MISION ARQUEOLOGICA ANDINA
INSTITUTO DE ARQUEOLOGIA
UNIVERSIDAD DE VARSOVIA

EL FENOMENO EL NIÑO

A TRAVES DE LAS FUENTES ARQUEOLOGICAS Y GEOLOGICAS

ACTAS DE LA CONFERENCIA

dr Jerzy Grodzicki (ed.)

VARSOVIA 1990

MISION ARQUEOLOGICA ANDINA

INSTITUTO DE ARQUEOLOGIA

UNIVERSIDAD DE VARSOVIA

EL FENOMENO EL NINO

A TRAVES DE LAS FUENTES ARQUEOLOGICAS Y GEOLOGICAS

ACTAS DE LA CONFERENCIA

EN VARSOVIA 18 - 19 de mayo 1990

REDACCION: dr Jerzy Grodzicki

VARSOVIA 1990

THE RESOLVING POWER OF CALIBRATED RADIOCARBON DATES

Danuta J. MICHCZYNSKA, Adam MICHCZYNSKI, Mieczyslaw F. PAZDUR

Introduction

The radiocarbon dating relies on the fundamental assumption that the biospheric inventory of ^{14}C has remained constant during the past 100 000 years. This assumption was tested 40 years ago by Arnold and Libby (1949) with the accuracy of ca 10% by dating know-age Egyptian samples. However, with the improvement of the accuracy it was realized that this assumption is not precisely true.Systematic studies of discrepancies between ^{14}C and calendric dates, based on accurate ^{14}C determinations in dendrochronologically dated tree-ring samples have led to publication of numerous versions of calibration curves and tables based on dendrochronologically dated American trees (Pinus longaeva and Sequoia gigantea).

The real breakthrough in the calibration was achieved in the last decade and was stimulated by the progress in dendrochronology of the European fossil oak in West Germany (Becker,1980;1988) and in Ireland (Baillie,1982) and by

---

Danuta J.Michczyńska, Adam Michczyński, Mieczyslaw F.Pazdur
Laboratorium C-14, Instytut Fizyki Politechniki Śląskiej,
Gliwice, ul. Krzywoustego 2.

important improvements of the accuracy of radiocarbon dating (cf chapter on technical problems).The continued international collaboration between radiocarbon dating laboratories in Belfast (directed by G.W.Pearson) and in Seattle (directed by M.Stuiver) has led to elaboration of the first high-prcision calibration curves based on measurements verified by two mentioned laboratories using different high-accuracy techniques GC in Seattle and LS in Belfast). This research was also supported by several other laboratories (Groningen, Heidelberg and Pretoria) and the results obtained, after detailed discussion were accepted by the participants of the 12th International Radiocarbon Conference in Trondheim in 1985.

The decision of this conference was the publication of the "Calibration Issue" of "Radiocarbon", with three high-precision calibration curves by Stuiver and Pearson (1986), Pearson and Stuiver (1986) and Pearson et al (1986).

Practical application of those high-precision calibration curves is, however, not simple, and interpretation of obtained calendric ages is not straightforward. Because of numerous wiggles of calibration curve the correspondence between conventional ^{14}C dates and calendric ages is not equivocal, and, as a rule, there are several values of calendric age corresponding to a given ^{14}Cdate.

Probabilistic calibration of radiocarbon dates

In order to overcome the difficulties caused by multiple intercepts with calibration curve we hawe introduced the concept of probabilistic calibration of radiocarbon dates and developed a set of appropriate computer procedures.

The idea of probabilistic calibration consist of transforming initial probability distribution of conventional ^{14}C date into calendric scale and appropriate parameters of resulting probability distribution as the measures of calendric age and its uncertainty.

Description of the computer procedure

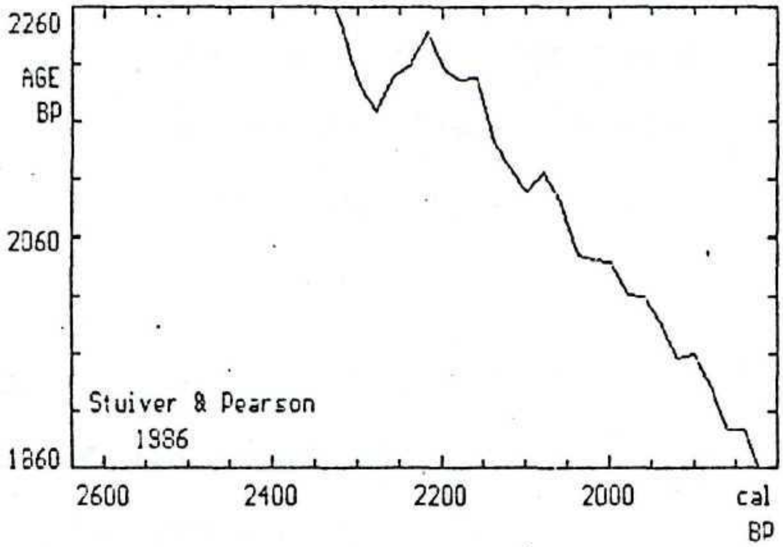
The idea of probabilistic calibration was first introduced by Robinson (1985) and applied by Hassan and Robinson (1986) to calibration of a series of dates from Egypt, Nubia and Mesopotamia.The critique of this approach (Michczynska et al,1989) has led to more strict mathematical formulation of the algorithm of calibration, and the first version of calibration procedure was presented during the 2nd Symposium "Archeology and ^{14}C " in Groningen, September 1987, and the improved version was presented during the 13th International Radiocarbon Conference in Dubrovnik (Pazdur and Michczynska, in print).

