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CALIBRATION ISSUE

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Trondheim, Norway

Edited by Minze Stuiver and Renee Kra

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New Haven, Connecticut 06511

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NOTICE TO READERS AND CONTRIBUTORS

Since its inception, the basic purpose of Radiocarbon has been the publication of compilations of ^{14}C dates produced by various laboratories. These lists are extremely useful for the dissemination of basic ^{14}C information.

In recent years, Radiocarbon has also been publishing technical and interpretative articles on all aspects of ^{14}C. We would like to encourage this type of publication on a regular basis. In addition, we will be publishing compilations of published *and unpublished* dates along with interpretative text for these dates on a regional basis. Authors who would like to compose such an article for his/her area of interest should contact the Managing Editor for information.

Another section is added to our regular issues, "Notes and Comments." Authors are invited to extend discussions or raise pertinent questions to the results of scientific investigations that have appeared on our pages. The section includes short, technical notes to relay information concerning innovative sample preparation procedures. Laboratories may also seek assistance in technical aspects of radiocarbon dating. Book reviews will also be included for special editions.

Manuscripts of radiocarbon papers should follow the recommendations in *Suggestions to Authors** and *RADIOCARBON* Style Guide (R, 1984, v 26, p 152–158). Our deadline schedule for submitting manuscripts is:

For	*Date*
Vol 29, No. 1, 1987	Sept 1, 1986
Vol 29, No. 2, 1987	Jan 1, 1987
Vol 29, No. 3, 1987	May 1, 1987

Half life of ^{14}C. In accordance with the decision of the Fifth Radiocarbon Dating Conference, Cambridge, 1962, all dates published in this volume (as in previous volumes) are based on the Libby value, 5570 ± 30 yr, for the half life. This decision was reaffirmed at the 11th International Radiocarbon Conference in Seattle, Washington, 1982. Because of various uncertainties, when ^{14}C measurements are expressed as dates in years BP the accuracy of the dates is limited, and refinements that take some but not all uncertainties into account may be misleading. The mean of three recent determinations of the half life, 5730 ± 40 yr, (Nature, v 195, no. 4845, p 984, 1962), is regarded as the best value presently available. Published dates in years BP can be converted to this basis by multiplying them by 1.03.

AD/BC Dates. In accordance with the decision of the Ninth International Radiocarbon Conference, Los Angeles and San Diego, 1976, the designation of AD/BC, obtained by subtracting AD 1950 from conventional BP determinations is discontinued in Radiocarbon. Authors or submitters may include calendar estimates as a comment, and report these estimates as cal AD/BC, citing the specific calibration curve used to obtain the estimate. Calibrated dates will now be reported as "cal BP" or "cal AD/BC" according to the consensus of the Twelfth International Radiocarbon Conference, Trondheim, Norway, 1985.

Meaning of $\delta^{14}C$. In Volume 3, 1961, we endorsed the notation Δ (Lamont VIII, 1961) for geochemical measurements of ^{14}C activity, corrected for isotopic fractionation in samples and in the NBS oxalic-acid standard. The value of $\delta^{14}C$ that entered the calculation of Δ was defined by reference to Lamont VI, 1959, and was corrected for age. This fact has been lost sight of, by editors as well as by authors, and recent papers have used $\delta^{14}C$ as the observed deviation from the standard. At the New Zealand Radiocarbon Dating Conference it was recommended to use $\delta^{14}C$ only for age-corrected samples. Without an age correction, the value should then be reported as percent of modern relative to 0.95 NBS oxalic acid (Proceedings 8th Conference on Radiocarbon Dating, Wellington, New Zealand, 1972). The Ninth International Radiocarbon Conference, Los Angeles and San Diego, 1976, recommended that the reference standard, 0.95 times NBS oxalic acid activity, be normalized to $\delta^{13}C = -19‰$.

In several fields, however, age corrections are not possible. $\delta^{14}C$ and Δ, uncorrected for age, have been used extensively in oceanography, and are an integral part of models and theories. For the present, therefore, we continue the editorial policy of using Δ notations for samples not corrected for age.

*Suggestions to Authors of the Reports of the United States Geological Survey, 6th ed, 1978, Supt of Documents, U S Govt Printing Office, Washington, DC 20402.

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The Proceedings of the Twelfth International Radiocarbon Conference, Vol 28, Nos. 2A and 2B, 1986 are $60.00. No. 2B, the Special Calibration Issue, is available separately for $30.00. The full subscription for 1986 which includes the Proceedings is $80.00 (institutions) and $60.00 (individuals). The Proceedings of the Eleventh International Radiocarbon Conference, Vol 25, No. 2, 1983 are $50.00, and the Proceedings of the Tenth International Radiocarbon Conference, Vol 22, Nos. 2 and 3, 1980 are $60.00.

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Citations. A number of radiocarbon dates appear in publications without laboratory citation or refererence to published date lists. We ask that laboratories remind submitters and users of radiocarbon dates to include proper citation (laboratory number and date-list citation) in all publications in which radiocarbon dates appear.

Radiocarbon Measurements: Comprehensive Index, 1950–1965. This index covers all published ^{14}C measurements through Volume 7 of RADIOCARBON, and incorporates revisions made by all laboratories. It is available to all subscribers to RADIOCARBON at $20.00 US per copy.

List of laboratories. The comprehensive list of laboratories at the end of each volume appears in the third number of each volume. Changes in names or addresses should be reported to the Managing Editor by May 1.

Annual Index. All dates appear in index form at the end of the third number of each volume. Authors of date lists are asked to supply indexed material of *archaeologic samples only* with their date lists.

VOLUME 28 / NUMBER 2B / 1986

Radiocarbon

Published by THE AMERICAN JOURNAL OF SCIENCE

Proceedings of the Twelfth International Radiocarbon Conference—Trondheim, Norway

Editors
MINZE STUIVER and RENEE S KRA

EDITORIAL COMMENT

This special calibration issue of *RADIOCARBON* is an offshoot of the Proceedings of the 12th International Radiocarbon Conference, Trondheim, June 24–28, 1985 (*RADIOCARBON*, Vol. 28, No. 2A). Current "state of the art" radiocarbon age calibration is discussed in 12 papers. The age range covered by tree rings (with ages derived from dendrochronologic methods) approaches 10,000 yr (Fig 1). The various time intervals covered include the most recent millennia where the twin papers of Stuiver and Pearson and Pearson and Stuiver constitute *the* internationally accepted calibration curve for the AD 1950–2500 BC interval. This curve is based on the measurements of bi-decadal wood samples. More detailed time separation for the same interval can be obtained from the Stuiver and Becker curve which is based on decadal data.

Pearson *et al* provide a bi-decadal data set for the 4500–7200 cal yr BP interval. This interval is also covered by sections of Vogel, Fuls and Visser, de Jong, Becker and Mook, and Kromer *et al.* Bristlecone Pine data are given by Linick *et al* for the 7300–8500 cal yr BP stretch. Kromer *et al* and Stuiver *et al* go back to ca 9200 cal yr BP through ^{14}C matching of floating German Oak chronologies. Becker and and Kromer and Kromer *et al* provide information on the $\Delta\,^{14}C$ levels back to 9800 cal yr BP, and Stuiver *et al* use varve chronologies for the tentative calibration of a few additional millennia.

A calibration curve for marine samples is available back to 9200 cal yr BP (Stuiver, Pearson & Braziunas).

The calibration curves and tables provide the maximum amount of information for a single issue of *RADIOCARBON.* But the conversion procedure which involves curve reading and number interpolation is rather cumbersome. The solution, of course, is a computerized version of the conversion process. An IBM compatible program is described in the Stuiver and Reimer paper. This program converts radiocarbon ages, with associated standard deviation, into cal ages and cal ranges. The program which utilizes the above data sets, can be obtained from the Quaternary Isotope laboratory, University of Washington, Seattle, Washington 98195, USA, on a floppy diskette. For additional details, see Stuiver and Reimer.

The cal AD/BC (cal BP) nomenclature recommended by the Trondheim meeting has been used throughout the calibration issue. Further discussions on nomenclature are planned by the archaeological community for the Symposium on C14 and Archaeology, to be held in Groningen in September 1987.

MINZE STUIVER

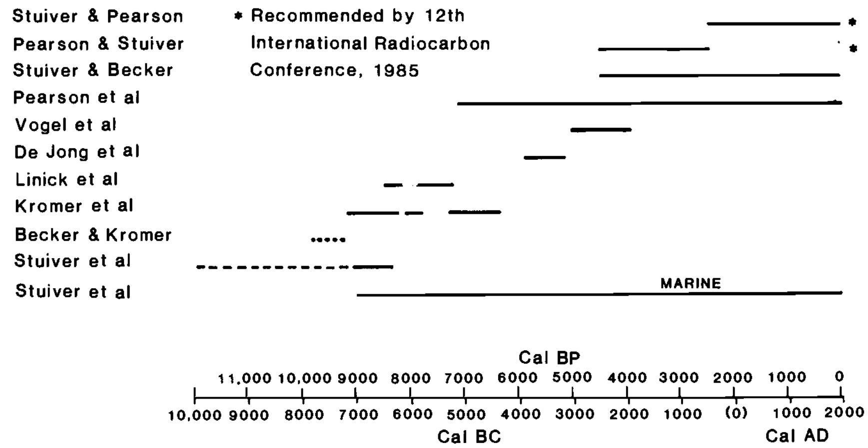

Fig 1. Intervals used for age calibration, as discussed in the listed papers of this calibration issue. The dashed portions are based on either floating tree chronologies or varve chronologies. The information obtained from these chronologies is preliminary.

ACKNOWLEDGMENT

The Twelfth International Radiocarbon Conference, Trondheim, Norway, June 24–28, 1985 was sponsored by the Norwegian Institute of Technology which also provided partial funding for these Proceedings. *RADIOCARBON* gratefully acknowledges its support.

CALIBRATION ISSUE

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[RADIOCARBON, VOL 28, NO. 2B, 1986, P 805–838]

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HIGH-PRECISION CALIBRATION OF THE RADIOCARBON TIME SCALE, AD 1950–500 BC

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INTRODUCTION

Radiocarbon ages of dendrochronologically-dated wood spanning the last 4500 years were determined at both the Seattle and Belfast laboratories. The combined results are reported in this issue of *RADIOCARBON* in two papers, with this paper covering the AD 1950–500 BC interval, and the twin (Pearson & Stuiver, 1986) covering the 500 BC–2500 BC interval.

Specific discussion of detail effecting only one of the two laboratories is given in the paper which has, as the premier author, the person responsible for the particular laboratory's measurement. Factors effecting both laboratories can be in either paper, but are carefully referenced to the other. Outline details are given in both papers.

The construction of a calibration curve from ^{14}C ages with statistically limited precision is not a simple matter. Not only should the standard error in the determination be as small as possible, but the calculation of this error also has to be realistic in that it should account for all variability encountered in the laboratory procedures. Independent dendrochronologic calibration of the samples is also a must. Proof of accuracy has to come from a comparison of the results obtained in two or more facilities. It will be shown that the results obtained in Seattle and in Belfast on wood of the same age, but from different regions, give consistent replication within the quoted errors over the entire interval. The aspects of replication are first discussed, and are followed by the detailed calibration curves and tables.

DENDROCHONOLOGY AND SAMPLE TREATMENT

The trees used at Seattle for the AD interval were either Douglas Fir (*Pseudotsuga menziesii*) from the US Pacific Northwest, or Sequoia (*Sequoiadendron giganteum*) from California. Dendrochronologic work on these materials was discussed in Stuiver (1982). Most of the BC material measured in Seattle was obtained from Becker's South German Donau series (Becker, 1983). The amount of wood available near 500 BC was limited, and here the Seattle laboratory measured samples from the Irish Oak chronology (Pilcher *et al*, 1984). All Belfast measurements are on oak wood from this chronology, except for a few samples that came from Scotland and northern England (Pearson & Stuiver, 1986).

The Seattle wood samples were either 1) treated with dilute NaOH and HCl solutions to remove resins, sugars, and a portion of the lignin (de Vries method, Stuiver & Quay, 1980) or 2) subjected to a more rigorous extraction yielding alpha cellulose. The cellulose preparation procedure is similar to the ^{13}C sample treatment given in Stuiver, Burk and Quay (1984), with slight modifications due to the bulk of the ^{14}C samples. The de Vries method does not remove all components added after the year of growth, but our experiments show that the influence on a ^{14}C age of the incomplete removal of late additions is limited to 2 or 3 ^{14}C years (Stuiver & Quay, 1981). All Belfast samples were pretreated to reduce the sample to cellulose of which the details are given in the twin paper (Pearson & Stuiver, 1986). The treatment given to the Seattle samples is listed in Table 2.

TECHNIQUE AND LABORATORY REPRODUCIBILITY

By the early 1970s the counting of large numbers of samples with improved precision (ca 30 years for the standard error based on counting statistics alone) was applied at the Universities of Washington (Seattle), Miami, and Heidelberg to ocean water samples collected on the GEOSECS and METEOR cruises. The systematic high-precision measurements (standard errors in the 12- to 20-year range) of wood samples began at Seattle (M Stuiver) in December 1973, at Belfast (G W Pearson) in 1975, and at Heidelberg (K O Münnich) and Groningen (W G Mook) in 1977.

Different techniques are applied in Seattle and Belfast. CO_2 gas proportional counters are used at Seattle (Stuiver, Robinson & Yang, 1979), whereas the liquid scintillation counting of benzene is applied at Belfast (Pearson, 1983). The true error in the measurement of the ^{14}C activity of a sample is only partially determined by the propogated statistical uncertainty in the number of counts accumulated for the sample and standards. This counting uncertainty is expressed as a standard deviation which is equal to the square root of the number of accumulated counts. Other factors sometimes more significant also play a role in the measuring process and will increase the standard deviation calculated from counting statistics alone. An exhaustive study of the parameters contributing to the error in ^{14}C measurements has been made for the Belfast liquid scintillation counting system (Pearson, 1979, 1980; Pearson *et al*, 1986). Taking into account the full spectrum of known uncertainties, the mean quoted error in a set of 55 individual measurements was determined to be 15.4 years at Belfast. However, replicate analysis of these samples at varying time intervals and assuming constant efficiency based on a mean standard count rate gives a calculated standard deviation of 19.0 years, suggesting that for a long-term series of measurements the quoted error is underestimated by ca 23% (Pearson *et al*, 1986). The ratio K = 19.0/15.4 or 1.23 is designated the "error multiplier" and is a convenient, if not the most accurate method of correcting for the inability to define exactly a sample counting efficiency and/or background even after all applicable corrections have been applied. All Belfast data used in this paper include the 1.23 error multiplier.

The traditionally quoted Seattle ^{14}C age error is based on the counting statistics of sample and standards only. The following estimates of the Seattle K value are available: 1) From a set of 30 comparisons of pairs of contemporaneous wood samples of different trees, all measured in the Seattle laboratory, K = 1.53 (Stuiver, 1982). The 1.53 value is an upper limit for laboratory reproducibility because part of the differences may also be due to differences in tree ^{14}C activity. 2) Tree-ring samples are usually counted for 4 days at Seattle. Samples are counted only once, but recounts are made when the measured sample activity deviates more than expected (eg, in a series of 6 samples the measured activity of 5 samples demonstrates a monotonic increase, but the 6th sample deviates). Seventy-five of these comparisons yielded K = 1.62. Again, this is an upper limit for laboratory reproducibility because there is a certain bias towards "outliers" in this data set.

From the above reproducibility tests we derive an error multiplier approaching 1.6 for Seattle. A rather "generous" K value of 1.6 has been incorporated in all Seattle data used in this paper. A more detailed discussion of the validity and accuracy of K factors is given elsewhere in this issue (Stuiver *et al*, 1986).

SYSTEMATIC DIFFERENCES BETWEEN LABORATORIES

The samples measured in the Belfast and Seattle laboratories span, respectively, 20-year and 10-year intervals. The mid-point of the Belfast samples occasionally may change from its 20-year rhythm by 10 years because successive 20-year blocks of wood were not always available. The starting years of the Seattle decadal wood and the Belfast bi-decadal wood also may differ (eg, a Seattle decade may start at 1971 BC and the corresponding Belfast bi-decade at 1970 BC). There also has been an ajdustment in dendrochronologic ages of some of the German oak samples which resulted in a shift of 71 years of "decadal" samples (Pilcher *et al*, 1984). The differences in timing are relatively small, however, and we have been able to average the Seattle decadal ^{14}C ages in such a manner that the mid-point of a Seattle bi-decade differs only in a few instances (see Table 1) by more than 1.5 years from the mid-point of the corresponding Belfast sample.

The weighted mean ^{14}C age difference of the Seattle and Belfast bi-decadal data set is -0.6 ± 1.6 years (with number of comparisons n = 214). Positive values for the mean indicate a younger Seattle data set. For the AD interval the difference is 2.6 ± 2.3 yr (n = 90); for the BC portion it is -3.4 ± 2.1 (n = 124). Clearly, the systematic differences in ^{14}C age are negligible between both laboratories.

The wood used to construct the calibration curve was collected from three geographic regions: Ireland, southern Germany, and the west Pacific coastal region of the United States. Irish oak wood, measured in Belfast, differs from German oak wood, measured in Seattle by -4.2 ± 2.4 yr (n = 106). Belfast-measured Irish oak wood differs from Seattle-measured US wood (Sequoia and Douglas Fir) by 2.4 ± 2.3 years (n = 87), and duplicate samples of Irish wood gave a mean difference between both laboratories of 3.2 ± 6 yr (n = 7).

The above results indicate that 1) systematic ^{14}C age differences are a few years or less between the Belfast and Seattle laboratories, and 2) ^{14}C ages of wood of the same age from Ireland, south Germany, and the northwest United States differ, on average, by only a few years.

SEATTLE-BELFAST COMPARISON OF VARIANCE

Proof was given in the preceding section that the systematic difference between the Belfast and Seattle ^{14}C determinations is negligible. It remains to be proven that the laboratory standard deviation in the single measurements is a realistic one.

Histograms of analytical results from repeat analyses of the same sample usually follow the normal (Gaussian) distribution. The procedures followed in determining a ^{14}C age may lead to a slight departure from the Gaussian distribution, resulting in some broadening at the top. For the calculations given here all variance is considered to be of the Gaussian variety.

The average Belfast standard deviation (which includes the 1.23 error multiplier) of the bi-decadal samples is 18.5 yr. For the Seattle bi-decadal averages the average standard deviation (which includes the 1.6 error multiplier) is 14.7 yr. The weighted average standard deviation in the ^{14}C age differences of contemporaneous samples, as measured in Seattle and Belfast, and calculated from the laboratory errors, is 22.9 yr.

