of about 600 years (Marsadolov 1988). In order to fix this tree-ring series to calendar time sets of radiocarbon dates for different parts of the tree-ring series were obtained in the ^{14}C laboratory of the Institute of the History of Material Culture in the 1980s. The results are collected in table 1 and shown in fig. 2. It should be noted, that the first comparison of radiocarbon dating of the floating tree-ring chronology with a cal-

Table 1. ^{14}C dates for the "floating" tree-ring scale from the Sayan-Altai barrows (See Fig. 2).

No.	Lab. No.	No tree-rings sample (see Fig. 2)	Sum of tree-rings	Amount of tree-rings for ^{14}C dating (counting from the centre)	^{14}C age, years BP
PAZYRYK-1					
1	Le-1694	D-2	86	1–20	2240 ± 40
2	Le-1695	D-2	86	21–40	2390 ± 40
3	Le-2456	D-2	86	41–55	2340 ± 40
PAZYRYK-2					
4	Le-1692	D-9	108	1–30	2479 ± 40
5	Le-1693	D-9	108	31–50	2450 ± 40
6	Le-2446	D-6	70	15–30	2430 ± 40
7	Le-2453	D-6	70	41–60	2380 ± 40
PAZYRYK-5					
8	Le-2448	D-15	186	161–186	2360 ± 40
9	Le-2455	D-17	102	81–102	2290 ± 40
10	Le-1700	D-19	120	1–40	2410 ± 40
TUEKTA-1					
11	Le-2447	D-24	113	31–50	2450 ± 40
12	Le-2450	D-27	119	31–60	2490 ± 40
ARZHAN					
13	Le-1698	D-36	126	1–25	2770 ± 40
14	Le-2452	D-36	126	48–60	2790 ± 40
15	Le-2444	D-38	80	15–35	2790 ± 40
16	Le-2449	D-38	80	36–60	2740 ± 40

endar time scale was realised at the initial stage of investigations without calibration, and the position of the beginning of the floating tree-ring series was concluded to be at 360 ± 40 years BC (Marsadolov 1984, 1988). Later, the calibration curves have revealed that the fluctuations of ^{14}C concentration in the atmosphere had a complicated character for the interval of the radiocarbon age of the Sayan-Altai barrows. By the computer program CAL15 the obtained ^{14}C ages were converted to calendar time and as a result the zero point of the floating tree-ring chronology was set to 400 ± 40 years BC (Marsadolov 1994, Zaitseva,1996). These results were determined without statistical analysis and therefore they required to be corrected. It should be noted, that the use of the calibration curves gave a new impact to chronological research.

The calibration procedure does not, however, always result in a single calendar age for the following reasons:

1. The calibration curves are not monotonous and a ^{14}C date can therefore correspond to several calendar time intervals.
2. Both radiocarbon dates and data for the calibration curves are based on measurements and they all have statistical errors, which influence on the interpretation of the results.

In order to fix the floating chronology to calendar years with the help of the radiocarbon dates the following statistical approach was used.

Most of our radiocarbon datings of the floating tree-ring series were carried out on