The system of calibration procedure was designed taking into account the specific tasks of archeological application; and includes three main options :

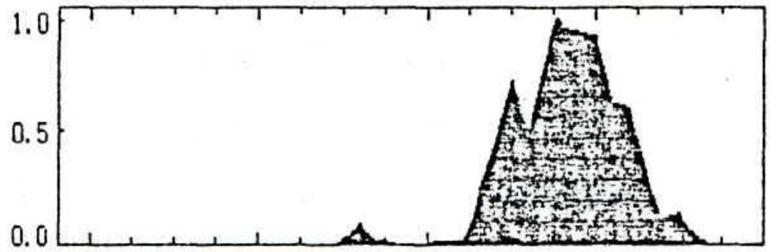
1. calibration of single date
2. calibration of a set of arbitrary dates, representing same

<F1> Help
<F2> AD/BC
<F3> Next Scr
<Esc> Exit
<PrtSc>

D=2060 conv BP
Sigma= 50



Analysed interval:
[D - 3*Sigma , D + 3*Sigma]
Max. probability for dates:
2045, 2099, 1900, 2279
Intervals of cal age:
[1867, 2200] [2238, 2306]



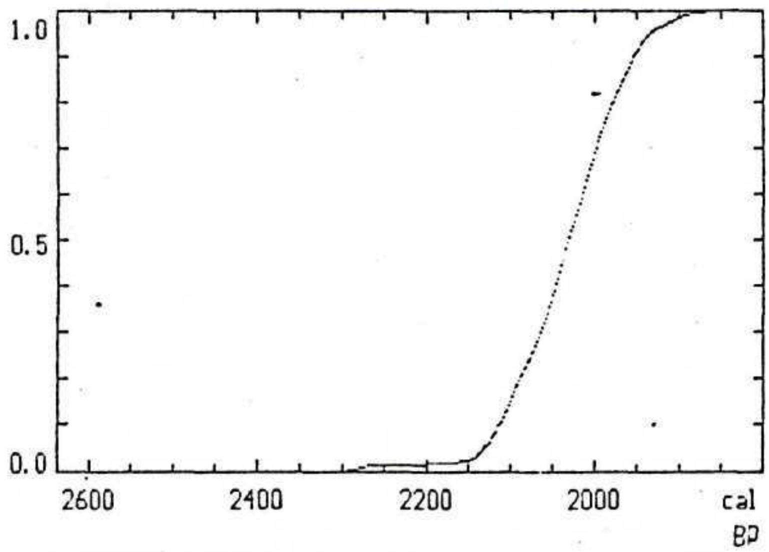
<F1> Help <F2> AD/BC
<F3> First Scr <Esc> Exit
<PrtSc>

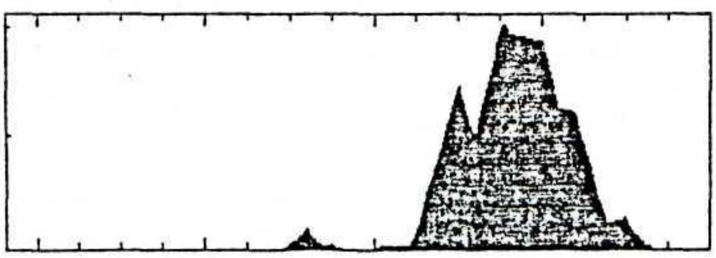
D=2060 BP Sigma=50 yr

P(T < To)	To cal. BP
0.01	2276
0.05	2131
0.10	2113
0.25	2076
0.50	2031
0.75	1990
0.90	1954
0.95	1934
0.99	1893

Ranges

0.50	[2076,1990]
0.95	[2151,1911]
0.98	[2276,1893]





or different cultures (phases) objects

3. calibration of a set of related dates obtained from a series of samples representing well-defined culture or phase.

Calibration is preformed according to recently published high precision calibration curves of Stuiver and Pearson (1986), Pearson and Stuiver (1986) and Pearson et al (1986); range of conventional ^{14}C dates extends back to 6210 BP.

The resolving power of calibrated radiocarbon dates

Because the shape of the high-accuracy calibration curve is irregular and wiggled, different shapes of resulting probability distribution of calendric age obtained. When calibration of single date is considered we may distinguish three different cases, depending upon the shape of probability density function of calendric age. For the user of radiocarbon dates it is important to note that the accuracy of resulting estimate of calendric date in some intervals of time can be much better then the accuracy of conventional radiocarbon dates, and in other periods of time it can be significantly worse. The resolving power of the radiocarbon method, defined as the ability to distinguish two separate events in the past, is depends therefore not only on the accuracy of conventional radiocarbon dates, but also varie significantly indifferent periods.