The actual differences in ^{14}C ages (n = 214) are given in Figure 3. The Gaussian distribution for a 22.9-yr standard deviation is given by the solid curve. The observed sample variance yields a standard deviation of 25.6 years, which is only 1.12 times the predicted 22.9 years.

A portion of the 12% difference between observed and predicted standard deviation must be due to actual differences in wood ^{14}C activity. There are small differences in mid-point age of the "contemporaneous" 20-yr blocks of up to 1.5 yr. There are also differences in ring-thickness ^{14}C distribution between the Belfast and Seattle samples. For instance, if the first 5 yr of bi-decadal block A are relatively narrow, but wide in contemporaneous block B, the average ^{14}C activity of both samples may differ when the sample covers an interval of variable atmospheric ^{14}C levels. Of course, there could also be errors in wood splitting and dendrochronology.

The variance difference of 25.6^2–22.9^2 yr^2 gives an additional error source with a standard deviation of 11 yr that includes the differences in wood ^{14}C activity. We conclude:

1) The laboratory standard deviations assigned by both laboratories account for nearly 90% of the standard deviation in the end result.

2) The remaining 10% not accounted for by the laboratory measuring process includes the variability introduced by differences in wood ^{14}C activity.

The additional variance introduced by wood ^{14}C differences is so small that it has been neglected in the construction of the calibration curves. Increasing the standard deviation in the bidecadal means by 12% would have increased the 12.1-yr average standard deviation to 13.5 yr only.

CONSTRUCTION OF RADIOCARBON AGE CALIBRATION CURVES

The calibration curves were constructed from the set of ^{14}C ages obtained for samples each spanning a 20-yr interval, with some exceptions as noted in the Table 1 heading. The cal AD/BC (or cal BP) ages follow the mid-points of the Belfast bi-decadal series whenever possible, starting in AD 1840. The AD 1940–AD 1860 data set is based on the Seattle data alone; all other ^{14}C ages are based on the weighted Belfast/Seattle averages except when Belfast skipped a decade. Here the gaps were filled by averaging 30-yr blocks of Seattle data (see Table 1).

As discussed previously, the standard deviations in the ^{14}C age determinations of each laboratory are based on the reproducibility of the measurements within each laboratory and are larger than the errors usually quoted by both laboratories. For Belfast, where additional factors are used to calculate the routinely reported standard deviation beyond the counting statistics, the reproducibility tests indicate an error multiplier of 1.23. For Seattle, where the routinely reported standard deviations include only the error derived from counting statistics, the error multiplier is 1.6.

The standard deviation assigned to the curve (the vertical difference between center and outer curve) accounts for nearly 90% of the demonstrated standard deviation in the ^{14}C age differences of both laboratories. The mean standard deviation reported with the curves is 12.1 yr and is solely based on the Belfast and Seattle measuring reproducibility. The variance in the differences in ^{14}C ages of contemporaneous samples measured independently in Belfast and Seattle indicate a measure of uncertainty that is equivalent with an average standard deviation of 13.5 yr.

The wood used for the ^{14}C measurements came from the western United States, Ireland, and southern Germany (Table 2). Oak wood was used for the European chronologies (Becker, 1983; Pilcher *et al*, 1984) and Douglas Fir and Sequoia for the US portion. In the preceeding sections it was shown that contemporaneous wood from these trees differed, on average, by only a few ^{14}C years. Thus, although the curves are based on wood from different trees, identical results would have been obtained if all measurements had been made on a single tree from one locality.

THE AGE ERROR REPORTED WITH THE RADIOCARBON DATE

The international ^{14}C community follows strict calculation procedures when determining a conventional ^{14}C age (Stuiver & Polach, 1977). Unfortunately, age error calculations are much less bound by rules.

The error in any laboratory determination is a composite of 1) the Poisson statistical error based on the number of counts observed for sample and standards, assuming constant counting conditions, and 2) the errors associated with factors that cause deviation from the above constant counting conditions and other non-systematic errors which affect the reproducibility of the laboratory results. The latter can be derived from replicate sample measurements. Attempts to determine systematic errors are rarely made by the ^{14}C community. The reported sample age error (one standard deviation) is often based solely on Poisson statistics in the number of registered sample and standard counts. Such a substitute for a repeat-measurement derived standard deviation leads to an underestimate because it neglects other factors that add to the variance (Pearson, 1979, 1983).

When identical tree-ring samples (with approximate ages of ca 5000 ^{14}C yr) were measured by 20 laboratories (International Study Group, 1982) it was found that the reproducibility standard deviations in the submitted data set were substantially higher than the age errors reported by the laboratories. Systematic errors ranged from < 20 yr (3 laboratories) to 200 yr (1 laboratory).

When comparing the reproducibility standard deviation (obtained after removal of off-sets from the data set) with the laboratory reported error σ it was found that σ had to be multiplied with 1.3 for $\sigma < 20$ yr, with ca 2.0 for σ in the 20- to 80-yr range, and with 1.0 for $\sigma > 80$ yr (International Study Group). These multipliers are strictly laboratory-related and in principle independent of the magnitude of σ. Additional information on systematic errors is available for a set of samples in the 7000 to 8000 ^{14}C yr range measured in Seattle, La Jolla, Heidelberg, and Tucson (Stuiver *et al*, 1986). Off-sets of 29 ± 10, 27 ± 12 and 52 ± 8 yr were found, respectively, for Seattle-La Jolla, Seattle-Heidelberg, and Seattle-Tucson comparisons.

The above studies indicate that systematic errors may exist, and that the reported standard deviation of a ^{14}C age measurement is usually too low. The degree of under-reporting has only been determined so far for 20 odd laboratories for samples ca 5000 ^{14}C yr old. Unfortunately, the error multipliers determined in the above international group study cannot be applied to all age ranges because the multiplier values are age-dependent (Stuiver *et al*, 1986). Error multipliers also may change from year to year (or even day to day) at a specific laboratory with improving (or deteriorating) experimental conditions. It is recommended that the user of a ^{14}C date obtain additional information on reproducibility and systematic error determinations from the reporting laboratory. This information should lead to a realistic standard deviation in the age (based on repeat measurements of test samples) although care must be taken in its use, particularly when determining 2σ and 3σ probabilities. Limitations on systematic error size also should be provided. A systematic error, of course, should not be part of the regular ± reported with the date.

In the absence of the above information, the user can only take as the ^{14}C age error the actual reported σ, with the understanding that this error is usually too small. In case the user would take twice the reported standard deviation it should be realized that 1) for some laboratories the actual error may be smaller than $2\ \sigma$, and 2) statistical rules (such as stating that only 1 event out of 20 would be outside $2\ \sigma$ bounds) are not valid because, after all, the original σ is not a properly-defined standard deviation in many instances.

CALIBRATION INSTRUCTIONS

The Figure 1 calibration curves consist of three lines. The center line is the actual calibration curve whereas the outer lines indicate the one-sigma (standard deviation) uncertainty in the calibration curve. The calibration curve depicts the (non-linear) transformation of ^{14}C ages to calibrated AD/BC (or BP) ages. The nomenclature adopted for the dendro (calendar) year time scale is cal AD/BC or cal BP. The cal AD/BC ages are plotted along the lower horizontal axis and the cal BP ages along the upper one.

Cal BP ages are relative to the year AD 1950, with 0 cal BP equal to AD 1950. The relationship between cal AD/BC and cal BP ages is simple: cal BP = 1950 − cal AD, and cal BP = 1949 + cal BC. The switch from 1950 to 1949 when converting BC ages is caused by the absence of the zero year in the AD/BC chronology (when progressing from 1 BC to 1 AD, the cal BP ages should be without a gap).

The conversion of a ^{14}C age to a cal age is straightforward: 1) Draw a horizontal (parallel to the bottom axis) line (A) through the ^{14}C age to be converted, and 2) draw vertical lines through the intercept(s) of line A and the calibration curve (center line). The cal AD/BC ages can be read at the bottom axis, the cal BP ages at the top. A single ^{14}C age can correspond with multiple cal ages, due to past changes in atmospheric ^{14}C levels (see Stuiver, 1982 for illustration).

The user has to determine the calibrated ages from the Figure 1 graphs by drawing lines. An alternate approach is the use of Table 3, where the cal ages are listed for ^{14}C ages that increase by 20-yr steps. Obviously, the user has to interpolate between the 20-yr steps of ^{14}C ages and sigmas if further fine tuning is desired.

The conversion of the standard error in the ^{14}C age into a range of cal AD/BC (BP) ages is more complicated. The user should first determine whether he/she wants to use 1) the laboratory-quoted error (see previous section for a discussion), or 2) increase the quoted error by a known "error multiplier." Once the sample σ has been targeted, the curve σ (one standard deviation) should be read from the calibration curve by taking the difference in ^{14}C years between center curve and outer curve(s) in Figure 1. The curve σ and sample σ should then be used to calculate total $\sigma = \sqrt{(\text{sample }\sigma)^2 + (\text{curve }\sigma)^2}$ (Stuiver, 1982).

Horizontal lines should now be drawn through the ^{14}C age + total σ, and ^{14}C age − total σ value. The vertical lines, drawn through the intercepts with the CENTRAL curve, yield the outer limits of possible cal AD/BC (or BP) ages that are compatible with the sample standard deviation.

The above procedure was used to derive the "ranges" of cal AD/BC (BP) ages listed in Table 3.

The conversion procedure yields 1) single or multiple cal AD/BC (BP) ages that are compatible with a certain ^{14}C age, and 2) the range(s) of cal ages that corresponds to the standard deviation in the ^{14}C age. The probability that a certain cal age is the actual sample age may be quite variable within the cal age range. Higher probabilities are encountered around the intercept ages. Low, or near zero probabilities are encountered when part of the calibration curve 'snakes' outside the total σ boundaries. The non-linear transform of a Gaussian standard deviation around a ^{14}C age into cal AD/BC (BP) ages leads to a very complex probability distribution that can only be calculated with the aid of computers. We are currently developing suitable programs for these probability calculations, and plan to make these programs available in the near future.

The calibration data presented in this paper are to be used for samples formed in isotopic (^{14}C) equilibrium with atmospheric CO_2. Although the wood samples were collected from specific regions (Ireland, Germany, and western USA) the calibration data can be used for a large part of the Northern Hemisphere (Stuiver, 1982). However, systematic age differences are possible for Southern Hemispheric samples where ^{14}C ages of wood samples tend to be ca 30 yr older (Lerman, Mook & Vogel, 1970; Vogel, Fuls & Visser, 1986). Thus, ^{14}C ages of Southern Hemispheric samples should be reduced by 30 years before being converted into a cal AD/BC (BP) age.

SMOOTHING OF THE CALIBRATION CURVE

The Figure 1 points have a 20-yr time separation, *ie,* the calibration points are the mid-points of wood samples spanning 20 years. Samples submitted for dating may cover shorter (eg, seed samples) or longer intervals (eg, lake sediment samples). The decadal calibration results of the Seattle laboratory are available when better time resolution is needed (Stuiver & Becker, 1986). If less resolution is desired, the Figure 2 curves can be used. Here, a 5-point moving average (usually identical with a 100-yr moving average of the Figure 1 data set) was used to construct the curves. A single line is given in Figure 2 because the uncertainty in the 5-point moving average is only a few ^{14}C years. The instructions for determining the cal AD/BC (BP) ages are listed in the preceding section. Samples falling outside the ranges covered by the twin papers (Stuiver & Pearson, 1986; Pearson & Stuiver, 1986) can be provisionally converted using the curves provided by Pearson *et al* (1986) employing the same method outlined above.

MARINE SAMPLE AGES

The calibration curves should be applied only for age conversion of samples that were formed in equilibrium with atmospheric CO_2. Conventional ^{14}C ages of materials not in equilibrium with atmospheric reservoirs do not take into account the off-set in ^{14}C age that may occur (Stuiver & Polach, 1977). This off-set, or reservoir deficiency, has to be deducted from the reported age before any attempt can be made to convert to cal AD/BC (BP) ages. The reservoir deficiency is time-dependent for the mixed layer of the ocean. Model-calculated calibration curves for marine samples are listed separately in this volume (Stuiver, Pearson & Braziunas, 1986).

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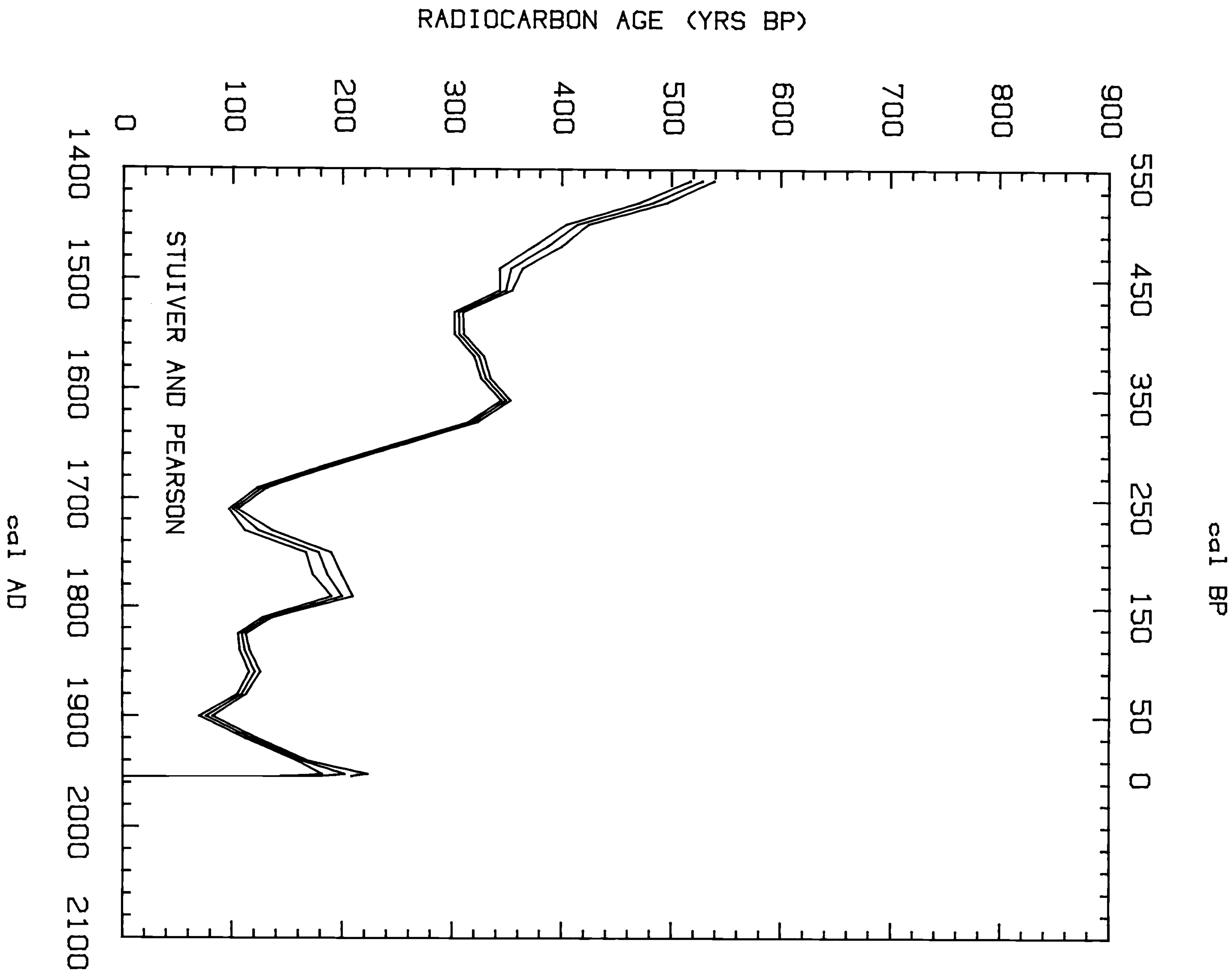

RADIOCARBON AGE (YRS BP)
0
100
200
300
400
500
600
700
800
900
cal BP
550
450
350
250
150
50
0
1400
1500
1600
1700
1800
1900
2000
2100
cal AD
STUIVER AND PEARSON