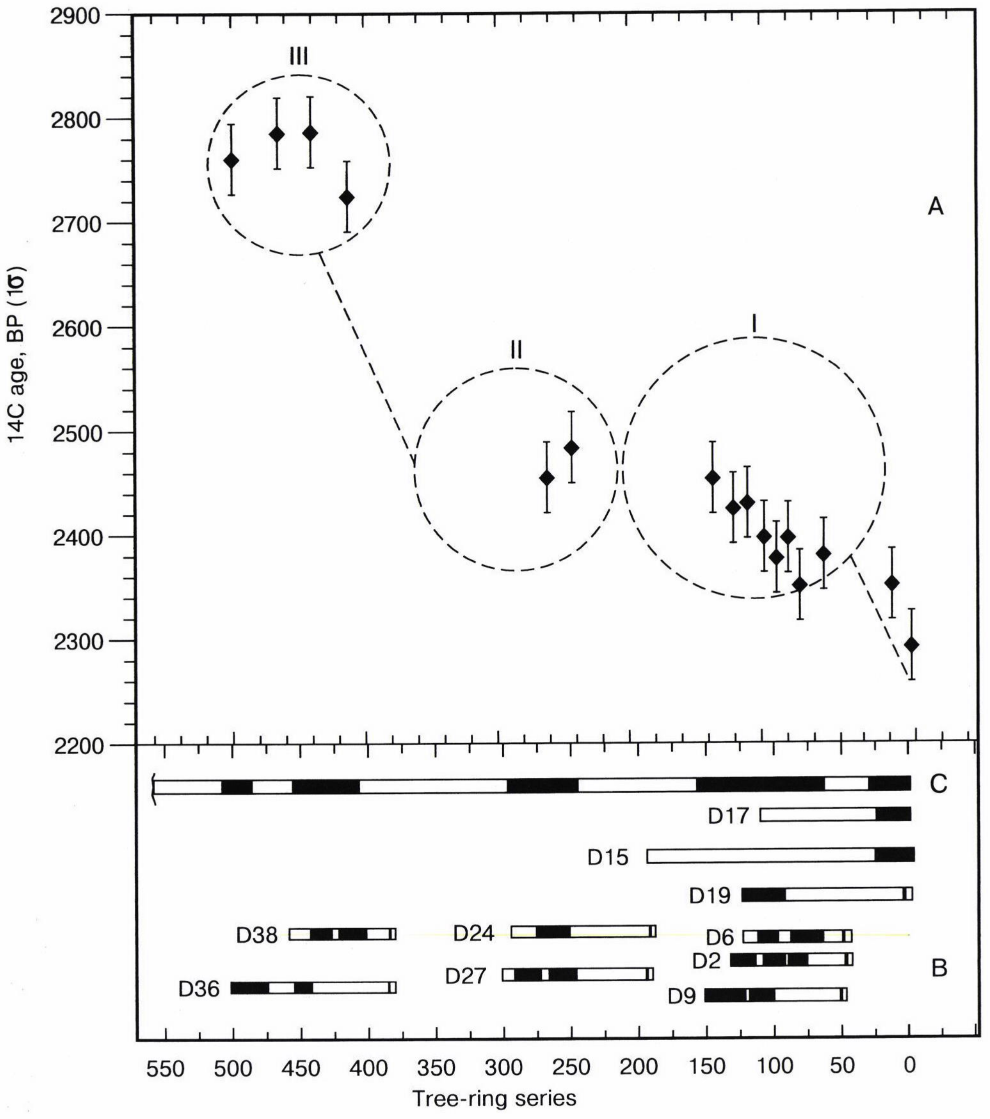

Fig. 2. The position of radiocarbon dates of the Sayan-Altai barrows on the floating tree-ring scale. A – radiocarbon dates, B – parts of floating tree-ring scale dated by radiocarbon, C – the combined floating tree-ring scale.

bidecadal tree-ring samples, and the bidecadal calibration curve of Stuiver and Pearson (1993) was therefore used in the fitting procedure.

To compare a theoretical curve with a set of experimental points the χ^2 criterion can be used as a test for goodness of fit. If the theoretical function (in this case the calibration curve) at a moment t_i has a value $C(t_i)$ and the result from measurements for the same moment is indicated by $Y(t_i)$, then the goodness of fit (χ^2) is determined by the expression:

$$\chi_N^2 = \sum_{i=1}^{N} \frac{Y(t_i)-C(t_i)^2}{\sigma_i^2} \quad (1)$$

where σ_i is the standard error of the radiocarbon measurement.

The agreement between theoretical and experimental data is the better the smaller the χ^2 value is. The theoretical value for χ^2 depends on the confidence level and the degree of freedom. In this case the degree of freedom is equal to the number of experimental points, N.

The age difference between the samples used for radiocarbon dating is known from their tree ring number. If the tree ring series is shifted a value (t relative to the previously assumed zero point at 360 BC, χ^2 can be given by

$$\chi_{N-1}^2 = \sum_{i=1}^{N} \frac{Y(t_i + \Delta t)-C(t_i)^2}{\sigma_i^2} \quad (2)$$

In this case the degrees of freedom is diminished by 1 (m = N-1).

Taking into account that both the experimental points in the calibration curve and the radiocarbon determination (Y) have statistical errors σ_c and σ_e respectively the total statistical error is $\sigma_i^2 = \sigma_{e,i}^2 + \sigma_{c,i}^2$.