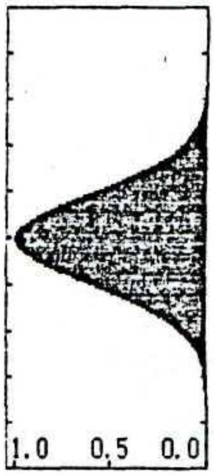
Let us consider in details three special cases of calibration output obtained for some artificial dates. Figure 1 shows results of calibration of conventional C-14 date 2060 $\pm$50 BP. The probability density function of calendric age is similiar to initial Gaussian shape assumed for conventional date. This means that the median of obtained probability distribution can be taken as a measure of calendric age of dated sample. The uncertainty of calendric age is given by the computational program in form of three confidence intervals corresponding to 3 confidence levels, equal to 50%, 95% and 98%. The first confidence interval is usually called interquartile range (introduced by Barbara Ottoway and Marion Scott). It seems that the interquartile range is the most suitable for characterization of the accuracy of calibrated radiocarbon dates. In the considered case the result of calibration may be summarized as 2031 $\pm$ 40 BP or 81 $\pm$ 40 BC.

Figure 2 shows promising case when the accuracy calibrated date is much better than the accuracy of conventional date. Conventional C-14 date is 1350 $\pm$25 BP. Probability distribution of calendric age is similiar to the Gaussian bell curve. It covers 163 year, but in fact the main probability maximum is centered around 1285 BP and confidence intervals are listed below as :

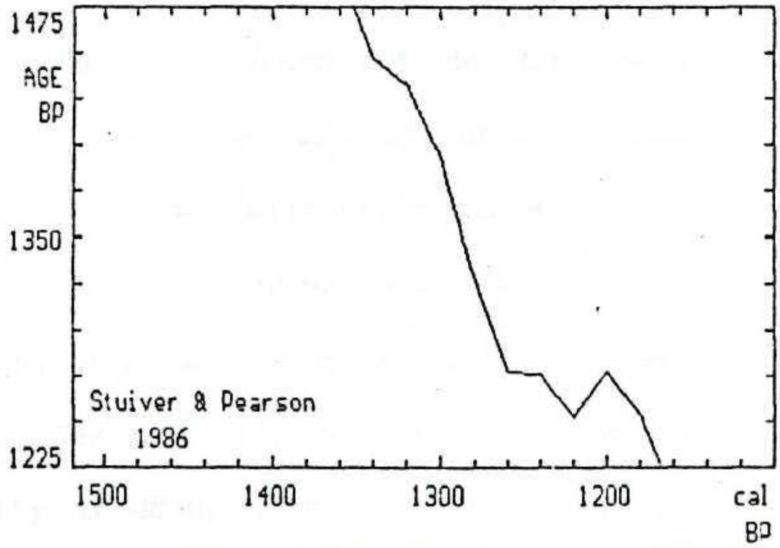
98%	90 years
95%	50 years
50%	12 years

Fig. 1. Calibration output obtained for artificial radiocarbon date 2060 $\pm$ 50 BP. Accuracy of conventional radiocarbon dates is similiar.

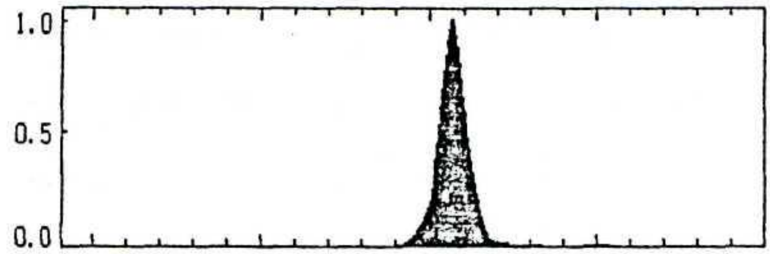
<F1> Help
<F2> AD/BC
<F3> Next Scr
<Esc> Exit
<PrtSc>



D=1350 conv BP
Sigma= 25



Analysed interval:
[D - 4*Sigma , D + 4*Sigma]
Max. probability for dates:
1287, 1200
Interval of cal age:
[1177, 1340]