Fig 1A

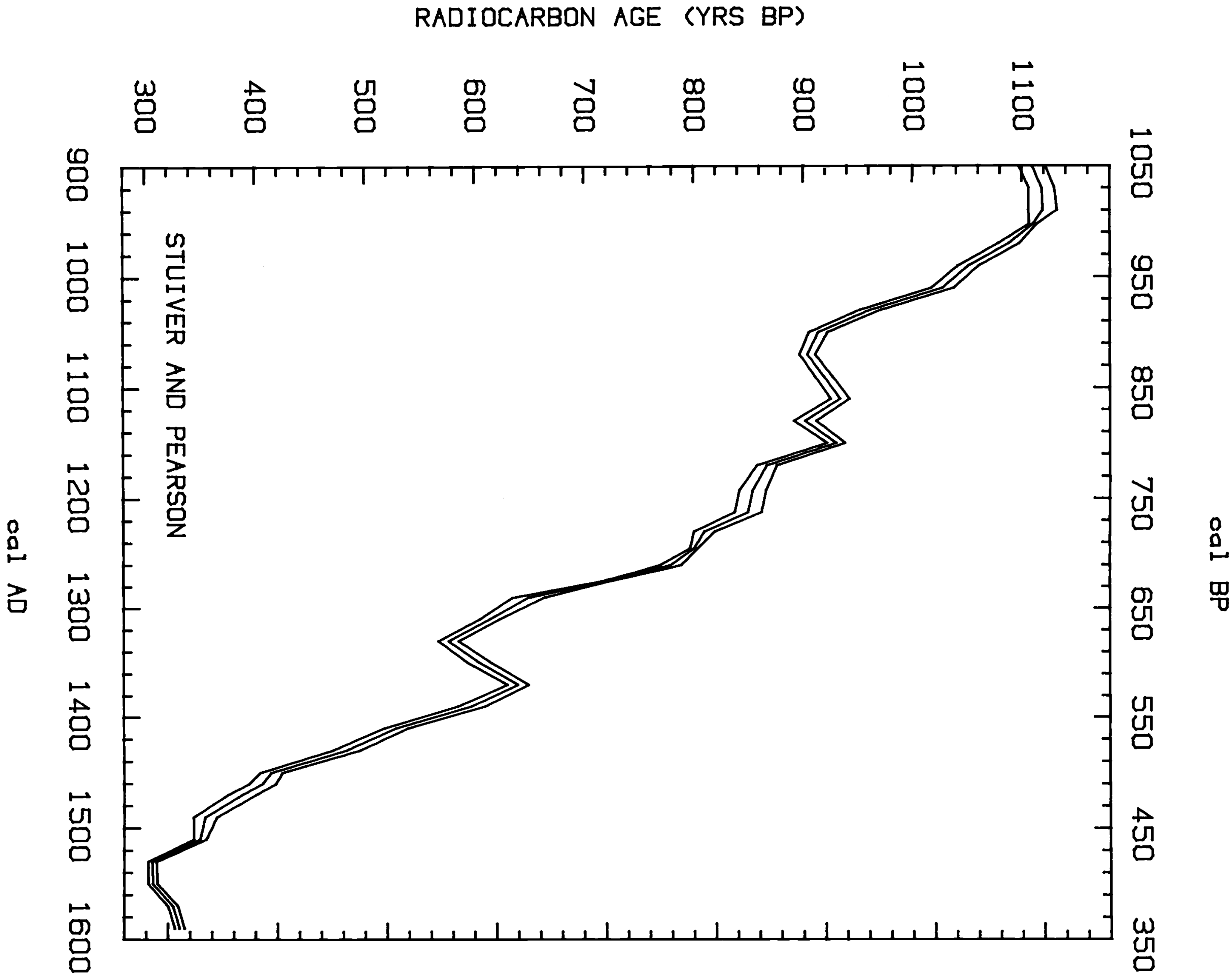
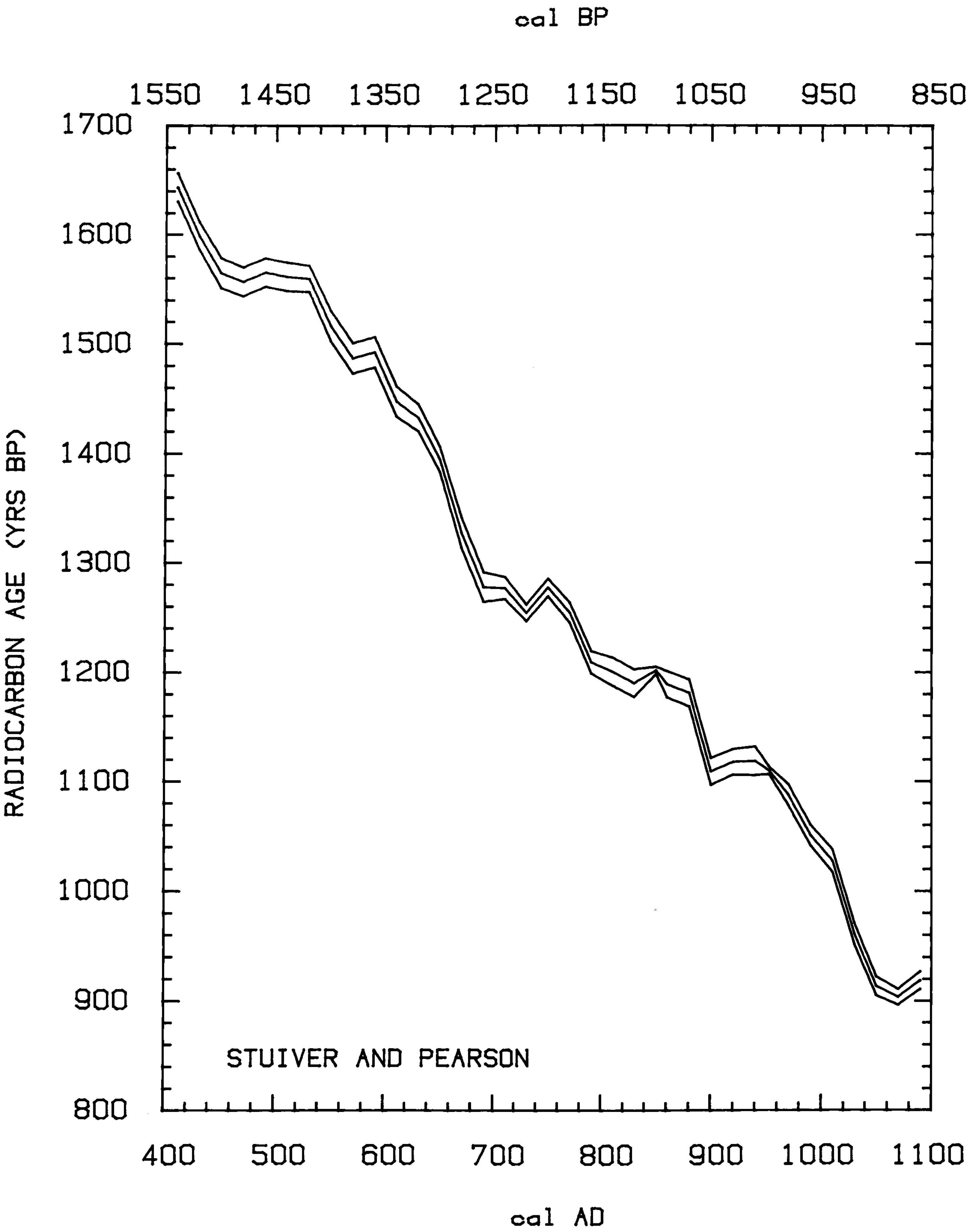

RADIOCARBON AGE (YRS BP)
300 400 500 600 700 800 900 1000 1100
cal BP
1050 950 850 750 650 550 450 350
STUIVER AND PEARSON
900 1000 1100 1200 1300 1400 1500 1600
cal AD

Fig 1B



cal BP
1550
1450
1350
1250
1150
1050
950
850
RADIOCARBON AGE (YRS BP)
1700
1600
1500
1400
1300
1200
1100
1000
900
800
STUIVER AND PEARSON
400
500
600
700
800
900
1000
1100
cal AD

Fig 1C

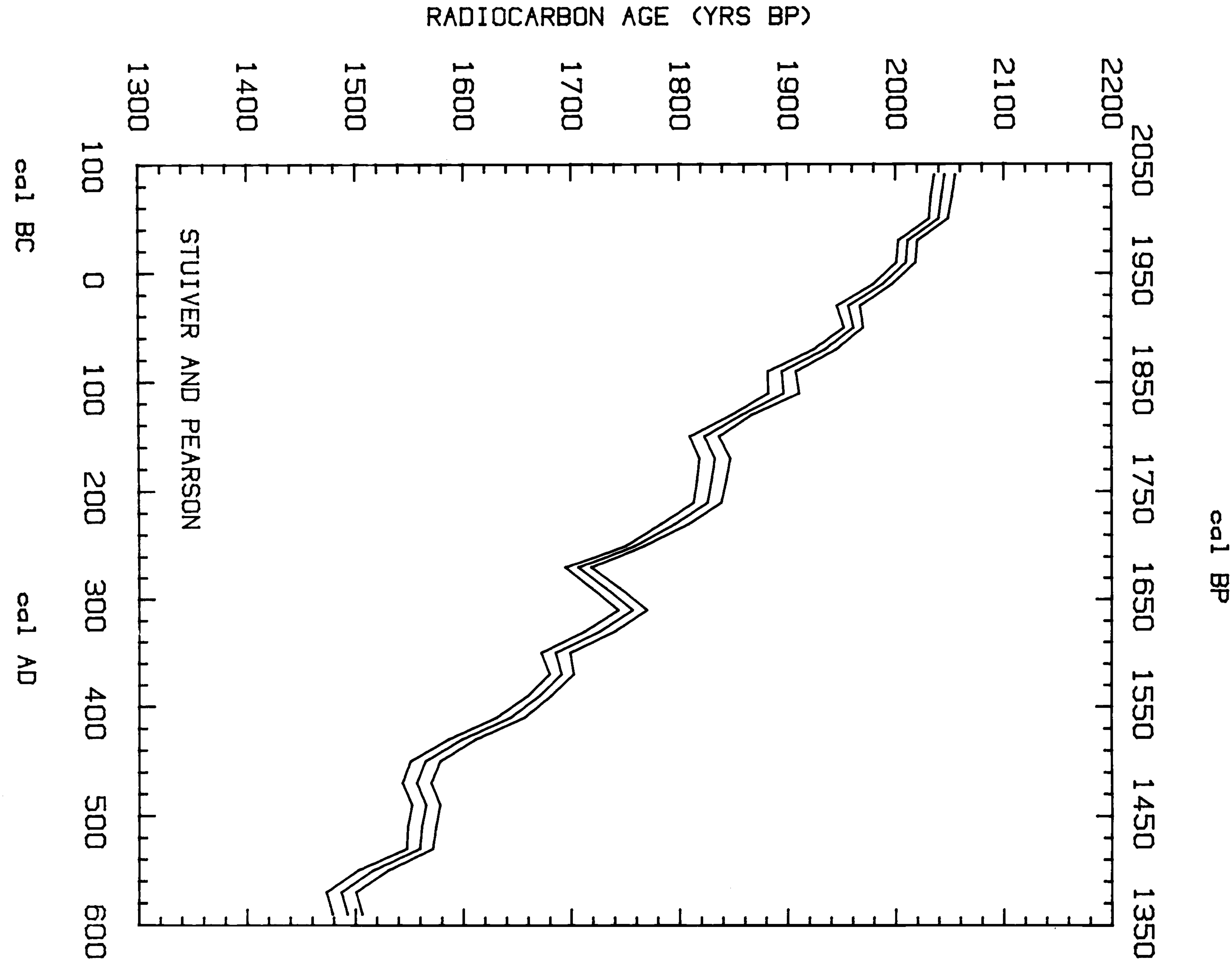

RADIOCARBON AGE (YRS BP)
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
cal BP
2050
1950
1850
1750
1650
1550
1450
1350
STUIVER AND PEARSON
100
0
100
200
300
400
500
600
cal BC
cal AD

Fig 1D

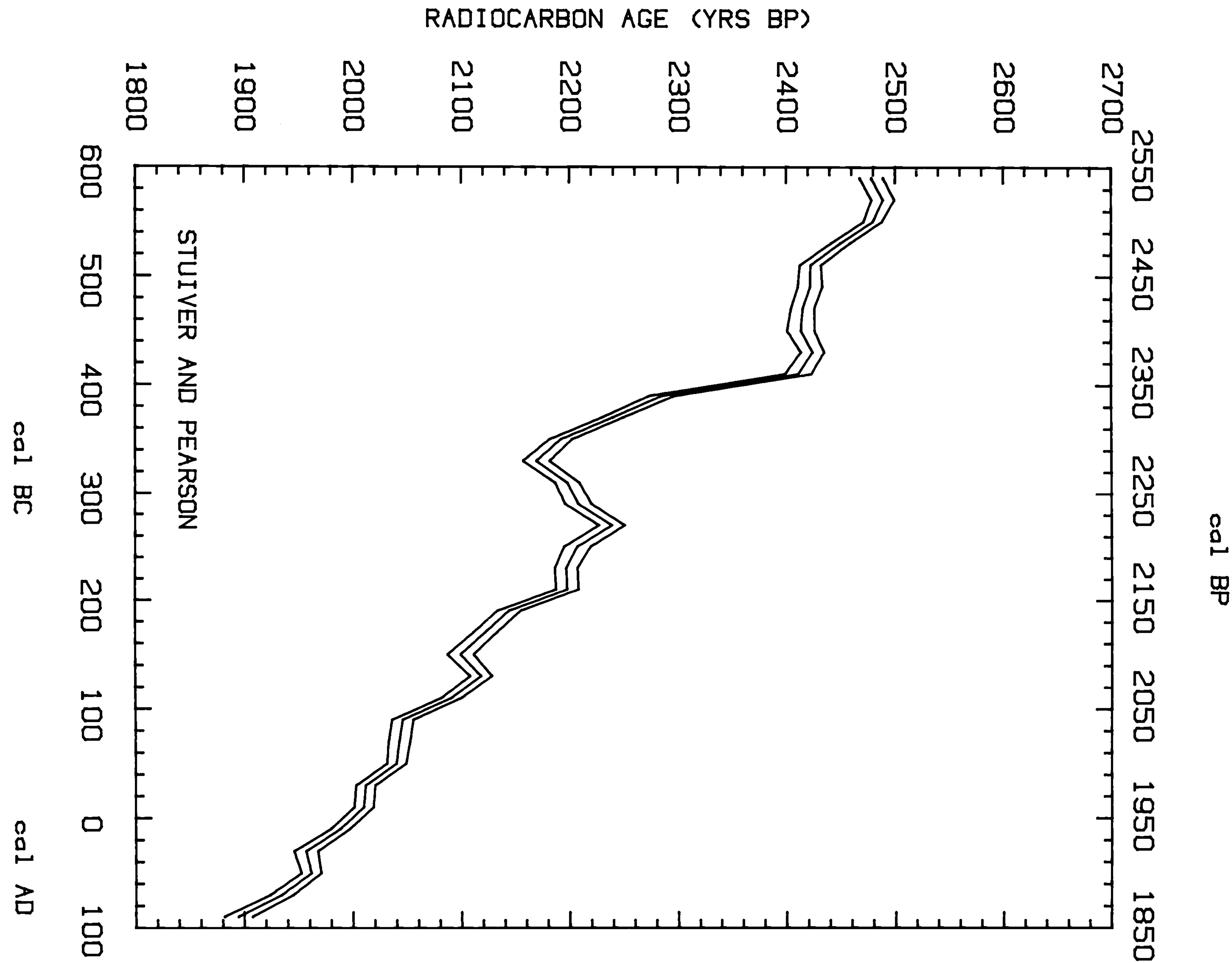
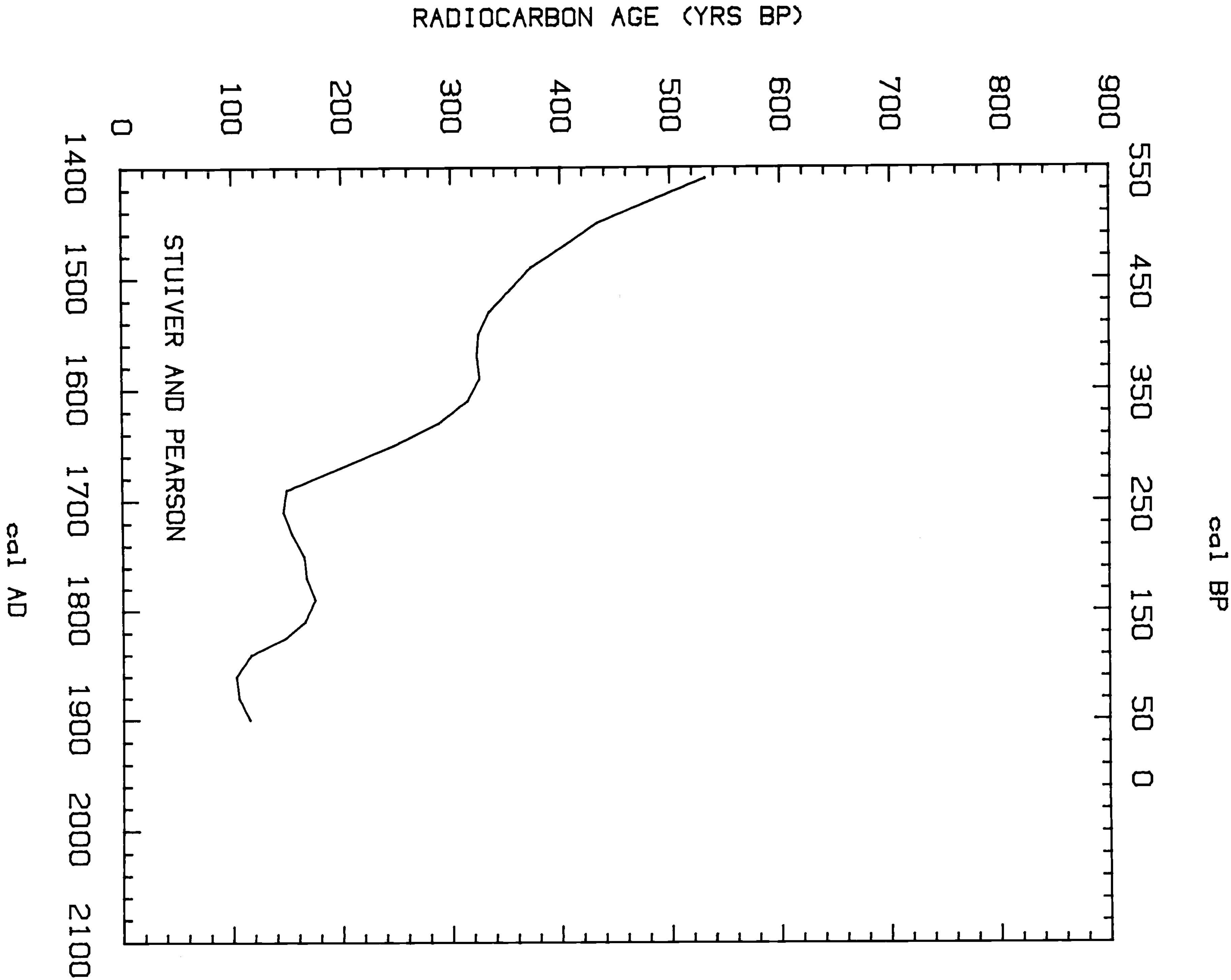

RADIOCARBON AGE (YRS BP)
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
cal BP
2550
2450
2350
2250
2150
2050
1950
1850
600
500
400
300
200
100
0
100
cal BC
cal AD
STUIVER AND PEARSON

Fig 1E


RADIOCARBON AGE (YRS BP)
0
100
200
300
400
500
600
700
800
900
cal BP
550
450
350
250
150
50
0
STUIVER AND PEARSON
1400
1500
1600
1700
1800
1900
2000
2100
cal AD
Fig 2A