When the test for goodness of fit is used for the analysis of archaeological data one more parameter i.e. a systematic error in the determination of value $Y(t_i)$ should be taken into consideration . In the present research this parameter is assumed to be free and denoted by ΔY. The criterion χ^2 is then given as

$$\chi_{N-2}^2 = \sum_{i=1}^{N} \frac{Y(t_i + \Delta t) + \Delta Y-C(t_i)^2}{\sigma_{e,i}^2 + \sigma_{c,i}^2} \quad (3)$$

Using this expression we calculated the goodness of fit (σ^2) for different values of the parameters Δt and ΔY. The confidence probabilities obtained are shown in fig. 3. Two fields "A" and "B" for the confidence probability >0.95 can be seen.

The values of the parameters corresponding to field B are $\Delta t = -60$ years and $\Delta Y = 40$ years. Compared to the values for field A these parameter values are more acceptable for the zero position of the floating tree-ring scale and from archaeological point of view. One can see quite clearly that the permissible fields are lacking beyond (t = 0. The position of the experimental points on the calibration curve when the above mentioned parameter values are used is presented in fig. 4. Although the coincidence can be considered as satisfactory, the 4 dates for the samples from Arzhan barrow need further correction. Recently a new radiocarbon date was obtained for the hoof of a horse from the Arzhan barrow. The result was 2790 ± 80 BP (Le-5141) and this fits into the same interval of dates as those obtained before. We assumed that one can not rule out the possibility of error in the determination of the position of Arzhan on the tree-ring scale. Taking this possibility into account, the criterion χ^2 can be written as

$$\chi_{N-3}^2 = \sum_{i=1}^{N} \frac{Y(t_i + \Delta t_i) + \Delta Y-C(t_i)^2}{\sigma_{e,i}^2 + \sigma_{c,i}^2} \quad (4)$$