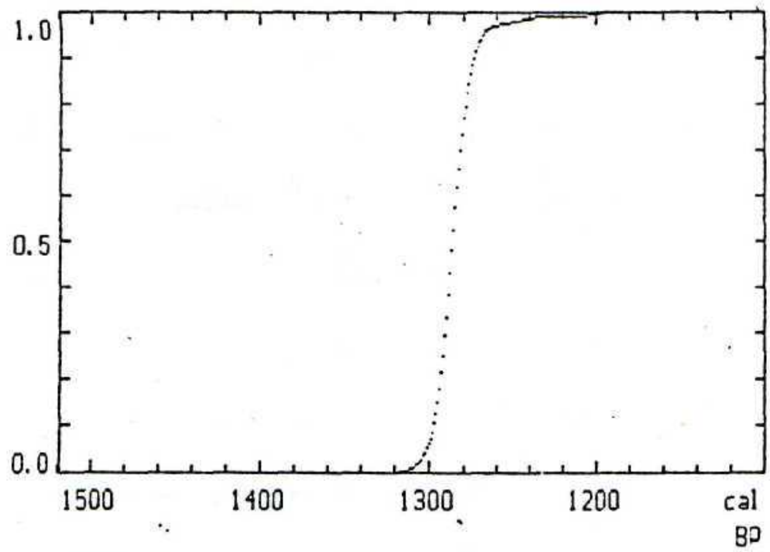
<F1> Help <F2> AD/BC
<F3> First Scr <Esc> Exit
<PrtSc>

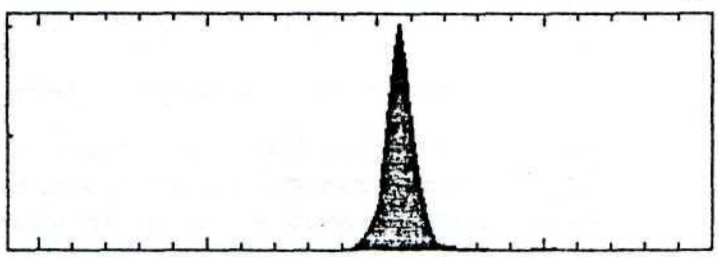
D=1350 BP Sigma=25 yr

P(T < To)	To cal. BP
0.01	1310
0.05	1301
0.10	1297
0.25	1292
0.50	1286
0.75	1280
0.90	1274
0.95	1268
0.99	1220

Ranges

0.50	[1292,1280]
0.95	[1305,1255]
0.98	[1310,1220]





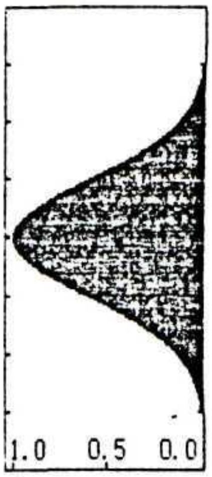
Calendric age corresponding to considered date can be stated as equal to 1286 $\pm$6 cal BP (or if 95% confidence interval will be taken, as 1286 $\pm$25 cal BP).

Finally, let we consider another not so optimistic situation. An example of calibration of conventional date 4200$\pm$25 BP is shown in Figure 3. The calibration curve in time interval 4000 - 4400 BP is highly irregular, and the resulting probability distribution of calendric age is scattered over almost 300 years (exactly 282 years) with four approximately equal maxima of probability at 4830, 4748, 4732 and 4660 BP, separated with intervals of zero or nearly zero probability. In this case it is imposible to state that there is any single calendric date corresponding to the given value of conventional radiocarbon date. There are only two types of answer: first possibility is to say that caledric age is confined with probability of 95% in the interval from 4843 to 4650 cal BP (or from 2893 to 2700 calBC). The second answer is that there are four possible values of calendric age, wich should be regarded as having practically same possibility : 4830, 4748, 4732, 4660 cal BP. Without any additional information it is impossible therefore to distinguish between prehistoric events separated by ca 200 - 250 years, even if

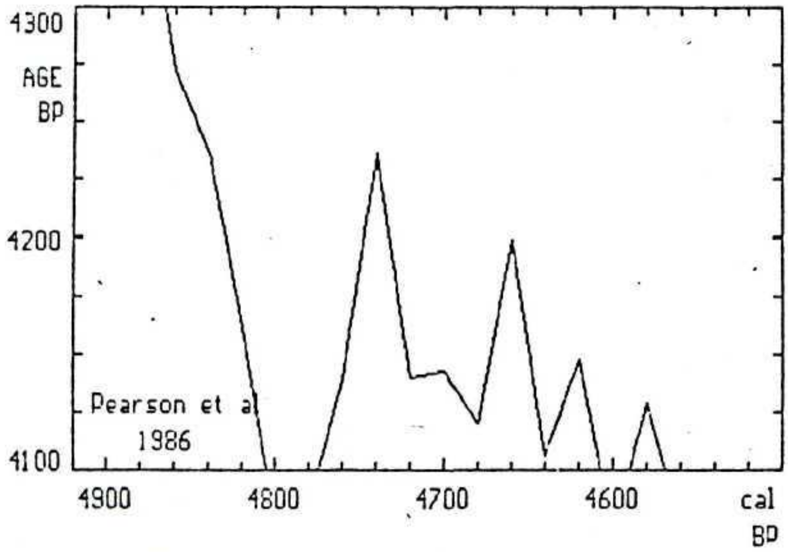
==

Fig. 2. Calibration output obtained for artificial radiocarbon date 1350 $\pm$ 25 BP. Accuracy of calibrated date is much higher than the accuracy of initial conventional date.