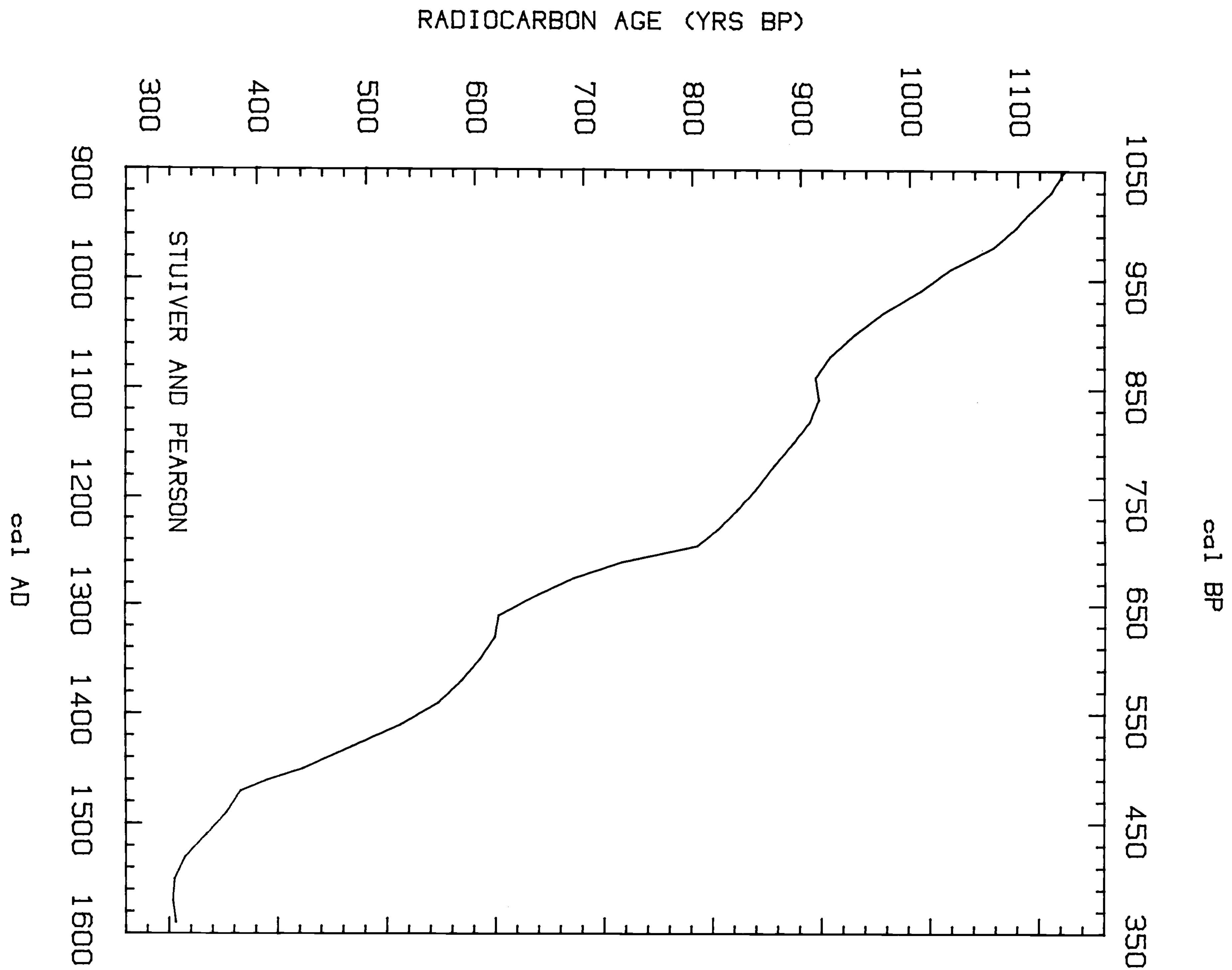

RADIOCARBON AGE (YRS BP)
300 400 500 600 700 800 900 1000 1100
cal BP
1050 950 850 750 650 550 450 350
STUIVER AND PEARSON
900 1000 1100 1200 1300 1400 1500 1600
cal AD

Fig 2B

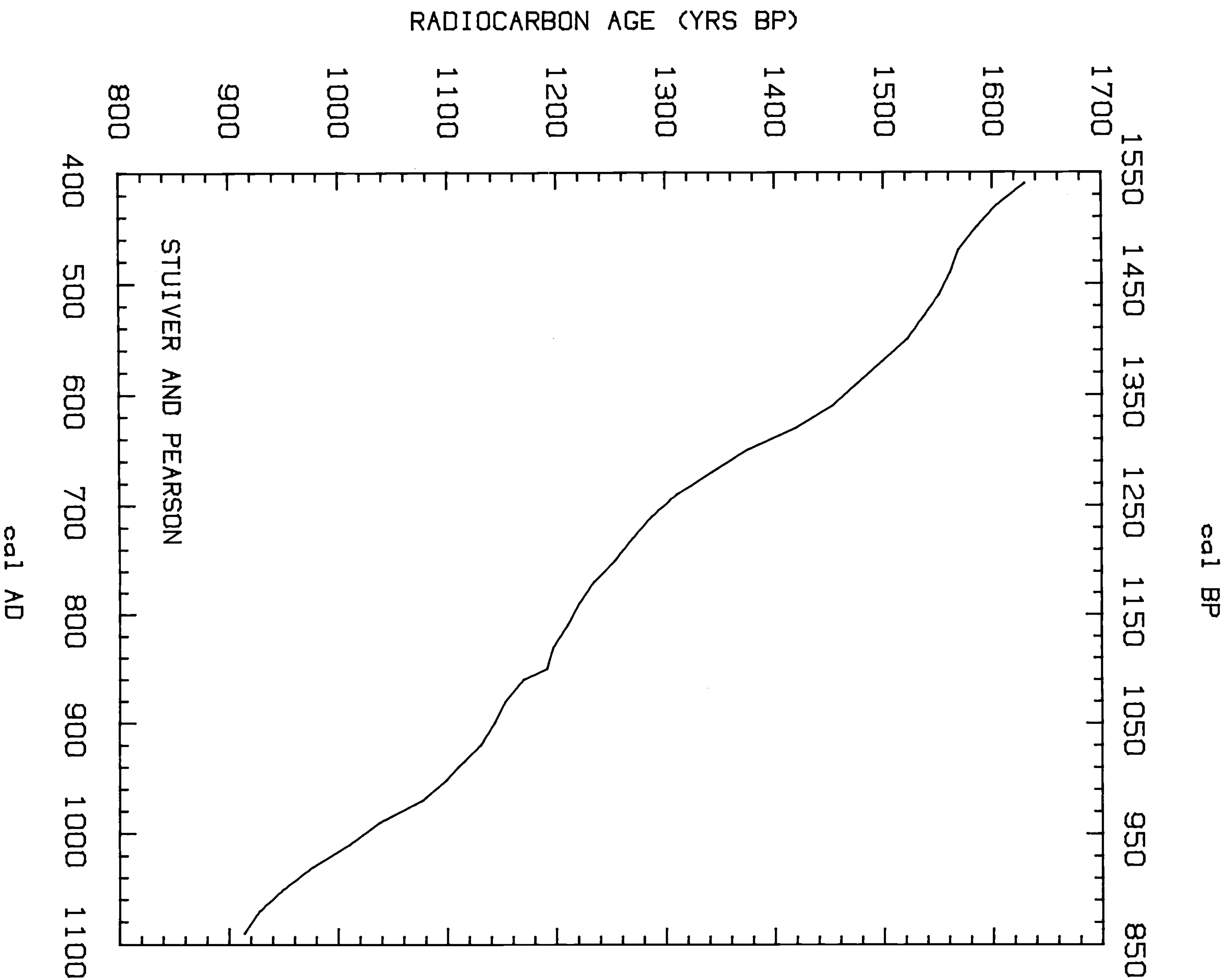

RADIOCARBON AGE (YRS BP)
800
900
1000
1100
1200
1300
1400
1500
1600
1700
cal BP
1550
1450
1350
1250
1150
1050
950
850
cal AD
400
500
600
700
800
900
1000
1100
STUIVER AND PEARSON

Fig 2C

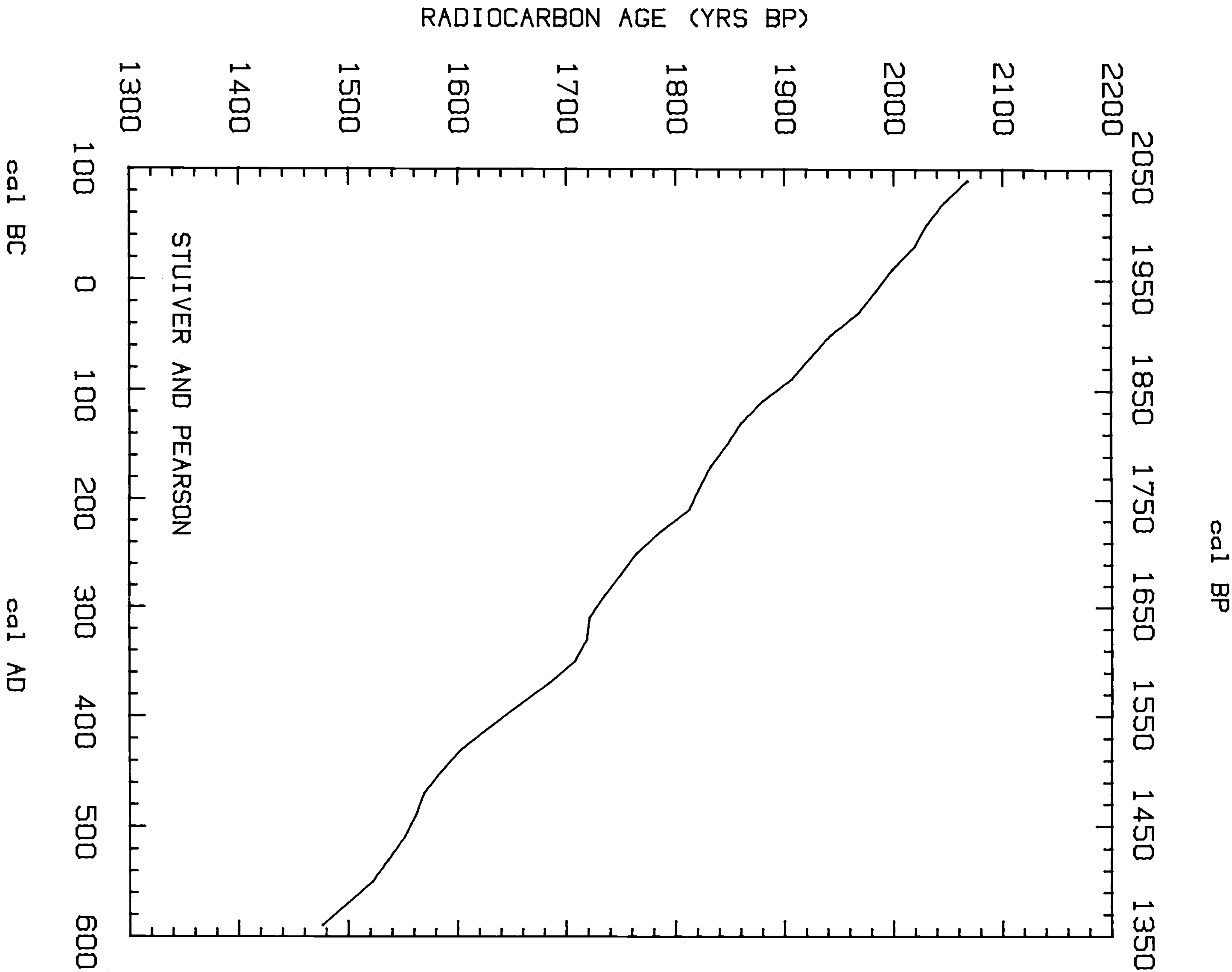
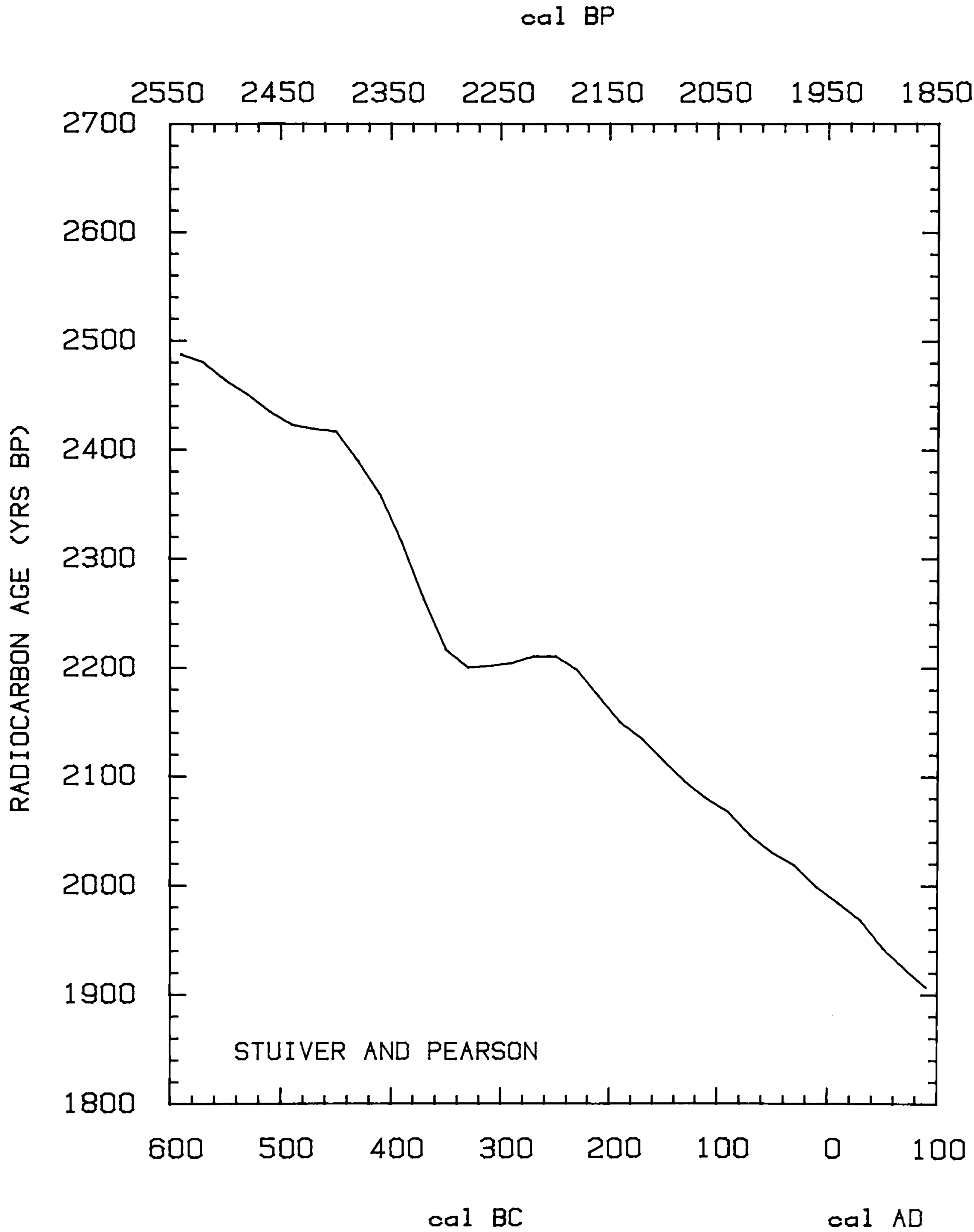

RADIOCARBON AGE (YRS BP)
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
cal BP
2050
1950
1850
1750
1650
1550
1450
1350
100
0
100
200
300
400
500
600
cal BC
cal AD
STUIVER AND PEARSON

Fig 2D


cal BP
2550
2450
2350
2250
2150
2050
1950
1850
RADIOCARBON AGE (YRS BP)
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
STUIVER AND PEARSON
600
500
400
300
200
100
0
100
cal BC
cal AD
Fig 2E

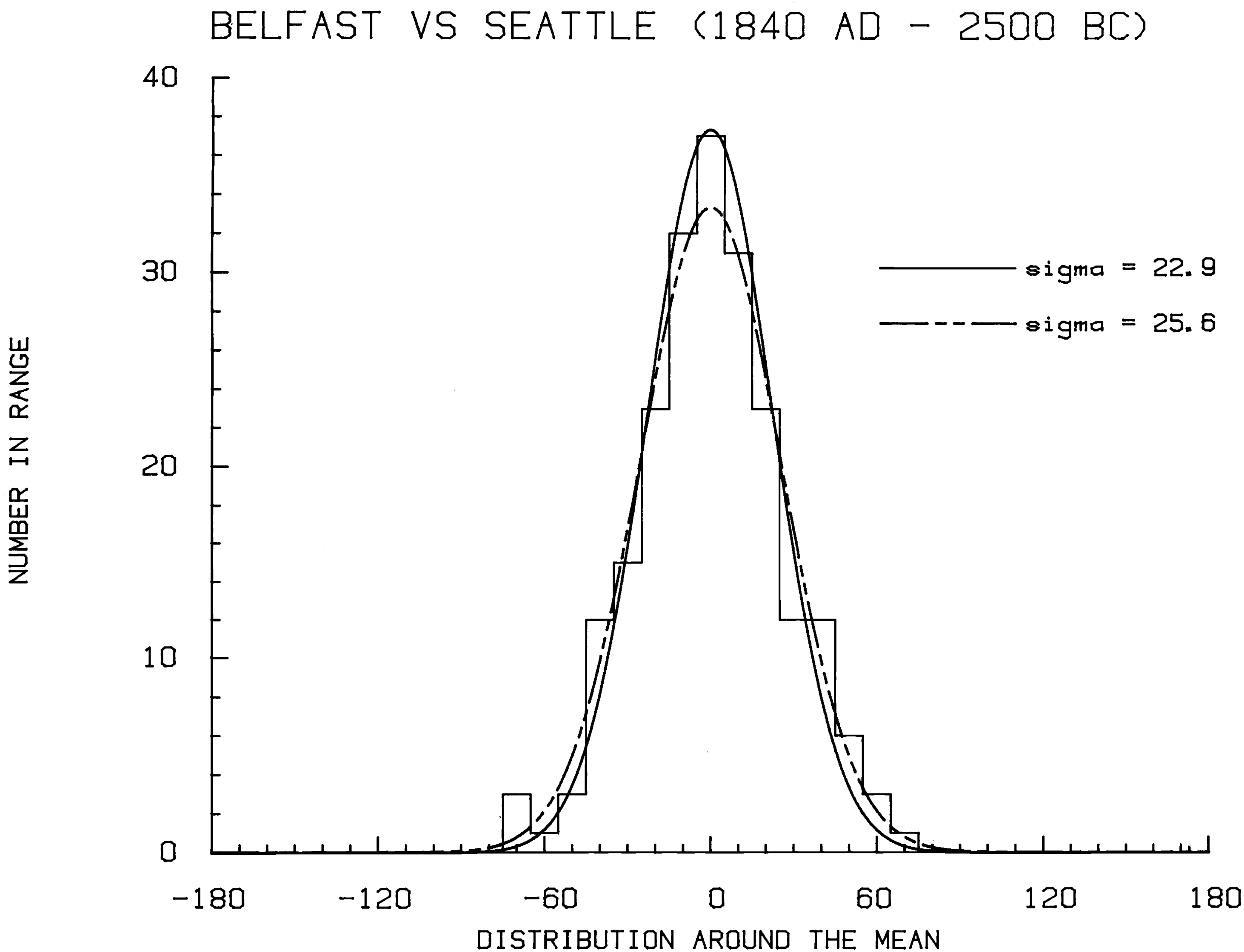


Fig 3. Differences in ^{14}C ages of contemporaneously formed wood samples measured in Belfast and Seattle. Belfast and Seattle laboratory errors predict a standard deviation of 22.9 yr in the differences. Observed distribution has a 25.6 yr standard deviation.