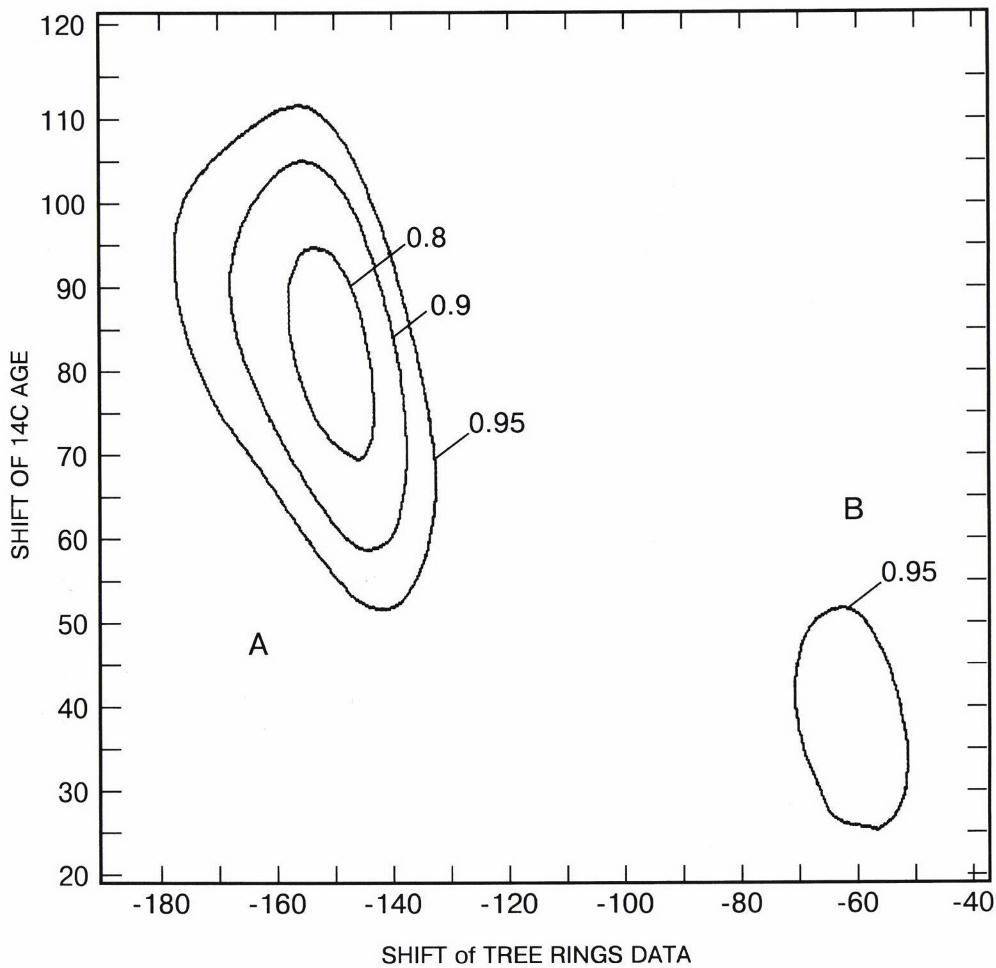

Fig. 3. The permissible values of the parameters: Δt (the shift of tree-rings dates) and ΔY (the shift of ^{14}C age) for the confidence probability 0.80, 0.90, 0.95. (The standard zero position of the floating tree-ring scale is 360 years BC.)

where $\Delta t_i = \Delta t + \Delta t_A$, if the point belongs to the Arzhan group and $\Delta t_i = \Delta t$ for other cases. Thus the parameter Δt_A is the shift of tree-ring dates of the Arzhan barrow relative to the other data of the tree-ring scale. The degree of freedom is in this case m = N-3.

The permissible values for the parameters (t and (Y for the optimal value of the parameter $\Delta t_A = -40$ years are shown in fig 5. Three fields for confidence probability 0.90 are observed, of which only one can be accepted as it does not contradict with radiocarbon and archaeological data for the Arzhan barrow. According to data obtained the optimal values of the parameters are Δt = –20 years, ΔY = 10 years. The position of the experimental points on the calibration curve for these parameters is shown in fig. 6. It can be seen, that the coincidence between experimental and theoretical data is improved by introducing the new parameter, which allows to shift the age of the Arzhan barrow relative to other experimental points, but it should also be noted that

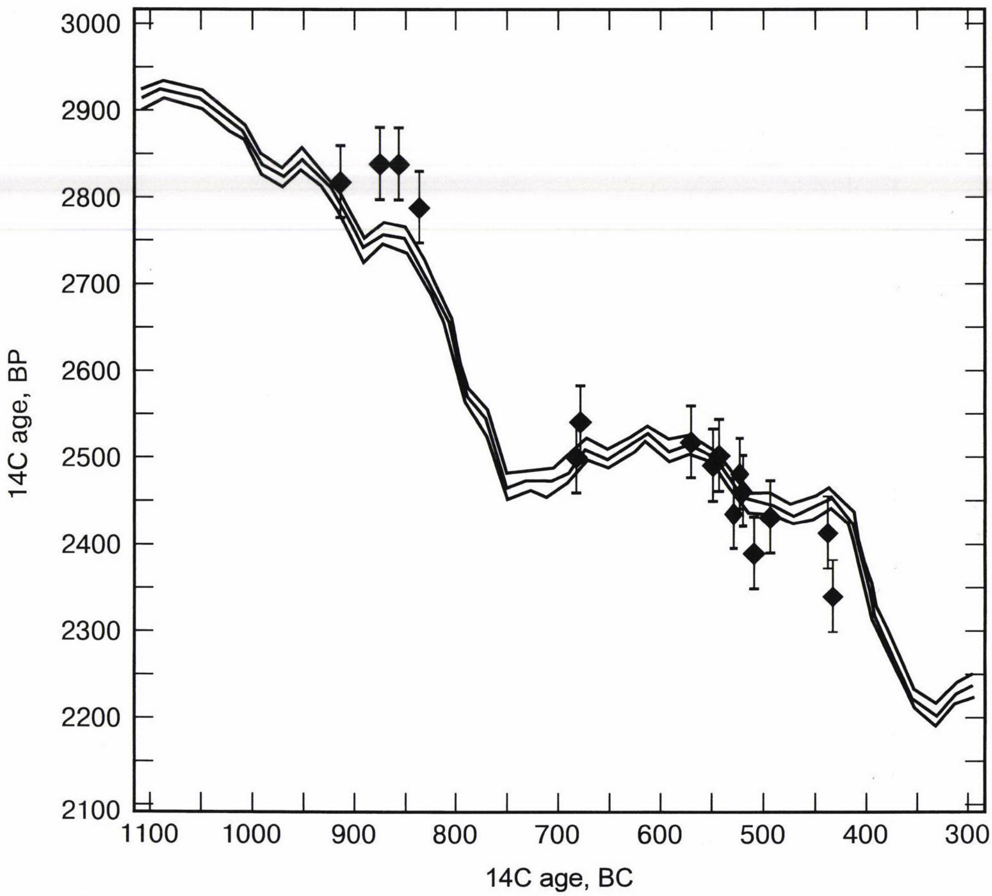

Fig. 4. The position of radiocarbon dates on the calibration curve.