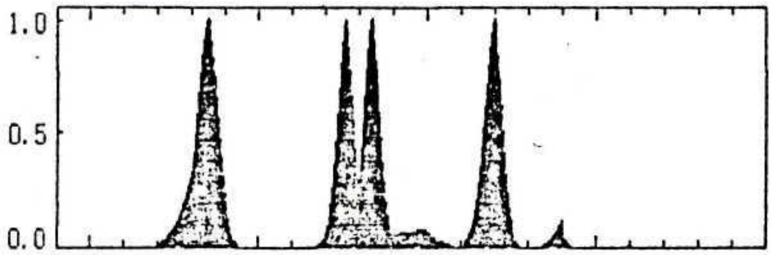
<F1> Help
<F2> AD/BC
<F3> Next Scr
<Esc> Exit
<PrtSc>



D=4200 conv BP
Sigma= 25



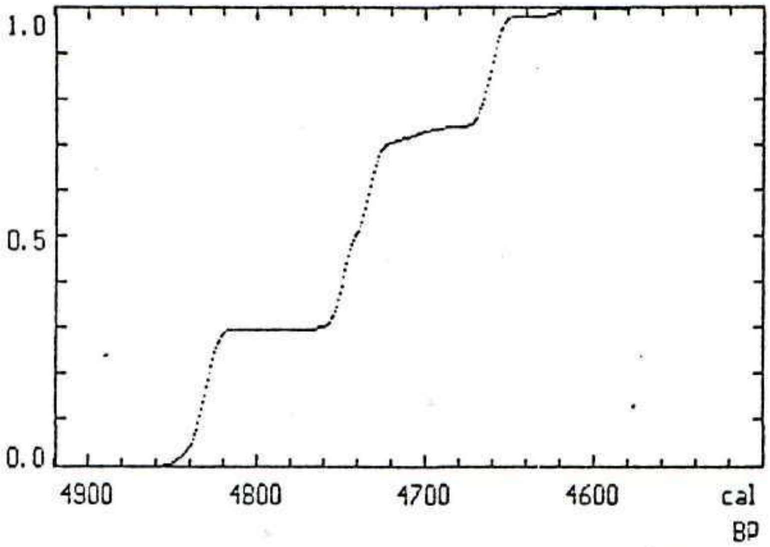
Analysed interval:
[D - 3*Sigma , D + 3*Sigma]
Max. probability for dates:
4830, 4660, 4732, 4748
Intervals of cal age:
[4578, 4581] [4614, 4631]
[4644, 4678] [4684, 4765]
[4812, 4850]

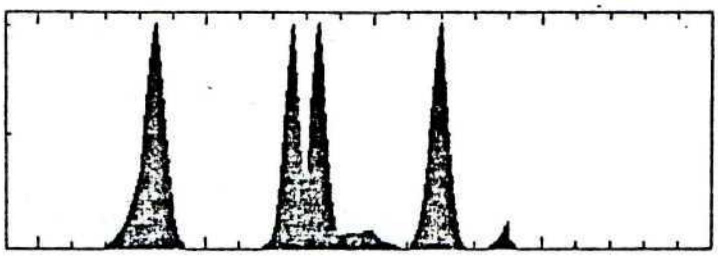


<F1> Help <F2> AD/BC
<F3> First Scr <Esc> Exit
<PrtSc>

D=4200 BP Sigma=25 yr

P(T < To)	To cal. BP
0.01	4849
0.05	4839
0.10	4834
0.25	4824
0.50	4741
0.75	4671
0.90	4658
0.95	4654
0.99	4621
Ranges	
0.50	[4824, 4671]
0.95	[4843, 4650]
0.98	[4849, 4621]