TABLE 1-A

The radiocarbon ages are the weighted averages of age determinations made at the University of Washington (Seattle) and the University of Belfast. The cal AD/BC (or cal BP) ages represent the mid-points of bi-decadal wood sections, except in a few instances, where Belfast skipped a decade (†). Here 3 10-year blocks of Seattle data were averaged to fill the gaps. Seattle bi-decadal results were also solely used for the AD 1940 to 1860 radiocarbon ages.

The cal AD/BC ages follow the mid-points of the Belfast bi-decadal series whenever possible, starting at AD 1840. The actual mid-points of the averages were occasionally slightly different. The differences have been neglected because the mid-points of the Seattle sample were always within 1.5 years of the mid-point of the corresponding Belfast sample, except for 3 samples denoted by *, where the Seattle/Belfast mid-points were 5 years apart. The standard deviation in the ages and Δ values include lab error multipliers of 1.23 for Belfast and 1.6 for Seattle. The trees used and sample treatments are listed in Table 2.

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 1940 BP 10	-19.0 ± .6	164 ± 5
AD 1920 BP 30	-10.9 ± .7	117 ± 5
AD 1900 BP 50	-3.4 ± .8	76 ± 6
AD 1880 BP 70	-5.1 ± .5	109 ± 4
AD 1860 BP 90	-4.1 ± .6	120 ± 5
AD 1840 BP 110	-.5 ± .6	111 ± 4
†AD 1825 BP 125	1.6 ± .4	109 ± 4
AD 1810 BP 140	.5 ± .5	132 ± 4
AD 1790 BP 160	-5.5 ± 1.2	200 ± 10
AD 1770 BP 180	-1.4 ± 1.6	186 ± 13
AD 1750 BP 200	2.0 ± 1.4	179 ± 12
AD 1730 BP 220	11.2 ± 1.6	124 ± 13
AD 1710 BP 240	16.6 ± .5	101 ± 4
AD 1690 BP 260	15.7 ± .5	128 ± 4
AD 1670 BP 280	10.6 ± .5	188 ± 4
AD 1650 BP 300	4.8 ± .5	253 ± 4
AD 1630 BP 320	-1.0 ± .5	319 ± 4
AD 1610 BP 340	-2.3 ± .5	349 ± 4
AD 1590 BP 360	2.4 ± .5	331 ± 4
AD 1570 BP 380	5.6 ± .6	324 ± 5
AD 1550 BP 400	10.3 ± .5	306 ± 4
AD 1530 BP 420	12.9 ± .5	306 ± 4
AD 1510 BP 440	9.8 ± .7	349 ± 6
AD 1490 BP 460	11.7 ± 1.3	354 ± 11
AD 1470 BP 480	10.0 ± 1.6	387 ± 13
AD 1450 BP 500	8.9 ± 1.3	414 ± 10
AD 1430 BP 520	2.8 ± 1.6	483 ± 12
AD 1410 BP 540	-.4 ± 1.4	528 ± 11
AD 1390 BP 560	-6.5 ± 1.5	597 ± 12
AD 1370 BP 580	-9.4 ± 1.2	639 ± 10
AD 1350 BP 600	-2.7 ± 1.3	605 ± 11
AD 1330 BP 620	3.3 ± 1.2	576 ± 9
AD 1310 BP 640	1.1 ± 1.1	613 ± 9
AD 1290 BP 660	-.9 ± 1.8	648 ± 14

TABLE 1-B

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
†AD 1275 BP 675	-7.8 ± .4	719 ± 4
AD 1260 BP 690	-13.4 ± 1.2	779 ± 10
†AD 1245 BP 705	-14.2 ± .4	800 ± 4
AD 1230 BP 720	-13.6 ± 1.2	809 ± 9
*AD 1212.5 BP 737.5	-16.4 ± 1.5	849 ± 12
*AD 1192.5 BP 757.5	-14.5 ± 1.5	854 ± 12
AD 1170 BP 780	-13.4 ± 1.1	867 ± 9
AD 1150 BP 800	-18.8 ± 1.0	930 ± 8
AD 1130 BP 820	-12.9 ± 1.3	901 ± 10
AD 1110 BP 840	-14.5 ± 1.1	934 ± 9
AD 1090 BP 860	-10.3 ± 1.0	919 ± 8
AD 1070 BP 880	-6.0 ± .9	904 ± 7
AD 1050 BP 900	-4.8 ± 1.1	914 ± 9
AD 1030 BP 920	-8.3 ± 1.2	961 ± 10
AD 1010 BP 940	-14.1 ± 1.3	1027 ± 10
AD 990 BP 960	-14.6 ± 1.2	1051 ± 9
AD 970 BP 980	-16.7 ± 1.2	1088 ± 10
*AD 952.5 BP 997.5	-17.4 ± .4	1110 ± 3
AD 940 BP 1010	-17.0 ± 1.6	1119 ± 13
AD 920 BP 1030	-14.5 ± 1.5	1118 ± 12
AD 900 BP 1050	-11.0 ± 1.5	1109 ± 12
AD 880 BP 1070	-17.5 ± 1.5	1181 ± 12
AD 860 BP 1090	-16.1 ± 1.5	1189 ± 12
AD 850 BP 1100	-16.4 ± .4	1202 ± 3
AD 830 BP 1120	-12.6 ± 1.6	1190 ± 13
AD 810 BP 1140	-11.5 ± 1.6	1201 ± 13
AD 790 BP 1160	-10.2 ± 1.3	1209 ± 10
AD 770 BP 1180	-13.3 ± 1.2	1255 ± 9
AD 750 BP 1200	-13.8 ± 1.0	1278 ± 8
AD 730 BP 1220	-8.5 ± .9	1254 ± 8
AD 710 BP 1240	-8.9 ± 1.3	1277 ± 10
AD 690 BP 1260	-6.6 ± 1.7	1278 ± 13
AD 670 BP 1280	-10.3 ± 1.7	1327 ± 14
AD 650 BP 1300	-16.2 ± 1.4	1395 ± 11
AD 630 BP 1320	-18.5 ± 1.5	1433 ± 12
AD 610 BP 1340	-17.9 ± 1.7	1448 ± 14
AD 590 BP 1360	-21.1 ± 1.7	1493 ± 14
AD 570 BP 1380	-18.0 ± 1.7	1487 ± 14
AD 550 BP 1400	-19.2 ± 1.7	1516 ± 14
AD 530 BP 1420	-22.1 ± 1.5	1560 ± 12
AD 510 BP 1440	-20.0 ± 1.6	1562 ± 13
AD 490 BP 1460	-18.1 ± 1.6	1565 ± 13
AD 470 BP 1480	-14.6 ± 1.6	1557 ± 13
AD 450 BP 1500	-13.2 ± 1.7	1565 ± 14
AD 430 BP 1520	-15.0 ± 1.6	1598 ± 13
AD 410 BP 1540	-18.1 ± 1.6	1643 ± 13
AD 390 BP 1560	-19.1 ± 1.3	1671 ± 11
AD 370 BP 1580	-19.2 ± 1.4	1691 ± 11
AD 350 BP 1600	-16.1 ± 1.7	1685 ± 13
AD 330 BP 1620	-18.7 ± 1.7	1726 ± 14

TABLE 1-C

cal AD/BC	cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC	cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 310	BP 1640	-20.1 ± 1.6	1757 ± 13	BC 190	BP 2139	-8.1 ± 1.3	2144 ± 11
AD 290	BP 1660	-14.7 ± 1.6	1732 ± 13	BC 210	BP 2159	-12.3 ± 1.3	2198 ± 10
AD 270	BP 1680	-9.1 ± 1.5	1706 ± 12	BC 230	BP 2179	-9.8 ± 1.3	2197 ± 10
AD 250	BP 1700	-13.2 ± 1.1	1759 ± 9	BC 250	BP 2199	-8.7 ± 1.5	2207 ± 12
AD 230	BP 1720	-15.3 ± 1.6	1796 ± 13	BC 270	BP 2219	-10.2 ± 1.5	2239 ± 12
AD 210	BP 1740	-16.7 ± 1.6	1826 ± 13	BC 290	BP 2239	-4.0 ± 1.5	2208 ± 12
AD 190	BP 1760	-14.7 ± 1.7	1830 ± 13	BC 310	BP 2259	-.3 ± 1.4	2198 ± 11
AD 170	BP 1780	-12.7 ± 1.8	1833 ± 14	BC 330	BP 2279	5.7 ± 1.5	2169 ± 12
AD 150	BP 1800	-9.1 ± 1.7	1823 ± 13	BC 350	BP 2299	5.2 ± 1.3	2192 ± 10
AD 130	BP 1820	-11.0 ± 1.2	1857 ± 9	BC 370	BP 2319	1.8 ± 1.2	2240 ± 10
AD 110	BP 1840	-13.4 ± 1.8	1896 ± 14	BC 390	BP 2339	-1.6 ± 1.5	2286 ± 12
AD 90	BP 1860	-10.8 ± 1.6	1895 ± 13	BC 410	BP 2359	-14.7 ± 1.5	2411 ± 12
AD 70	BP 1880	-13.3 ± 1.3	1934 ± 10	BC 430	BP 2379	-13.9 ± 1.3	2424 ± 11
AD 50	BP 1900	-14.2 ± 1.1	1961 ± 9	BC 450	BP 2399	-10.2 ± 1.6	2413 ± 13
AD 30	BP 1920	-11.2 ± 1.3	1957 ± 11	BC 470	BP 2419	-8.0 ± 1.3	2415 ± 11
AD 10	BP 1940	-12.7 ± 1.1	1988 ± 9	BC 490	BP 2439	-6.4 ± 1.4	2422 ± 11
BC 10	BP 1959	-13.1 ± 1.1	2010 ± 9	BC 510	BP 2459	-4.1 ± 1.2	2422 ± 10
BC 30	BP 1979	-10.9 ± 1.1	2012 ± 9	BC 530	BP 2479	-5.0 ± 1.1	2450 ± 9
BC 50	BP 1999	-12.0 ± 1.1	2040 ± 9	BC 550	BP 2499	-6.3 ± 1.0	2480 ± 8
BC 70	BP 2019	-10.0 ± 1.2	2043 ± 10	BC 570	BP 2519	-5.1 ± 1.3	2489 ± 10
BC 90	BP 2039	-8.0 ± 1.2	2046 ± 10	BC 590	BP 2539	-1.4 ± 1.3	2478 ± 11
BC 110	BP 2059	-11.1 ± 1.1	2091 ± 9	BC 610	BP 2559	-1.9 ± 1.2	2502 ± 10
BC 130	BP 2079	-12.1 ± 1.3	2118 ± 10	BC 630	BP 2579	2.3 ± 1.2	2488 ± 10
BC 150	BP 2099	-7.4 ± 1.5	2099 ± 12	BC 650	BP 2599	7.3 ± 1.2	2468 ± 10
BC 170	BP 2119	-7.8 ± 1.3	2122 ± 11	BC 670	BP 2619	5.0 ± 1.8	2505 ± 15

TABLE 2

Lab code	Species	Dendro-ages used	Wood treatment*	Location	Dendro-chronology
C	Douglas fir	AD 1915–1954 (single year)	CL	Olympic Pennisula, WA (47°46′N, 124°06′W)	Ring counted only
A	Douglas fir	AD 1820–1913 (single year)	DV**	Olympic Pennisula, WA (47°46′N, 124°06′W)	Ring counted only
B	Douglas fir	AD 1690–1719 AD 1790–1819 (single year)	DV	Mt Rainier Natl Park, Washington (46°45′N, 121°45′W)	Ring counted only
F	Douglas fir	AD 1510–1699 (single year) AD 1505–1935 (decadal)	DV DV†	Coos Bay, OR (43°07′N, 123°40′W)	Ring counted only
R	Douglas fir	AD 1305–1505 (single year) AD 1505–1935 (decadal)	DV	Pierce County, WA (47°N, 122°W)	Ring counted only
S	Douglas fir	AD 945–1315 (decadal)	DV	Shawnigan Lake, Vancouver Island, BC Canada (48°40′N, 123°40′W)	Cross-dated by M Parker *et al*, Western Products Forestry, Vancouver, BC
RC	Sequoia	AD 265–935 (decadal)	DV	Sequoia Natl Park, CA (36.5°N, 118.5°W)	Cross-dated by H Garfinkel, University of Washington, Seattle
ECK	Oak	AD 705–765 (decadal)	DV	Northern Germany	Cross-dated by D Eckstein, University of Hamburg
SR	Sequoia	145 BC–AD 265 (decadal)	DV	Sequoia Natl Park, CA (36.5°N, 118.5°W)	Cross-dated by H Garfinkel
BK	Oak	495 BC–AD 45	CL	Southern Germany	Cross-dated by B Becker, University of Hohenheim, Stutgart, W Germany
BK‡	Oak	505–2495 BC (decadal)	CL	Southern Germany	Cross-dated by B Becker
PQ‡	Oak	515–625 BC (decadal)	CL	Ireland	Cross-dated by J R Pilcher, M G L Baillie, and G W Pearson, University of Belfast, Northern Ireland

* CL = cellulose method; DV = De Vries method
** Cellulose duplicates run for AD 1836, 1837, and 1853
† Cellulose treatment AD 1505 and 1515
‡ These trees were used for Pearson and Stuiver (1986)

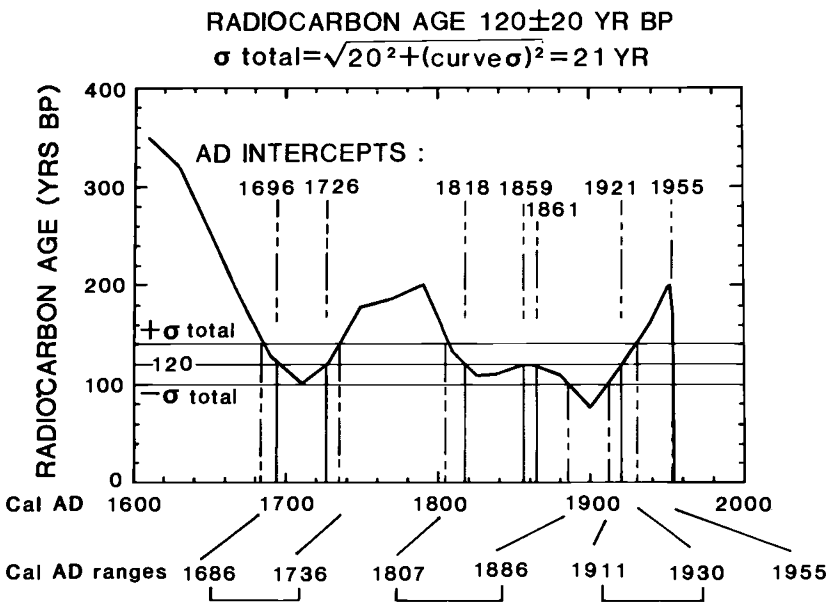
TABLE 3

The conversion of the radiocarbon ages to a series of ranges of cal AD/BC (*and* BP) dates is determined by the AD/BC intercepts of the sample radiocarbon age ± $\sqrt{(\text{sample }\sigma)^2 + (\text{curve }\sigma)^2}$ and the calibration curve. Intercepts of the radiocarbon age with the calibration curve are listed to the right. Sample σ is the standard error in the radiocarbon age.

The youngest point of the 20-year calibration curve is AD 1940 with a conventional radiocarbon age of 164 years BP. The curve has been extended to 1954 using data from Stuiver and Quay (1981). Nuclear bomb testing increased atmospheric ^{14}C substantially in 1955, resulting in the "vertical" portion of the Fig 1A calibration curve. Intercepts with this vertical portion yield the 1955*s of the table. In those instances where cal AD/BC ages, indicate "negative" BP ages, the BP age is given as 0* BP.

For sample sigmas and ranges larger or equal to 100 years the data were rounded to the nearest decade. When the gap between two successive ranges was less than 10 years, the two ranges were combined to a single one.

Illustrations of the above are given below.



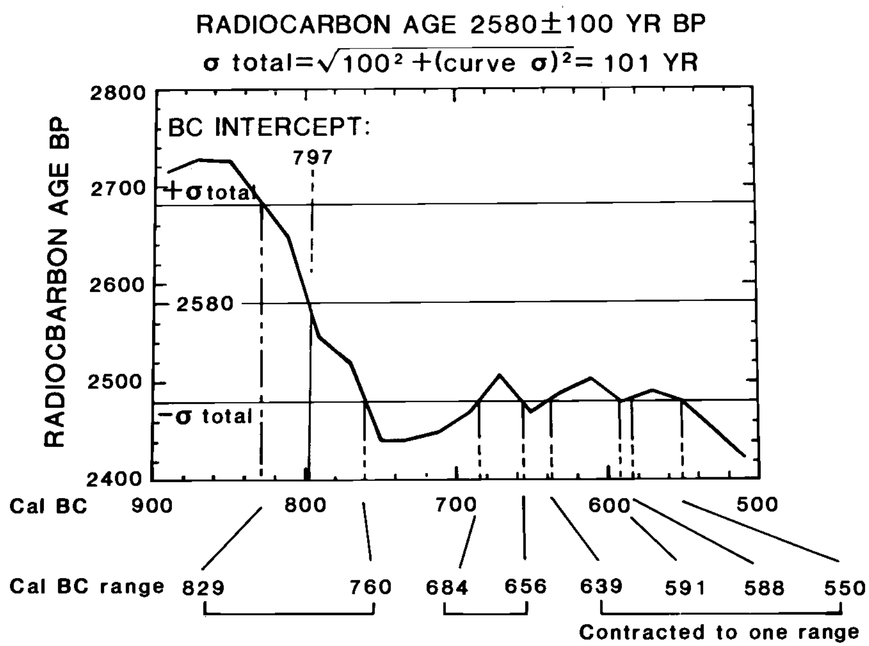


Table 3-A

RADIOCARBON AGE BP 80 CALIBRATED AGES: cal AD 1898, 1902, 1955*
cal BP 52, 48, 0*

Sample σ and cal AD(cal BP) ranges:

σ = 20	1709-1711(241-239)	1884-1913(66-37)	1955*
σ = 40	1695-1727(255-223)	1817-1922(133-28)	1955*
σ = 60	1686-1736(264-214)	1807-1930(143-20)	1955*
σ = 80	1679-1743(271-207)	1802-1939(148-11)	1955*
σ = 100	1672-1755(278-195)	1800-1955*(150-0*)	
σ = 120	1670-1955*(280-0*)		
σ = 160	1650-1955*(300-0*)		
σ = 200	1640-1955*(310-0*)		

RADIOCARBON AGE BP 100 CALIBRATED AGES: cal AD 1885, 1912, 1955*
cal BP 65, 38, 0*

Sample σ and cal AD(cal BP) ranges:

σ = 20	1694-1728(256-222)	1817-1922(133-28)	1955*
σ = 40	1686-1736(264-214)	1807-1930(143-20)	1955*
σ = 60	1679-1743(271-207)	1802-1939(148-11)	1955*
σ = 80	1672-1755(278-195)	1796-1955*(154-0*)	
σ = 100	1670-1955*(280-0*)		
σ = 120	1660-1955*(290-0*)		
σ = 160	1650-1955*(300-0*)		
σ = 200	1640-1955*(310-0*)		