the age of the Arzhan barrow remains around 800 BC. Taking into consideration the complicated character of calibration curve for the time interval of Arzhan and the first experience of this kind of investigations, more accurate conclusions can be obtained when new supplementary radiocarbon and tree-ring results are available.

Chronological data for the Sayan-Altai barrows obtained during the last 10 years of investigations are summarised in Table 2.

Conclusions

From the combination of calibrated radiocarbon dates and tree-ring chronology we conclude that two possible zero positions for the floating tree-ring scale on the calendar time can be accepted: 420 BC, if the position of the tree ring series from Arzhan barrow is kept fixed on the floating tree-ring scale, and 380 BC, if there is a shift of the position of the tree-ring dates of the Arzhan barrow relative to the main tree ring series. In both cases the age of Arzhan is about 800 years BC. The different assumptions discussed show that the zero-position of the floating tree-ring chronology in no

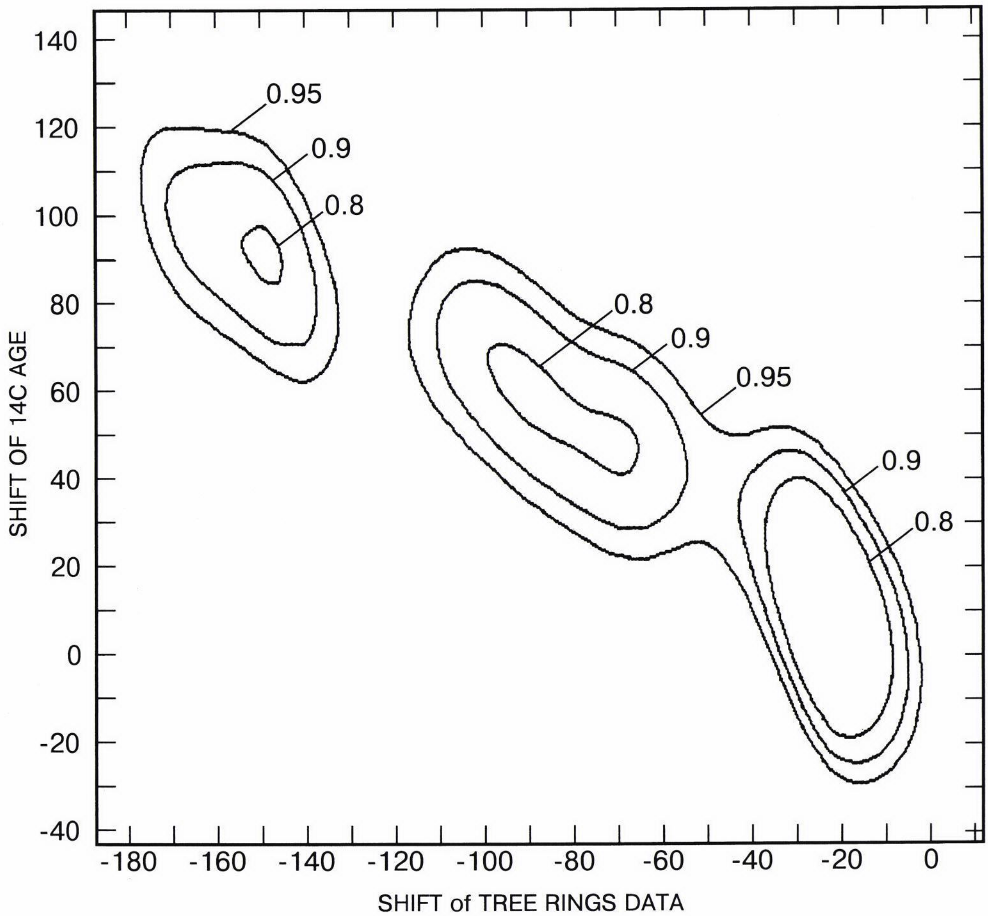

Fig. 5. The permissible values of the parameters: Δt and ΔY. Compared to fig. 3 the Arzhan barrow tree-ring series has been shifted by –40 years relative the other tree-ring series.