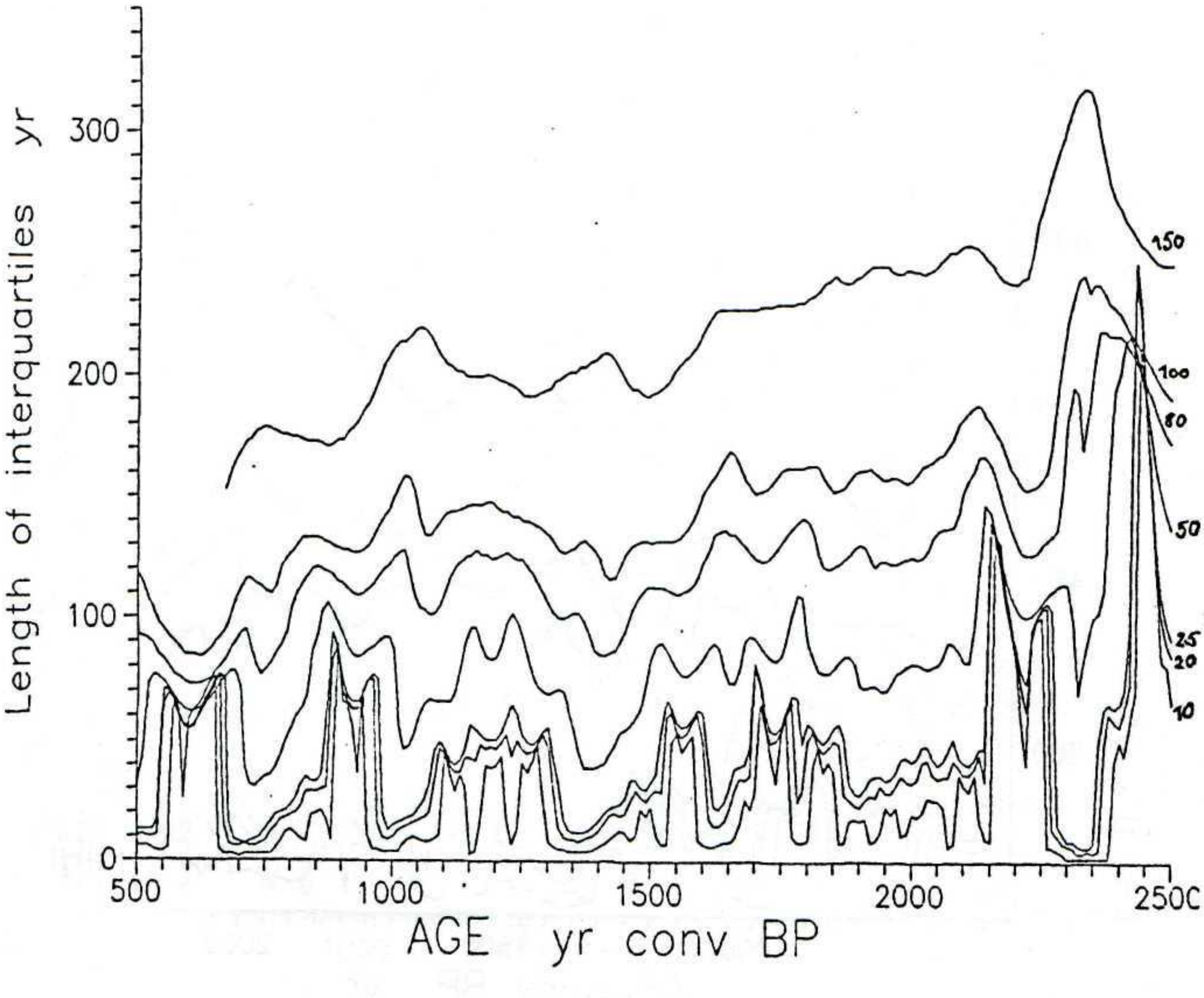


Fig. 4. Accuracy of calibrated radiocarbon dates determined by the interquartile range (50% confidence intervals) in the time ranging from 500 to 2500 cal BP. Errors of initial conventional radiocarbon dates equal to 10, 20, 25,50, 80, 100 and 150 yr are indicated.