RADIOCARBON AGE BP 120 CALIBRATED AGES: cal AD 1696, 1726, 1818, 1859, 1861, 1921, 1955*
cal BP 254, 224, 132, 91, 89, 29, 0*

Sample σ and cal AD(cal BP) ranges:

σ = 20	1686-1736(264-214)	1807-1886(143-64)	1911-1930(39-20)
	1955*		
σ = 40	1679-1743(271-207)	1802-1939(148-11)	1955*
σ = 60	1672-1755(278-195)	1796-1955*(154-0*)	
σ = 80	1666-1955*(284-0*)		
σ = 100	1660-1955*(290-0*)		
σ = 120	1650-1955*(300-0*)		
σ = 160	1640-1955*(310-0*)		
σ = 200	1523-1565(427-385)	1630-1955*(320-0*)	

RADIOCARBON AGE BP 140 CALIBRATED AGES: cal AD 1686, 1736, 1808, 1930, 1955*
cal BP 264, 214, 142, 20, 0*

Sample σ and cal AD(cal BP) ranges:

σ = 20	1679-1697(271-253)	1725-1744(225-206)	1801-1819(149-131)
	1855-1864(95-86)	1920-1939(30-11)	1955*
σ = 40	1672-1756(278-194)	1796-1886(154-64)	1911-1955*(39-0*)
σ = 60	1666-1955*(284-0*)		
σ = 80	1660-1955*(290-0*)		
σ = 100	1650-1955*(300-0*)		
σ = 120	1650-1955*(300-0*)		
σ = 160	1640-1955*(310-0*)		
σ = 200	1514-1600(436-350)	1620-1955*(330-0*)	

Table 3-B

RADIOCARBON AGE BP 160 CALIBRATED AGES: cal AD 1679, 1743, 1802, 1938, 1955*
cal BP 271, 207, 148, 12, 0*

Sample σ and cal AD(cal BP) ranges:

σ = 20	1672-1687(278-263)	1735-1759(215-191)	1795-1808(155-142)
	1929-1955*(21-0*)		
σ = 40	1666-1696(284-254)	1726-1818(224-132)	1857-1862(93-88)
	1921-1955*(29-0*)		
σ = 60	1660-1886(290-64)	1911-1955*(39-0*)	
σ = 80	1654-1955*(296-0*)		
σ = 100	1650-1955*(300-0*)		
σ = 120	1640-1955*(310-0*)		
σ = 160	1523-1565(427-385)	1630-1955*(320-0*)	
σ = 200	1490-1955*(460-0*)		

RADIOCARBON AGE BP 180 CALIBRATED AGES: cal AD 1673, 1754, 1796, 1945, 1954
cal BP 277, 196, 154, 5, 0*

Sample σ and cal AD(cal BP) ranges:

σ = 20	1665-1680(285-270)	1742-1803(208-147)	1937-1955*(13-0*)
σ = 40	1659-1687(291-263)	1735-1808(215-142)	1929-1955*(21-0*)
σ = 60	1654-1697(296-253)	1725-1819(225-131)	1856-1863(94-87)
	1921-1955*(29-0*)		
σ = 80	1648-1886(302-64)	1911-1955*(39-0*)	
σ = 100	1640-1955*(310-0*)		
σ = 120	1640-1955*(310-0*)		
σ = 160	1514-1601(436-349)	1620-1955*(330-0*)	
σ = 200	1470-1955*(480-0*)		

RADIOCARBON AGE BP 200 CALIBRATED AGES: cal AD 1666, 1790, 1951, 1952
cal BP 284, 160, 0*, 0*

Sample σ and cal AD(cal BP) ranges:

σ = 20	1659-1674(291-276)	1749-1797(201-153)	1944-1955*(6-0*)
σ = 40	1653-1680(297-270)	1742-1802(208-148)	1937-1955*(13-0*)
σ = 60	1647-1686(303-264)	1735-1808(215-142)	1929-1955*(21-0*)
σ = 80	1641-1697(309-253)	1726-1818(224-132)	1857-1863(93-87)
	1921-1955*(29-0*)		
σ = 100	1640-1890(310-60)	1911-1955*(39-0*)	
σ = 120	1523-1566(427-384)	1630-1955*(320-0*)	
σ = 160	1490-1955*(460-0*)		
σ = 200	1460-1955*(490-0*)		

RADIOCARBON AGE BP 220 CALIBRATED AGE: cal AD 1660
cal BP 290

Sample σ and cal AD(cal BP) ranges:

σ = 20	1654-1666(296-284)	1789-1790(161-160)	1951-1952(0*)
σ = 40	1648-1673(302-277)	1753-1796(197-154)	1945-1954(5-0*)
σ = 60	1642-1679(308-271)	1743-1802(207-148)	1938-1955*(12-0*)
σ = 80	1636-1686(314-264)	1736-1808(214-142)	1930-1955*(20-0*)
σ = 100	1523-1565(427-385)	1629-1696(321-254)	1726-1818(224-132)
	1859-1861(91-89)	1921-1955*(29-0*)	
σ = 120	1514-1600(436-350)	1620-1890(330-60)	1912-1955*(38-0*)
σ = 160	1470-1955*(480-0*)		
σ = 200	1450-1955*(500-0*)		

TABLE 3-C

```
RADIOCARBON AGE BP  240   CALIBRATED AGE:   cal AD 1654
                                            cal BP  296
Sample σ and cal AD(cal BP) ranges:
σ =  20    1648-1660(302-290)
σ =  40    1642-1666(308-284)    1951-1952(0*)
σ =  60    1636-1673(314-277)    1753-1796(197-154)    1945-1954(5-0*)
σ =  80    1523-1565(427-385)    1629-1679(321-271)    1743-1802(207-148)
           1938-1955*(12-0*)
σ = 100    1514-1600(436-350)    1616-1686(334-264)    1736-1808(214-142)
           1930-1955*(20-0*)
σ = 120    1490-1700(460-250)    1726-1818(224-132)    1859-1861(91-89)
           1921-1955*(29-0*)
σ = 160    1460-1955*(490-0*)
σ = 200    1440-1955*(510-0*)
```

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```
RADIOCARBON AGE BP  260   CALIBRATED AGE:   cal AD 1648
                                            cal BP  302
Sample σ and cal AD(cal BP) ranges:
σ =  20    1642-1654(308-296)
σ =  40    1636-1660(314-290)
σ =  60    1523-1565(427-385)    1629-1666(321-284)    1951-1952(0*)
σ =  80    1514-1600(436-350)    1616-1673(334-277)    1753-1796(197-154)
           1945-1954(5-0*)
σ = 100    1490-1680(460-270)    1743-1802(207-148)    1938-1955*(12-0*)
σ = 120    1470-1690(480-260)    1736-1808(214-142)    1930-1955*(20-0*)
σ = 160    1450-1890(500-60)     1912-1955*(38-0*)
σ = 200    1440-1955*(510-0*)
```

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RADIOCARBON AGE BP  280   CALIBRATED AGE:   cal AD 1642
                                            cal BP  308
Sample σ and cal AD(cal BP) ranges:
σ =  20    1636-1648(314-302)
σ =  40    1523-1565(427-385)    1629-1654(321-296)
σ =  60    1514-1600(436-350)    1616-1660(334-290)
σ =  80    1486-1666(464-284)    1951-1952(0*)
σ = 100    1470-1670(480-280)    1753-1796(197-154)    1945-1954(5-0*)
σ = 120    1460-1680(490-270)    1743-1802(207-148)    1938-1955*(12-0*)
σ = 160    1440-1700(510-250)    1726-1818(224-132)    1859-1861(91-89)
           1921-1955*(29-0*)
σ = 200    1430-1955*(520-0*)
```

TABLE 3-D

```
RADIOCARBON AGE BP  300   CALIBRATED AGE:   cal AD 1636
                                            cal BP  314
Sample σ and cal AD(cal BP) ranges:
σ =  20    1523-1566(427-384)    1629-1642(321-308)
σ =  40    1514-1601(436-349)    1616-1648(334-302)
σ =  60    1486-1654(464-296)
σ =  80    1474-1660(476-290)
σ = 100    1460-1670(490-280)    1951-1952(0*)
σ = 120    1450-1670(500-280)    1753-1796(197-154)    1945-1954(5-0*)
σ = 160    1440-1690(510-260)    1736-1808(214-142)    1930-1955*(20-0*)
σ = 200    1420-1890(530-60)     1912-1955*(38-0*)
```

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```
RADIOCARBON AGE BP  320   CALIBRATED AGES:  cal AD 1523, 1565, 1629
                                            cal BP  427,  385,  321
Sample σ and cal AD(cal BP) ranges:
σ =  20    1514-1601(436-349)    1616-1636(334-314)
σ =  40    1486-1642(464-308)
σ =  60    1474-1648(476-302)
σ =  80    1460-1654(490-296)
σ = 100    1450-1660(500-290)
σ = 120    1440-1670(510-280)    1951-1952(0*)
σ = 160    1430-1680(520-270)    1743-1802(207-148)    1938-1955*(12-0*)
σ = 200    1410-1700(540-250)    1726-1818(224-132)    1859-1861(91-89)
           1921-1955*(29-0*)
```

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```
RADIOCARBON AGE BP  340   CALIBRATED AGES:  cal AD 1514, 1600, 1616
                                            cal BP  436,  350,  334
Sample σ and cal AD(cal BP) ranges:
σ =  20    1486-1524(464-426)    1565-1630(385-320)
σ =  40    1474-1636(476-314)
σ =  60    1460-1642(490-308)
σ =  80    1448-1648(502-302)
σ = 100    1440-1650(510-300)
σ = 120    1440-1660(510-290)
σ = 160    1420-1670(530-280)    1754-1796(196-154)    1945-1954(5-0*)
σ = 200    1410-1690(540-260)    1736-1808(214-142)    1930-1955*(20-0*)
```