case can be younger than 360 years BC. This conclusion corroborates earlier results indicating that the zero position is at 360 ± 40 years BC (Marsadolov 1988, Marsadolov and Zaitseva 1994, Zaitseva et al. 1996).

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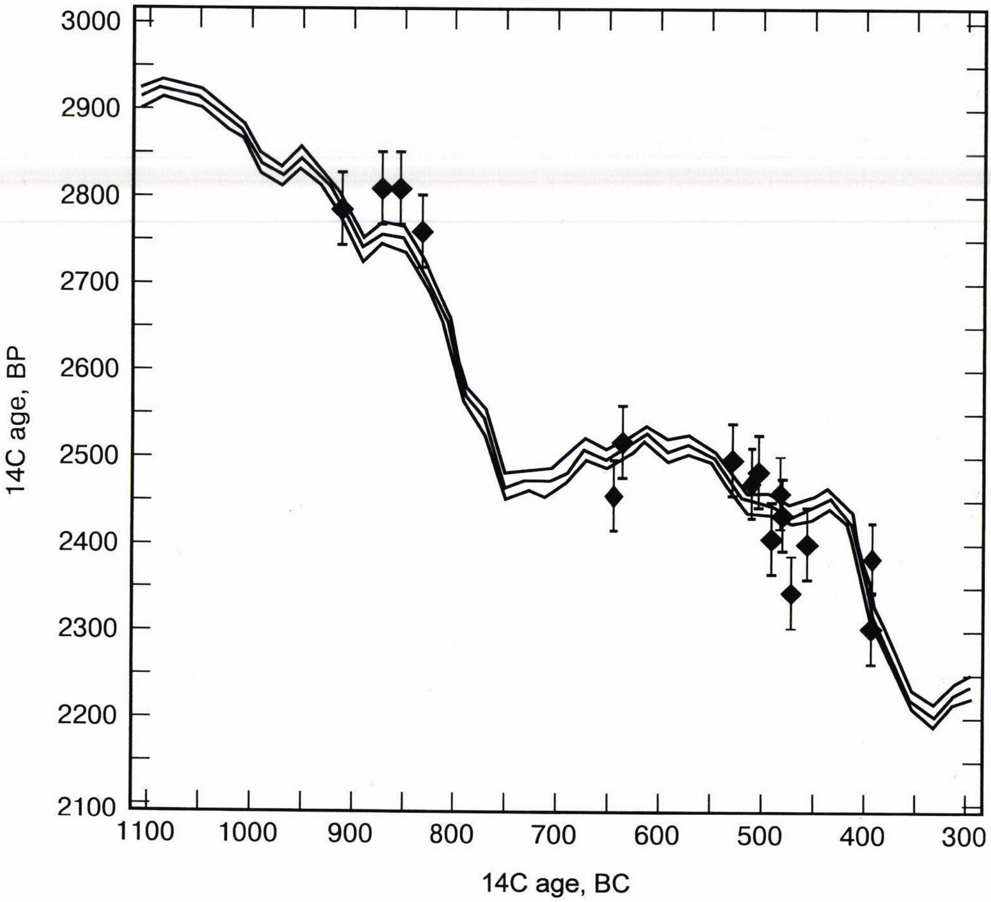

Fig. 6. The position of radiocarbon dates on the calibration curve when the shift of tree-ring dates of Arzhan is –40 years.

Table 2. The chronological sequence of the elite barrows constructions at Sayan-Altai obtained during 10 years of investigation.

Barrow	The age, years BC			
	1984 (Marsadolov)	1994 (Marsadolov, Zaitseva)	1996 (Zaitseva, Vasiliev, Marsadolov) m = N-2	m = N-3
Pazyryk-5	360	400	420	380
Pazyryk-1,2	410	450	470	430
Tuekta-1	540	580	600	560
Arzhan	745	780	800	800

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