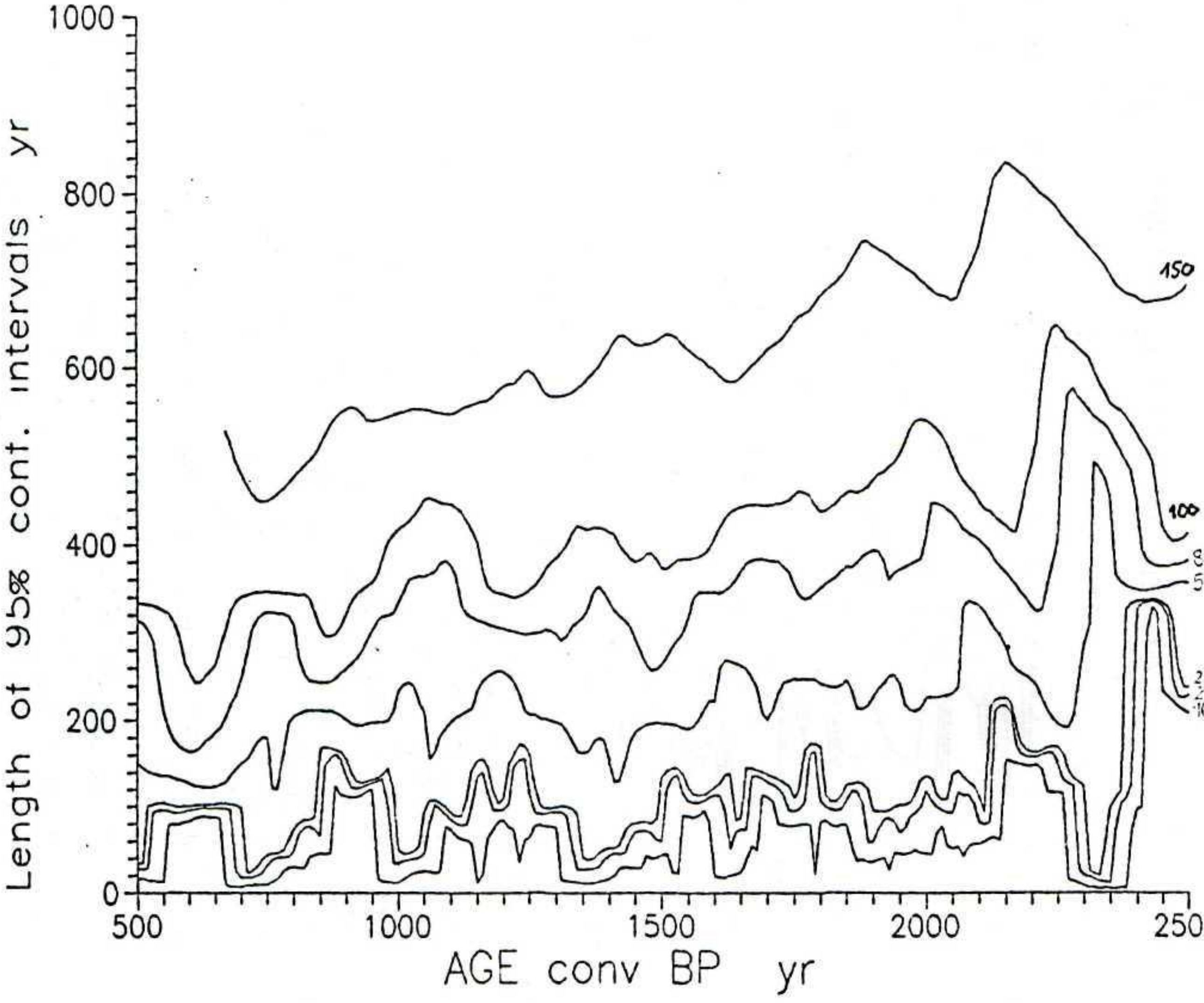


Fig. 5. Accuracy of calibrated radiocarbon dates determined by the 95% confidence intervals in the time ranging from 500 to 2500 cal BP. Errors of initial conventional radiocarbon dates equal to 10, 20, 25, 50, 80, 100 and 150yr are indicated.