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```
RADIOCARBON AGE BP  360   CALIBRATED AGE:   cal AD 1486
                                            cal BP  464
Sample σ and cal AD(cal BP) ranges:
σ =  20    1472-1516(478-434)    1597-1618(353-332)
σ =  40    1459-1524(491-426)    1563-1630(387-320)
σ =  60    1448-1636(502-314)
σ =  80    1442-1642(508-308)
σ = 100    1440-1650(510-300)
σ = 120    1430-1650(520-300)
σ = 160    1410-1670(540-280)    1789-1790(161-160)    1951-1952(0*)
σ = 200    1400-1680(550-270)    1743-1802(207-148)    1938-1955*(12-0*)
```

Table 3-E

RADIOCARBON AGE BP 380 CALIBRATED AGE: cal AD 1474
cal BP 476

Sample σ and cal AD(cal BP) ranges:

σ = 20	1458-1488(492-462)		
σ = 40	1448-1515(502-435)	1598-1617(352-333)	
σ = 60	1442-1524(508-426)	1564-1630(386-320)	
σ = 80	1436-1636(514-314)		
σ = 100	1430-1640(520-310)		
σ = 120	1420-1650(530-300)		
σ = 160	1410-1660(540-290)		
σ = 200	1328-1333(622-617)	1390-1670(560-280)	1753-1796(197-154)
	1945-1954(5-0*)		

RADIOCARBON AGE BP 400 CALIBRATED AGE: cal AD 1460
cal BP 490

Sample σ and cal AD(cal BP) ranges:

σ = 20	1447-1476(503-474)		
σ = 40	1442-1487(508-463)		
σ = 60	1436-1515(514-435)	1599-1617(351-333)	
σ = 80	1431-1524(519-426)	1564-1630(386-320)	
σ = 100	1420-1640(530-310)		
σ = 120	1410-1640(540-310)		
σ = 160	1400-1650(550-300)		
σ = 200	1317-1347(633-603)	1390-1670(560-280)	1789-1790(161-160)
	1951-1952(0*)		

RADIOCARBON AGE BP 420 CALIBRATED AGE: cal AD 1448
cal BP 502

Sample σ and cal AD(cal BP) ranges:

σ = 20	1442-1463(508-487)	
σ = 40	1436-1475(514-475)	
σ = 60	1431-1487(519-463)	
σ = 80	1422-1514(528-436)	1599-1616(351-334)
σ = 100	1410-1520(540-430)	1564-1630(386-320)
σ = 120	1410-1640(540-310)	
σ = 160	1328-1333(622-617)	1390-1650(560-300)
σ = 200	1306-1359(644-591)	1380-1660(570-290)

RADIOCARBON AGE BP 440 CALIBRATED AGE: cal AD 1443
cal BP 507

Sample σ and cal AD(cal BP) ranges:

σ = 20	1436-1449(514-501)	
σ = 40	1430-1462(520-488)	
σ = 60	1422-1475(528-475)	
σ = 80	1413-1487(537-463)	
σ = 100	1410-1510(540-440)	1600-1616(350-334)
σ = 120	1400-1520(550-430)	1565-1630(385-320)
σ = 160	1317-1347(633-603)	1390-1640(560-310)
σ = 200	1290-1650(660-300)	

Table 3-F

RADIOCARBON AGE BP 460 CALIBRATED AGE: cal AD 1437
cal BP 513

Sample σ and cal AD(cal BP) ranges:

σ = 20	1430-1443(520-507)		
σ = 40	1422-1449(528-501)		
σ = 60	1413-1461(537-489)		
σ = 80	1406-1475(544-475)		
σ = 100	1401-1487(549-463)		
σ = 120	1328-1333(622-617)	1390-1510(560-440)	1600-1616(350-334)
σ = 160	1306-1359(644-591)	1380-1640(570-310)	
σ = 200	1290-1650(660-300)		

RADIOCARBON AGE BP 480 CALIBRATED AGE: cal AD 1431
cal BP 519

Sample σ and cal AD(cal BP) ranges:

σ = 20	1421-1438(529-512)	
σ = 40	1413-1443(537-507)	
σ = 60	1406-1449(544-501)	
σ = 80	1400-1461(550-489)	
σ = 100	1327-1333(623-617)	1395-1474(555-476)
σ = 120	1317-1347(633-603)	1388-1486(562-464)
σ = 160	1290-1520(660-430)	1565-1630(385-320)
σ = 200	1280-1640(670-310)	

RADIOCARBON AGE BP 500 CALIBRATED AGE: cal AD 1422
cal BP 528

Sample σ and cal AD(cal BP) ranges:

σ = 20	1412-1432(538-518)	
σ = 40	1406-1437(544-513)	
σ = 60	1400-1443(550-507)	
σ = 80	1327-1333(623-617)	1395-1449(555-501)
σ = 100	1317-1347(633-603)	1388-1461(562-489)
σ = 120	1306-1359(644-591)	1379-1474(571-476)
σ = 160	1290-1510(660-440)	1600-1616(350-334)
σ = 200	1280-1640(670-310)	

RADIOCARBON AGE BP 520 CALIBRATED AGE: cal AD 1414
cal BP 536

Sample σ and cal AD(cal BP) ranges:

σ = 20	1406-1424(544-526)	
σ = 40	1400-1431(550-519)	
σ = 60	1327-1334(623-616)	1395-1437(555-513)
σ = 80	1317-1347(633-603)	1388-1443(562-507)
σ = 100	1306-1359(644-591)	1379-1449(571-501)
σ = 120	1290-1460(660-490)	
σ = 160	1280-1490(670-460)	
σ = 200	1270-1520(680-430)	1565-1629(385-321)

Table 3-G

RADIOCARBON AGE BP 540 CALIBRATED AGE: cal AD 1407
cal BP 543

Sample σ and cal AD(cal BP) ranges:

σ = 20	1400-1415(550-535)	
σ = 40	1327-1334(623-616)	1394-1423(556-527)
σ = 60	1317-1348(633-602)	1388-1431(562-519)
σ = 80	1306-1359(644-591)	1379-1437(571-513)
σ = 100	1290-1440(660-510)	
σ = 120	1290-1450(660-500)	
σ = 160	1280-1470(670-480)	
σ = 200	1270-1510(680-440)	1600-1616(350-334)

RADIOCARBON AGE BP 560 CALIBRATED AGE: cal AD 1401
cal BP 549

Sample σ and cal AD(cal BP) ranges:

σ = 20	1326-1335(624-615)	1394-1407(556-543)
σ = 40	1316-1348(634-602)	1388-1414(562-536)
σ = 60	1306-1359(644-591)	1379-1423(571-527)
σ = 80	1294-1431(656-519)	
σ = 100	1290-1440(660-510)	
σ = 120	1280-1440(670-510)	
σ = 160	1270-1460(680-490)	
σ = 200	1260-1490(690-460)	

RADIOCARBON AGE BP 580 CALIBRATED AGES: cal AD 1328, 1333, 1395
cal BP 622, 617, 555

Sample σ and cal AD(cal BP) ranges:

σ = 20	1316-1348(634-602)	1387-1401(563-549)
σ = 40	1306-1360(644-590)	1378-1407(572-543)
σ = 60	1294-1414(656-536)	
σ = 80	1287-1423(663-527)	
σ = 100	1280-1430(670-520)	
σ = 120	1280-1440(670-510)	
σ = 160	1270-1450(680-500)	
σ = 200	1260-1470(690-480)	

RADIOCARBON AGE BP 600 CALIBRATED AGES: cal AD 1317, 1347, 1388
cal BP 633, 603, 562

Sample σ and cal AD(cal BP) ranges:

σ = 20	1305-1360(645-590)	1378-1396(572-554)
σ = 40	1294-1401(656-549)	
σ = 60	1287-1407(663-543)	
σ = 80	1283-1414(667-536)	
σ = 100	1280-1420(670-530)	
σ = 120	1270-1430(680-520)	
σ = 160	1260-1440(690-510)	
σ = 200	1240-1460(710-490)	

Table 3-H

RADIOCARBON AGE BP 620 CALIBRATED AGES: cal AD 1306, 1359, 1379
cal BP 644, 591, 571

Sample σ and cal AD(cal BP) ranges:

σ = 20	1293-1319(657-631)	1345-1390(605-560)
σ = 40	1287-1395(663-555)	
σ = 60	1283-1401(667-549)	
σ = 80	1279-1407(671-543)	
σ = 100	1270-1410(680-540)	
σ = 120	1270-1420(680-530)	
σ = 160	1260-1440(690-510)	
σ = 200	1230-1450(720-500)	

RADIOCARBON AGE BP 640 CALIBRATED AGE: cal AD 1295
cal BP 655

Sample σ and cal AD(cal BP) ranges:

σ = 20	1287-1308(663-642)	1357-1381(593-569)
σ = 40	1283-1318(667-632)	1346-1389(604-561)
σ = 60	1279-1395(671-555)	
σ = 80	1274-1401(676-549)	
σ = 100	1270-1410(680-540)	
σ = 120	1260-1410(690-540)	
σ = 160	1240-1430(710-520)	
σ = 200	1220-1440(730-510)	

RADIOCARBON AGE BP 660 CALIBRATED AGE: cal AD 1288
cal BP 662

Sample σ and cal AD(cal BP) ranges:

σ = 20	1283-1296(667-654)	1369-1371(581-579)
σ = 40	1279-1307(671-643)	1358-1380(592-570)
σ = 60	1275-1318(675-632)	1346-1389(604-561)
σ = 80	1270-1395(680-555)	
σ = 100	1260-1400(690-550)	
σ = 120	1260-1410(690-540)	
σ = 160	1230-1420(720-530)	
σ = 200	1180-1440(770-510)	

RADIOCARBON AGE BP 680 CALIBRATED AGE: cal AD 1283
cal BP 667

Sample σ and cal AD(cal BP) ranges:

σ = 20	1279-1288(671-662)	
σ = 40	1274-1295(676-655)	
σ = 60	1270-1307(680-643)	1358-1379(592-571)
σ = 80	1265-1317(685-633)	1346-1389(604-561)
σ = 100	1260-1390(690-560)	
σ = 120	1240-1400(710-550)	
σ = 160	1220-1410(730-540)	
σ = 200	1170-1430(780-520)	

TABLE 3-I

RADIOCARBON AGE BP 700 CALIBRATED AGE: cal AD 1279
cal BP 671

Sample σ and cal AD(cal BP) ranges:

σ = 20	1274-1284(676-666)	
σ = 40	1269-1288(681-662)	
σ = 60	1265-1295(685-655)	
σ = 80	1259-1307(691-643)	1359-1379(591-571)
σ = 100	1244-1317(706-633)	1346-1389(604-561)
σ = 120	1230-1390(720-560)	
σ = 160	1180-1410(770-540)	
σ = 200	1160-1420(790-530)	

RADIOCARBON AGE BP 720 CALIBRATED AGE: cal AD 1275
cal BP 675

Sample σ and cal AD(cal BP) ranges:

σ = 20	1269-1279(681-671)		
σ = 40	1265-1283(685-667)		
σ = 60	1259-1288(691-662)		
σ = 80	1245-1295(705-655)		
σ = 100	1225-1306(725-644)	1359-1379(591-571)	
σ = 120	1220-1320(730-630)	1347-1389(603-561)	
σ = 160	1170-1400(780-550)		
σ = 200	1047-1092(903-858)	1118-1143(832-807)	1150-1410(800-540)

RADIOCARBON AGE BP 740 CALIBRATED AGE: cal AD 1270
cal BP 680

Sample σ and cal AD(cal BP) ranges:

σ = 20	1264-1275(686-675)	
σ = 40	1259-1279(691-671)	
σ = 60	1244-1283(706-667)	
σ = 80	1225-1288(725-662)	
σ = 100	1217-1295(733-655)	
σ = 120	1180-1310(770-640)	1359-1379(591-571)
σ = 160	1160-1390(790-560)	
σ = 200	1040-1410(910-540)	

RADIOCARBON AGE BP 760 CALIBRATED AGE: cal AD 1265
cal BP 685

Sample σ and cal AD(cal BP) ranges:

σ = 20	1258-1270(692-680)		
σ = 40	1244-1275(706-675)		
σ = 60	1225-1279(725-671)		
σ = 80	1216-1283(734-667)		
σ = 100	1180-1290(770-660)		
σ = 120	1170-1290(780-660)		
σ = 160	1047-1092(903-858)	1118-1143(832-807)	1150-1320(800-630)
	1347-1388(603-562)		
σ = 200	1030-1400(920-550)		

TABLE 3-J

RADIOCARBON AGE BP 780 CALIBRATED AGE: cal AD 1259
cal BP 691

Sample σ and cal AD(cal BP) ranges:

σ = 20	1243-1265(707-685)	
σ = 40	1225-1270(725-680)	
σ = 60	1216-1275(734-675)	
σ = 80	1181-1279(769-671)	
σ = 100	1170-1280(780-670)	
σ = 120	1160-1290(790-660)	
σ = 160	1040-1310(910-640)	1359-1379(591-571)
σ = 200	1020-1390(930-560)	

RADIOCARBON AGE BP 800 CALIBRATED AGE: cal AD 1245
cal BP 705

Sample σ and cal AD(cal BP) ranges:

σ = 20	1225-1260(725-690)	
σ = 40	1216-1265(734-685)	
σ = 60	1181-1270(769-680)	
σ = 80	1166-1275(784-675)	
σ = 100	1160-1280(790-670)	
σ = 120	1047-1092(903-858)	1120-1280(830-670)
σ = 160	1030-1290(920-660)	
σ = 200	1020-1320(930-630)	1347-1388(603-562)

RADIOCARBON AGE BP 820 CALIBRATED AGE: cal AD 1225
cal BP 725

Sample σ and cal AD(cal BP) ranges:

σ = 20	1215-1247(735-703)	
σ = 40	1179-1260(771-690)	
σ = 60	1165-1265(785-685)	
σ = 80	1159-1270(791-680)	
σ = 100	1047-1092(903-858)	1120-1270(830-680)
σ = 120	1040-1280(910-670)	
σ = 160	1020-1290(930-660)	
σ = 200	1010-1310(940-640)	1359-1379(591-571)

RADIOCARBON AGE BP 840 CALIBRATED AGE: cal AD 1217
cal BP 733

Sample σ and cal AD(cal BP) ranges:

σ = 20	1177-1227(773-723)	
σ = 40	1165-1246(785-704)	
σ = 60	1159-1260(791-690)	
σ = 80	1047-1093(903-857)	1118-1265(832-685)
σ = 100	1040-1270(910-680)	
σ = 120	1030-1270(920-680)	
σ = 160	1020-1280(930-670)	
σ = 200	1000-1290(950-660)	

TABLE 3-K

RADIOCARBON AGE BP 860 CALIBRATED AGE: cal AD 1181
cal BP 769

Sample σ and cal AD(cal BP) ranges:

σ = 20	1165-1218(785-732)	
σ = 40	1159-1226(791-724)	
σ = 60	1047-1093(903-857)	1118-1246(832-704)
σ = 80	1039-1260(911-690)	
σ = 100	1030-1260(920-690)	
σ = 120	1020-1270(930-680)	
σ = 160	1010-1280(940-670)	
σ = 200	980-1290(970-660)	

RADIOCARBON AGE BP 880 CALIBRATED AGE: cal AD 1166
cal BP 784

Sample σ and cal AD(cal BP) ranges:

σ = 20	1159-1185(791-765)	
σ = 40	1047-1093(903-857)	1118-1217(832-733)
σ = 60	1039-1226(911-724)	
σ = 80	1030-1245(920-705)	
σ = 100	1020-1260(930-690)	
σ = 120	1020-1260(930-690)	
σ = 160	1000-1270(950-680)	
σ = 200	970-1280(980-670)	

RADIOCARBON AGE BP 900 CALIBRATED AGE: cal AD 1159
cal BP 791

Sample σ and cal AD(cal BP) ranges:

σ = 20	1047-1094(903-856)	1117-1166(833-784)
σ = 40	1038-1183(912-767)	
σ = 60	1030-1217(920-733)	
σ = 80	1024-1226(926-724)	
σ = 100	1020-1250(930-700)	
σ = 120	1010-1260(940-690)	
σ = 160	980-1270(970-680)	
σ = 200	960-1280(990-670)	

RADIOCARBON AGE BP 920 CALIBRATED AGES: cal AD 1047, 1092, 1119, 1143, 1153
cal BP 903, 858, 831, 807, 797

Sample σ and cal AD(cal BP) ranges:

σ = 20	1038-1160(912-790)
σ = 40	1030-1166(920-784)
σ = 60	1024-1183(926-767)
σ = 80	1018-1217(932-733)
σ = 100	1010-1230(940-720)
σ = 120	1000-1250(950-700)
σ = 160	970-1260(980-690)
σ = 200	900-1270(1050-680)

TABLE 3-L

RADIOCARBON AGE BP 940 CALIBRATED AGE: cal AD 1039
cal BP 911

Sample σ and cal AD(cal BP) ranges:

σ = 20	1030-1048(920-902)	1089-1120(861-830)	1142-1154(808-796)
σ = 40	1024-1160(926-790)		
σ = 60	1018-1166(932-784)		
σ = 80	1012-1182(938-768)		
σ = 100	1000-1220(950-730)		
σ = 120	980-1230(970-720)		
σ = 160	960-1260(990-690)		
σ = 200	890-1270(1060-680)		

RADIOCARBON AGE BP 960 CALIBRATED AGE: cal AD 1030
cal BP 920

Sample σ and cal AD(cal BP) ranges:

σ = 20	1024-1040(926-910)		
σ = 40	1018-1048(932-902)	1090-1119(860-831)	1142-1153(808-797)
σ = 60	1012-1160(938-790)		
σ = 80	999-1166(951-784)		
σ = 100	980-1180(970-770)		
σ = 120	970-1220(980-730)		
σ = 160	900-1250(1050-700)		
σ = 200	890-1260(1060-690)		

RADIOCARBON AGE BP 980 CALIBRATED AGE: cal AD 1024
cal BP 926

Sample σ and cal AD(cal BP) ranges:

σ = 20	1018-1031(932-919)		
σ = 40	1012-1039(938-911)		
σ = 60	999-1048(951-902)	1091-1119(859-831)	1142-1153(808-797)
σ = 80	985-1160(965-790)		
σ = 100	970-1170(980-780)		
σ = 120	960-1180(990-770)		
σ = 160	890-1230(1060-720)		
σ = 200	880-1260(1070-690)		

RADIOCARBON AGE BP 1000 CALIBRATED AGE: cal AD 1018
cal BP 932

Sample σ and cal AD(cal BP) ranges:

σ = 20	1012-1025(938-925)		
σ = 40	998-1031(952-919)		
σ = 60	985-1039(965-911)		
σ = 80	974-1048(976-902)	1091-1119(859-831)	1143-1153(807-797)
σ = 100	960-1160(990-790)		
σ = 120	900-1170(1050-780)		
σ = 160	890-1220(1060-730)		
σ = 200	810-1250(1140-700)		

TABLE 3-M

```
RADIOCARBON AGE BP 1020   CALIBRATED AGE:   cal AD 1012
                                            cal BP  938
Sample σ and cal AD(cal BP) ranges:
σ =  20   997-1019(953-931)
σ =  40   984-1025(966-925)
σ =  60   974-1031(976-919)
σ =  80   960-1039(990-911)
σ = 100   900-1050(1050-900)   1091-1119(859-831)   1143-1153(807-797)
σ = 120   890-1160(1060-790)
σ = 160   880-1180(1070-770)
σ = 200   790-1230(1160-720)
```

```
RADIOCARBON AGE BP 1040   CALIBRATED AGE:   cal AD  999
                                            cal BP  951
Sample σ and cal AD(cal BP) ranges:
σ =  20   984-1013(966-937)
σ =  40   974-1019(976-931)
σ =  60   960-1025(990-925)
σ =  80   897-1031(1053-919)
σ = 100   890-1040(1060-910)
σ = 120   890-1050(1060-900)   1091-1119(859-831)   1143-1153(807-797)
σ = 160   810-1170(1140-780)
σ = 200   780-1220(1170-730)
```

```
RADIOCARBON AGE BP 1060   CALIBRATED AGE:   cal AD  985
                                            cal BP  965
Sample σ and cal AD(cal BP) ranges:
σ =  20   973-1001(977-949)
σ =  40   960-1013(990-937)
σ =  60   897-1018(1053-932)
σ =  80   891-1024(1059-926)
σ = 100   890-1030(1060-920)
σ = 120   880-1040(1070-910)
σ = 160   790-1160(1160-790)
σ = 200   725-735(1225-1215)   770-1180(1180-770)
```

```
RADIOCARBON AGE BP 1080   CALIBRATED AGE:   cal AD  974
                                            cal BP  976
Sample σ and cal AD(cal BP) ranges:
σ =  20   959-986(991-964)
σ =  40   897-1000(1053-950)
σ =  60   891-1012(1059-938)
σ =  80   886-1018(1064-932)
σ = 100   880-1020(1070-930)
σ = 120   810-1030(1140-920)
σ = 160   780-1050(1170-900)   1091-1119(859-831)   1143-1153(807-797)
σ = 200   690-1170(1260-780)
```

TABLE 3-N

```
RADIOCARBON AGE BP 1100   CALIBRATED AGE:   cal AD  961
                                            cal BP  989
Sample σ and cal AD(cal BP) ranges:
σ =  20   897-975(1053-975)
σ =  40   891-985(1059-965)
σ =  60   886-1000(1064-950)
σ =  80   880-1012(1070-938)
σ = 100   810-1020(1140-930)
σ = 120   790-1020(1160-930)
σ = 160   725-735(1225-1215)   770-1040(1180-910)
σ = 200   680-1160(1270-790)
```

```
RADIOCARBON AGE BP 1120   CALIBRATED AGE:   cal AD  897
                                            cal BP 1053
Sample σ and cal AD(cal BP) ranges:
σ =  20   891-963(1059-987)
σ =  40   885-975(1065-975)
σ =  60   880-986(1070-964)
σ =  80   809-1000(1141-950)
σ = 100   780-1010(1170-940)
σ = 120   780-1020(1170-930)
σ = 160   690-1030(1260-920)
σ = 200   670-1050(1280-900)   1091-1119(859-831)   1143-1153(807-797)
```

```
RADIOCARBON AGE BP 1140   CALIBRATED AGE:   cal AD  891
                                            cal BP 1059
Sample σ and cal AD(cal BP) ranges:
σ =  20   885-898(1065-1052)   916-944(1034-1006)
σ =  40   879-962(1071-988)
σ =  60   809-975(1141-975)
σ =  80   785-986(1165-964)
σ = 100   780-1000(1170-950)
σ = 120   724-735(1226-1215)   760-1010(1190-940)
σ = 160   680-1020(1270-930)
σ = 200   670-1040(1280-910)
```

```
RADIOCARBON AGE BP 1160   CALIBRATED AGE:   cal AD  886
                                            cal BP 1064
Sample σ and cal AD(cal BP) ranges:
σ =  20   875-892(1075-1058)
σ =  40   807-898(1143-1052)   920-941(1030-1009)
σ =  60   785-962(1165-988)
σ =  80   776-975(1174-975)
σ = 100   724-736(1226-1214)   760-990(1190-960)
σ = 120   690-1000(1260-950)
σ = 160   670-1020(1280-930)
σ = 200   660-1030(1290-920)
```

TABLE 3-O

```
RADIOCARBON AGE BP 1180   CALIBRATED AGE:   cal AD  880
                                            cal BP 1070
Sample σ and cal AD(cal BP) ranges:
σ =  20   804-887(1146-1063)
σ =  40   784-892(1166-1058)
σ =  60   776-897(1174-1053)    933-940(1017-1010)
σ =  80   724-736(1226-1214)    764-961(1186-989)
σ = 100   690-970(1260-980)
σ = 120   680-990(1270-960)
σ = 160   670-1010(1280-940)
σ = 200   650-1020(1300-930)
```

```
RADIOCARBON AGE BP 1200   CALIBRATED AGES:  cal AD  811,  847,  851
                                            cal BP 1139, 1103, 1099
Sample σ and cal AD(cal BP) ranges:
σ =  20   784-881(1166-1069)
σ =  40   776-886(1174-1064)
σ =  60   724-736(1226-1214)    765-892(1185-1058)
σ =  80   689-897(1261-1053)
σ = 100   680-960(1270-990)
σ = 120   670-970(1280-980)
σ = 160   660-1000(1290-950)
σ = 200   650-1020(1300-930)
```

```
RADIOCARBON AGE BP 1220   CALIBRATED AGE:   cal AD  785
                                            cal BP 1165
Sample σ and cal AD(cal BP) ranges:
σ =  20   775-816(1175-1134)    843-853(1107-1097)
σ =  40   724-736(1226-1214)    764-881(1186-1069)
σ =  60   689-886(1261-1064)
σ =  80   681-892(1269-1058)
σ = 100   670-900(1280-1050)
σ = 120   670-960(1280-990)
σ = 160   650-990(1300-960)
σ = 200   640-1010(1310-940)
```

```
RADIOCARBON AGE BP 1240   CALIBRATED AGE:   cal AD  776
                                            cal BP 1174
Sample σ and cal AD(cal BP) ranges:
σ =  20   723-737(1227-1213)    763-786(1187-1164)
σ =  40   689-814(1261-1136)    845-852(1105-1098)
σ =  60   681-881(1269-1069)
σ =  80   673-886(1277-1064)
σ = 100   670-890(1280-1060)
σ = 120   660-900(1290-1050)
σ = 160   650-970(1300-980)
σ = 200   620-1000(1330-950)
```

TABLE 3-P

```
RADIOCARBON AGE BP 1260   CALIBRATED AGES:  cal AD  725,  735,  765
                                            cal BP 1225, 1215, 1185
Sample σ and cal AD(cal BP) ranges:
σ =  20   688-777(1262-1173)
σ =  40   681-786(1269-1164)
σ =  60   673-812(1277-1138)    846-852(1104-1098)
σ =  80   666-881(1284-1069)
σ = 100   660-890(1290-1060)
σ = 120   650-890(1300-1060)
σ = 160   640-960(1310-990)
σ = 200   600-990(1350-960)
```

```
RADIOCARBON AGE BP 1280   CALIBRATED AGE:   cal AD  689
                                            cal BP 1261
Sample σ and cal AD(cal BP) ranges:
σ =  20   679-769(1271-1181)
σ =  40   672-777(1278-1173)
σ =  60   666-786(1284-1164)
σ =  80   660-814(1290-1136)    845-852(1105-1098)
σ = 100   650-880(1300-1070)
σ = 120   650-890(1300-1060)
σ = 160   620-900(1330-1050)
σ = 200   600-970(1350-980)
```

```
RADIOCARBON AGE BP 1300   CALIBRATED AGE:   cal AD  681
                                            cal BP 1269
Sample σ and cal AD(cal BP) ranges:
σ =  20   671-711(1279-1239)    748-752(1202-1198)
σ =  40   666-767(1284-1183)
σ =  60   660-777(1290-1173)
σ =  80   654-786(1296-1164)
σ = 100   650-810(1300-1140)    845-852(1105-1098)
σ = 120   640-880(1310-1070)
σ = 160   600-890(1350-1060)
σ = 200   560-960(1390-990)
```