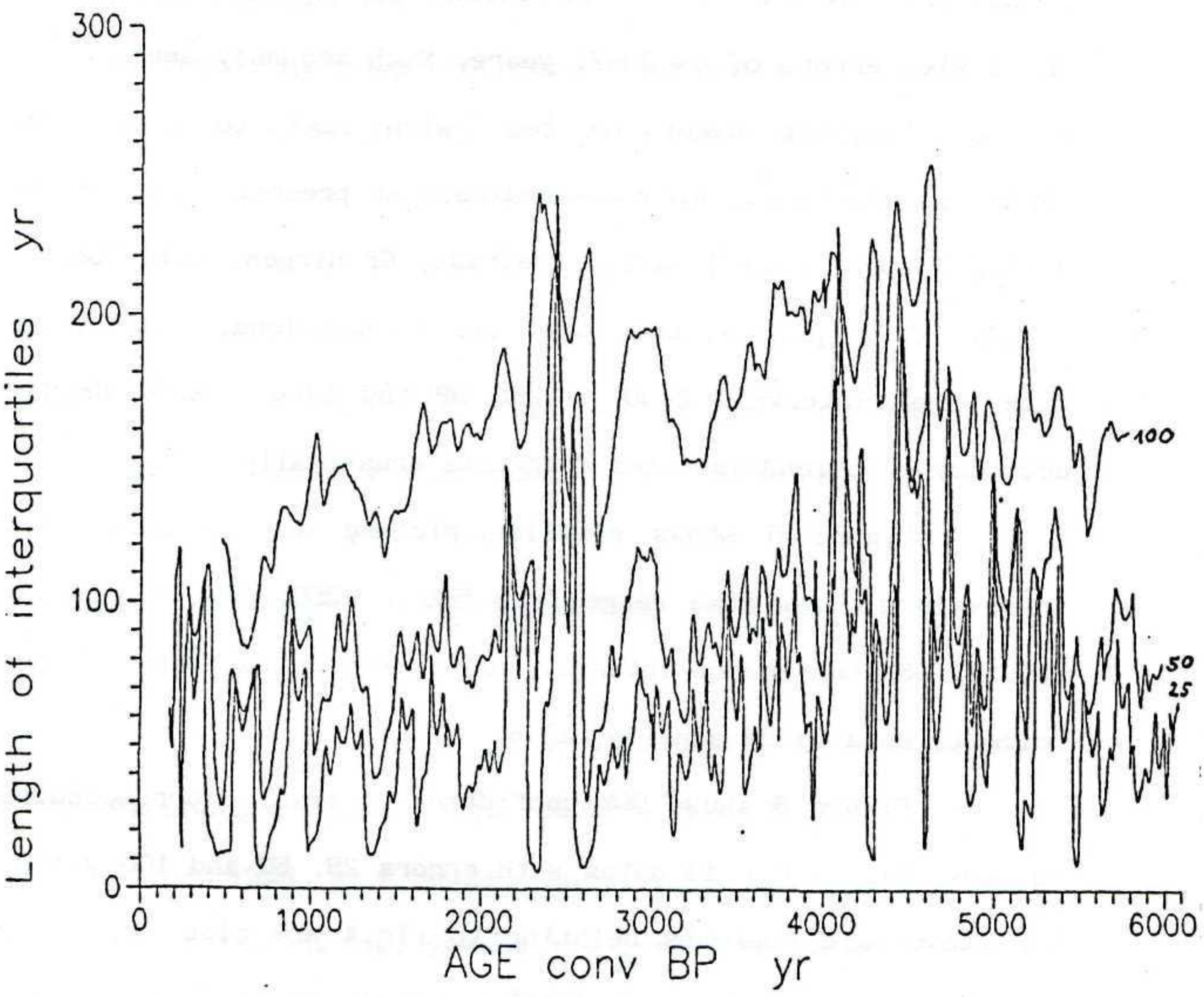


Fig. 6. Accuracy of calibrated radiocarbon dates determined by the interquartile ranges (50% confidence intervals) in the time ranging from 100 to 6100 cal BP. Errors of initial conventional radiocarbon dates equal to 25, 50 and 100 yr are indicated

cal BP. The periods with high accuracy of calibrated radiocarbon dates are clearly visible, especially on plots showing interquartile ranges corresponding to small values of dating error, 10, 20 and 25 years. The cyclicity with period equal to about 200 - 300 years is also visible. Moreover, it can be noted that 50% confidence interval corresponding to errors 10, 20 and 25 years do not differ significantly. This means that for satisfactory accuracy and reliable resolution of prehistoric events it is sufficient to produce radiocarbon dates with errors of ca 20-25 years. Such accuracy seems to be avaiable without excessive cost wich must be spend for high-accuracy dates, wich are avaiable at present only on few dating laboratories (Seattle, Belfast, Groningen, Heidelberg). It should be pointed out, that for convetional radiocarbon dates from intervals 2100 - 2250 BP and 2400 - 2500 BP the accuracy of calendric dates decreases drastically.

Figure 5 shows similiar picture of 95% confidence intervals in the time range from 500 to 2500 BP. The curves showing 95% confidence intervals are more smoothed but previous comments seem to be equally valid.

Figure 6 shows 50% confidence intervals corresponding to conventional C - 14 dates with errors 25, 50 and 100 years. All above-said comments relating to Fig.4 are also valid. In addition, there is clearly visible another period with very low accuracy of calendric dates, from 4000 to 4700 BP. It can be also noted, that, in general, the confidence intervals of calendric dates increase with increasing conventional C - 14 date, even if the dating error is constant.

Conclusions

Analysis of results presented in Figures 4,5 and 6 leads tothe following conclusions :

1. The resolving power of radiocarbon dating changes significantly and depends on specific shape of the calibration curve in a certain period
2. The accuracy of calendric dates obtained for conventional radiocarbon dates with errors 10, 20 and 25 years is practically the same.
3. The resolving power of radiocarbon dates is very low in periods : 2100-2250, 2400-2500 and 4000-4700 BP.

References

Arnold J.R., W.F.Libby - 1949- Age determination by radiocarbon content: checks with samples of known age. Science 110. 678 - 680.

Baillie M.G.L.- 1982 - Tree-ring dating and archeology.London, Croom-Helm, 274p.

Becker B.- 1980 - Tree-ring dating and radiocarbon calibration in South-Central Europe. Radiocarbon 22, 219 - 226

Becker B. - 1988 - A 9224 years long absolute european tree=ring chronology and its extension to Late Glacial times. (In:) Interntl ^{14}C conf. 13th, Abstracts,39.

Hassan F.A., S.W. Robinson - 1986 - High-precision radiocarbon cronometry of ancient Egypt,and comparison with Nubia, Palestine and Mesopotamia. Antiquity ,61. 119 - 135.

Michczyńska D.J., M.F. Pazdur,A.Walanus - 1988 - Bayesian approach calibration of radiocarbon dates. PACT (in print)

Michczyńska D.J.,M.F.Pazdur - 1989 - Probabilistyczna kalibracja dat radiowęglowych.Zesz.Nauk.Pol.Śl. ser.Mat.-Fiz.z.61 Geochronometria 6. 37 - 60.

Pazdur M.F., D.J.Michczyńska - 1989 - Improvement of the procedure for probabilistic calibration of radiocarbon dates.Radiocarbon 31. (in print).

Pearson G.W., M.Stuiver - 1986 - High-precision calibration of the radiocarbon time scale 500 - 2500 BC. Radiocarbon 28. 839 - 862.

Pearson G.W., J.R.Pilcher, M.G.L. Ballie, D.M.Corbett , F.Qua -1986 High-precision ^{14}C measurements of Irish oaks to show the natural ^{14}C variation from AD 840 -5210 BC.Radiocarbon 28. 911 - 934.

Robinson S.W.- 1985 = A computational procedure for utilization of high-precision radiocarbon curves. Open=File Report,USGS, Menlo Park.

Stuiver M., G.W Pearson - 1986 - High=precision calibration of the radiocarbon time scale, AD 1950 - 500 BC. Radiocarbon 28. 805 - 836.

x x x