```
RADIOCARBON AGE BP 1320   CALIBRATED AGE:   cal AD  673
                                            cal BP 1277
Sample σ and cal AD(cal BP) ranges:
σ =  20   665-683(1285-1267)
σ =  40   660-696(1290-1254)
σ =  60   654-767(1296-1183)
σ =  80   647-777(1303-1173)
σ = 100   640-790(1310-1160)
σ = 120   620-810(1330-1140)    846-852(1104-1098)
σ = 160   600-890(1350-1060)
σ = 200   550-900(1400-1050)
```

TABLE 3-Q

RADIOCARBON AGE BP 1340 CALIBRATED AGE: cal AD 666
cal BP 1284

Sample σ and cal AD(cal BP) ranges:

σ = 20	659-674(1291-1276)	
σ = 40	654-682(1296-1268)	
σ = 60	647-690(1303-1260)	
σ = 80	636-766(1314-1184)	
σ = 100	620-780(1330-1170)	
σ = 120	600-790(1350-1160)	
σ = 160	560-880(1390-1070)	
σ = 200	540-890(1410-1060)	

RADIOCARBON AGE BP 1360 CALIBRATED AGE: cal AD 660
cal BP 1290

Sample σ and cal AD(cal BP) ranges:

σ = 20	653-667(1297-1283)	
σ = 40	646-674(1304-1276)	
σ = 60	636-682(1314-1268)	
σ = 80	619-690(1331-1260)	
σ = 100	600-770(1350-1180)	
σ = 120	600-780(1350-1170)	
σ = 160	550-810(1400-1140)	846-852(1104-1098)
σ = 200	461-478(1489-1472)	520-890(1430-1060)

RADIOCARBON AGE BP 1380 CALIBRATED AGE: cal AD 654
cal BP 1296

Sample σ and cal AD(cal BP) ranges:

σ = 20	645-661(1305-1289)	
σ = 40	636-667(1314-1283)	
σ = 60	619-674(1331-1276)	
σ = 80	604-681(1346-1269)	
σ = 100	595-689(1355-1261)	
σ = 120	560-770(1390-1180)	
σ = 160	540-790(1410-1160)	
σ = 200	440-880(1510-1070)	

RADIOCARBON AGE BP 1400 CALIBRATED AGE: cal AD 647
cal BP 1303

Sample σ and cal AD(cal BP) ranges:

σ = 20	635-655(1315-1295)	
σ = 40	618-661(1332-1289)	
σ = 60	604-667(1346-1283)	
σ = 80	595-673(1355-1277)	
σ = 100	560-680(1390-1270)	
σ = 120	550-690(1400-1260)	
σ = 160	461-479(1489-1471)	520-780(1430-1170)
σ = 200	430-810(1520-1140)	846-852(1104-1098)

TABLE 3-R

RADIOCARBON AGE BP 1420 CALIBRATED AGE: cal AD 637
cal BP 1313

Sample σ and cal AD(cal BP) ranges:

σ = 20	616-649(1334-1301)	
σ = 40	604-655(1346-1295)	
σ = 60	595-661(1355-1289)	
σ = 80	560-667(1390-1283)	
σ = 100	550-670(1400-1280)	
σ = 120	540-680(1410-1270)	
σ = 160	440-770(1510-1180)	
σ = 200	420-790(1530-1160)	

RADIOCARBON AGE BP 1440 CALIBRATED AGE: cal AD 620
cal BP 1330

Sample σ and cal AD(cal BP) ranges:

σ = 20	603-639(1347-1311)	
σ = 40	595-648(1355-1302)	
σ = 60	560-655(1390-1295)	
σ = 80	548-661(1402-1289)	
σ = 100	540-670(1410-1280)	
σ = 120	460-479(1490-1471)	520-670(1430-1280)
σ = 160	430-690(1520-1260)	
σ = 200	410-780(1540-1170)	

RADIOCARBON AGE BP 1460 CALIBRATED AGE: cal AD 605
cal BP 1345

Sample σ and cal AD(cal BP) ranges:

σ = 20	594-626(1356-1324)	
σ = 40	559-638(1391-1312)	
σ = 60	547-648(1403-1302)	
σ = 80	538-655(1412-1295)	
σ = 100	460-480(1490-1470)	520-660(1430-1290)
σ = 120	440-670(1510-1280)	
σ = 160	420-680(1530-1270)	
σ = 200	400-770(1550-1180)	

RADIOCARBON AGE BP 1480 CALIBRATED AGE: cal AD 596
cal BP 1354

Sample σ and cal AD(cal BP) ranges:

σ = 20	558-606(1392-1344)	
σ = 40	547-623(1403-1327)	
σ = 60	538-638(1412-1312)	
σ = 80	459-480(1491-1470)	514-648(1436-1302)
σ = 100	440-650(1510-1300)	
σ = 120	430-660(1520-1290)	
σ = 160	410-670(1540-1280)	
σ = 200	380-690(1570-1260)	

TABLE 3-S

RADIOCARBON AGE BP 1500 CALIBRATED AGE: cal AD 561
cal BP 1389

Sample σ and cal AD(cal BP) ranges:

σ = 20	546-598(1404-1352)	
σ = 40	538-606(1412-1344)	
σ = 60	458-481(1492-1469)	510-622(1440-1328)
σ = 80	440-637(1510-1313)	
σ = 100	430-650(1520-1300)	
σ = 120	420-650(1530-1300)	
σ = 160	400-670(1550-1280)	
σ = 200	340-680(1610-1270)	

RADIOCARBON AGE BP 1520 CALIBRATED AGE: cal AD 548
cal BP 1402

Sample σ and cal AD(cal BP) ranges:

σ = 20	537-564(1413-1386)	
σ = 40	457-482(1493-1468)	507-597(1443-1353)
σ = 60	440-605(1510-1345)	
σ = 80	429-622(1521-1328)	
σ = 100	420-640(1530-1310)	
σ = 120	410-650(1540-1300)	
σ = 160	380-660(1570-1290)	
σ = 200	265-281(1685-1669)	330-670(1620-1280)

RADIOCARBON AGE BP 1540 CALIBRATED AGE: cal AD 539
cal BP 1411

Sample σ and cal AD(cal BP) ranges:

σ = 20	452-487(1498-1463)	498-550(1452-1400)
σ = 40	440-562(1510-1388)	
σ = 60	429-596(1521-1354)	
σ = 80	420-605(1530-1345)	
σ = 100	410-620(1540-1330)	
σ = 120	400-640(1550-1310)	
σ = 160	340-650(1610-1300)	
σ = 200	257-297(1693-1653)	320-670(1630-1280)

RADIOCARBON AGE BP 1560 CALIBRATED AGES: cal AD 462, 477, 526
cal BP 1488, 1473, 1424

Sample σ and cal AD(cal BP) ranges:

σ = 20	439-541(1511-1409)	
σ = 40	428-549(1522-1401)	
σ = 60	420-562(1530-1388)	
σ = 80	411-596(1539-1354)	
σ = 100	400-600(1550-1350)	
σ = 120	380-620(1570-1330)	
σ = 160	265-281(1685-1669)	330-650(1620-1300)
σ = 200	250-660(1700-1290)	

TABLE 3-T

RADIOCARBON AGE BP 1580 CALIBRATED AGE: cal AD 441
cal BP 1509

Sample σ and cal AD(cal BP) ranges:

σ = 20	428-532(1522-1418)	
σ = 40	419-540(1531-1410)	
σ = 60	411-549(1539-1401)	
σ = 80	397-562(1553-1388)	
σ = 100	380-600(1570-1350)	
σ = 120	340-600(1610-1350)	
σ = 160	257-297(1693-1653)	320-640(1630-1310)
σ = 200	240-650(1710-1300)	

RADIOCARBON AGE BP 1600 CALIBRATED AGE: cal AD 429
cal BP 1521

Sample σ and cal AD(cal BP) ranges:

σ = 20	419-443(1531-1507)	
σ = 40	411-531(1539-1419)	
σ = 60	397-540(1553-1410)	
σ = 80	380-549(1570-1401)	
σ = 100	340-560(1610-1390)	
σ = 120	265-281(1685-1669)	330-600(1620-1350)
σ = 160	250-620(1700-1330)	
σ = 200	230-650(1720-1300)	

RADIOCARBON AGE BP 1620 CALIBRATED AGE: cal AD 420
cal BP 1530

Sample σ and cal AD(cal BP) ranges:

σ = 20	410-431(1540-1519)	
σ = 40	396-442(1554-1508)	
σ = 60	379-530(1571-1420)	
σ = 80	342-539(1608-1411)	
σ = 100	264-281(1686-1669)	330-550(1620-1400)
σ = 120	257-297(1693-1653)	320-560(1630-1390)
σ = 160	240-600(1710-1350)	
σ = 200	210-640(1740-1310)	

RADIOCARBON AGE BP 1640 CALIBRATED AGE: cal AD 412
cal BP 1538

Sample σ and cal AD(cal BP) ranges:

σ = 20	395-422(1555-1528)		
σ = 40	379-430(1571-1520)		
σ = 60	342-442(1608-1508)		
σ = 80	264-281(1686-1669)	333-464(1617-1486)	475-530(1475-1420)
σ = 100	257-297(1693-1653)	320-540(1630-1410)	
σ = 120	250-550(1700-1400)		
σ = 160	230-600(1720-1350)		
σ = 200	140-620(1810-1330)		

Table 3-U

RADIOCARBON AGE BP 1660 CALIBRATED AGE: cal AD 398
cal BP 1552

Sample σ and cal AD(cal BP) ranges:

σ = 20	377-413(1573-1537)	
σ = 40	342-421(1608-1529)	
σ = 60	264-281(1686-1669)	332-430(1618-1520)
σ = 80	257-297(1693-1653)	320-441(1630-1509)
σ = 100	250-460(1700-1490)	476-530(1474-1420)
σ = 120	240-540(1710-1410)	
σ = 160	210-560(1740-1390)	
σ = 200	130-600(1820-1350)	

RADIOCARBON AGE BP 1680 CALIBRATED AGE: cal AD 381
cal BP 1569

Sample σ and cal AD(cal BP) ranges:

σ = 20	341-400(1609-1550)	
σ = 40	264-282(1686-1668)	332-412(1618-1538)
σ = 60	257-297(1693-1653)	320-421(1630-1529)
σ = 80	249-430(1701-1520)	
σ = 100	240-440(1710-1510)	
σ = 120	230-460(1720-1490)	476-530(1474-1420)
σ = 160	140-550(1810-1400)	
σ = 200	120-600(1830-1350)	

RADIOCARBON AGE BP 1700 CALIBRATED AGE: cal AD 343
cal BP 1607

Sample σ and cal AD(cal BP) ranges:

σ = 20	263-284(1687-1666)	331-385(1619-1565)
σ = 40	256-298(1694-1652)	319-399(1631-1551)
σ = 60	248-412(1702-1538)	
σ = 80	238-421(1712-1529)	
σ = 100	230-430(1720-1520)	
σ = 120	210-440(1740-1510)	
σ = 160	130-540(1820-1410)	
σ = 200	90-560(1860-1390)	

RADIOCARBON AGE BP 1720 CALIBRATED AGES: cal AD 265, 281, 333
cal BP 1685, 1669, 1617

Sample σ and cal AD(cal BP) ranges:

σ = 20	256-299(1694-1651)	319-344(1631-1606)
σ = 40	248-382(1702-1568)	
σ = 60	238-399(1712-1551)	
σ = 80	227-412(1723-1538)	
σ = 100	210-420(1740-1530)	
σ = 120	140-430(1810-1520)	
σ = 160	120-460(1830-1490)	476-530(1474-1420)
σ = 200	80-550(1870-1400)	

Table 3-V

RADIOCARBON AGE BP 1740 CALIBRATED AGES: cal AD 257, 296, 321
cal BP 1693, 1654, 1629

Sample σ and cal AD(cal BP) ranges:

σ = 20	247-266(1703-1684)	278-335(1672-1615)
σ = 40	237-344(1713-1606)	
σ = 60	226-382(1724-1568)	
σ = 80	213-398(1737-1552)	
σ = 100	140-410(1810-1540)	
σ = 120	130-420(1820-1530)	
σ = 160	90-440(1860-1510)	
σ = 200	70-540(1880-1410)	

RADIOCARBON AGE BP 1760 CALIBRATED AGE: cal AD 249
cal BP 1701

Sample σ and cal AD(cal BP) ranges:

σ = 20	237-258(1713-1692)	294-323(1656-1627)
σ = 40	226-265(1724-1685)	280-334(1670-1616)
σ = 60	213-343(1737-1607)	
σ = 80	140-381(1810-1569)	
σ = 100	130-400(1820-1550)	
σ = 120	120-410(1830-1540)	
σ = 160	80-430(1870-1520)	
σ = 200	30-460(1920-1490)	477-529(1473-1421)

RADIOCARBON AGE BP 1780 CALIBRATED AGE: cal AD 238
cal BP 1712

Sample σ and cal AD(cal BP) ranges:

σ = 20	225-251(1725-1699)	
σ = 40	213-258(1737-1692)	295-322(1655-1628)
σ = 60	140-265(1810-1685)	280-334(1670-1616)
σ = 80	128-343(1822-1607)	
σ = 100	120-380(1830-1570)	
σ = 120	90-400(1860-1550)	
σ = 160	70-420(1880-1530)	
σ = 200	20-440(1930-1510)	

RADIOCARBON AGE BP 1800 CALIBRATED AGE: cal AD 227
cal BP 1723

Sample σ and cal AD(cal BP) ranges:

σ = 20	150-152(1800-1798)	212-240(1738-1710)
σ = 40	139-250(1811-1700)	
σ = 60	128-258(1822-1692)	295-322(1655-1628)
σ = 80	118-265(1832-1685)	280-334(1670-1616)
σ = 100	90-340(1860-1610)	
σ = 120	80-380(1870-1570)	
σ = 160	30-410(1920-1540)	
σ = 200	cal BC 1-cal AD 430(1950-1520)	

TABLE 3-W

```
RADIOCARBON AGE BP 1820   CALIBRATED AGE:   cal AD  214
                                            cal BP 1736
Sample o and cal AD(cal BP) ranges:
o =  20   138-230(1812-1720)
o =  40   128-240(1822-1710)
o =  60   118-250(1832-1700)
o =  80   87-258(1863-1692)      296-322(1654-1628)
o = 100   80-270(1870-1680)      280-333(1670-1617)
o = 120   70-340(1880-1610)
o = 160   10-400(1940-1550)
o = 200   cal BC 40-cal AD 420(1990-1530)
```

```
RADIOCARBON AGE BP 1840   CALIBRATED AGE:   cal AD  140
                                            cal BP 1810
Sample o and cal AD(cal BP) ranges:
o =  20   127-216(1823-1734)
o =  40   118-228(1832-1722)
o =  60   87-239(1863-1711)
o =  80   77-250(1873-1700)
o = 100   70-260(1880-1690)      296-321(1654-1629)
o = 120   30-260(1920-1690)      280-333(1670-1617)
o = 160   cal BC 1-cal AD 380(1950-1570)
o = 200   cal BC 50-cal AD 410(2000-1540)
```

```
RADIOCARBON AGE BP 1860   CALIBRATED AGE:   cal AD  129
                                            cal BP 1821
Sample o and cal AD(cal BP) ranges:
o =  20   117-142(1833-1808)
o =  40   86-215(1864-1735)
o =  60   77-228(1873-1722)
o =  80   65-239(1885-1711)
o = 100   30-250(1920-1700)
o = 120   10-260(1940-1690)      296-321(1654-1629)
o = 160   cal BC 40-cal AD 340(1990-1610)
o = 200   cal BC 100-cal AD 400(2050-1550)
```

```
RADIOCARBON AGE BP 1880   CALIBRATED AGE:   cal AD  118
                                            cal BP 1832
Sample o and cal AD(cal BP) ranges:
o =  20   86-130(1864-1820)
o =  40   76-141(1874-1809)
o =  60   65-215(1885-1735)
o =  80   27-228(1923-1722)
o = 100   10-240(1940-1710)
o = 120   cal BC 1-cal AD 250(1950-1700)
o = 160   cal BC 50-cal AD 260(2000-1690)  280-333(1670-1617)
o = 200   cal BC 110-cal AD 380(2060-1570)
```

TABLE 3-X

```
RADIOCARBON AGE BP 1900   CALIBRATED AGE:   cal AD   87
                                            cal BP 1863
Sample o and cal AD(cal BP) ranges:
o =  20   76-120(1874-1830)
o =  40   65-129(1885-1821)
o =  60   27-141(1923-1809)
o =  80   15-215(1935-1735)
o = 100   cal BC 1-cal AD 230(1950-1720)
o = 120   cal BC 40-cal AD 240(1990-1710)
o = 160   cal BC 100-cal AD 260(2050-1690)  296-321(1654-1629)
o = 200   cal BC 151-149(2100-2098)  cal BC 120-cal AD 340(2070-1610)
```

```
RADIOCARBON AGE BP 1920   CALIBRATED AGE:   cal AD   77
                                            cal BP 1873
Sample o and cal AD(cal BP) ranges:
o =  20   64-89(1886-1861)
o =  40   27-119(1923-1831)
o =  60   14-129(1936-1821)
o =  80   cal BC 2-cal AD 141(1951-1809)
o = 100   cal BC 40-cal AD 210(1990-1740)
o = 120   cal BC 50-cal AD 230(2000-1720)
o = 160   cal BC 110-cal AD 250(2060-1700)
o = 200   cal BC 170-cal AD 260(2120-1690)  280-333(1670-1617)
```

```
RADIOCARBON AGE BP 1940   CALIBRATED AGE:   cal AD   66
                                            cal BP 1884
Sample o and cal AD(cal BP) ranges:
o =  20   26-78(1924-1872)
o =  40   14-88(1936-1862)
o =  60   cal BC 2-cal AD 119(1951-1831)
o =  80   cal BC 36-cal AD 129(1985-1821)
o = 100   cal BC 50-cal AD 140(2000-1810)
o = 120   cal BC 100-cal AD 210(2050-1740)
o = 160   cal BC 151-149(2100-2098)  cal BC 120-cal AD 240(2070-1710)
o = 200   cal BC 190-cal AD 260(2140-1690)  296-321(1654-1629)
```

```
RADIOCARBON AGE BP 1960   CALIBRATED AGES:  cal AD   28,   44,   51
                                            cal BP 1922, 1906, 1899
Sample o and cal AD(cal BP) ranges:
o =  20   14-68(1936-1882)
o =  40   cal BC 2-cal AD 78(1951-1872)
o =  60   cal BC 37-cal AD 88(1986-1862)
o =  80   cal BC 55-cal AD 119(2004-1831)
o = 100   cal BC 100-cal AD 130(2050-1820)
o = 120   cal BC 110-cal AD 140(2060-1810)
o = 160   cal BC 170-cal AD 230(2120-1720)
o = 200   cal BC 200-cal AD 250(2150-1700)
```

Table 3-Y

RADIOCARBON AGE BP 1980 CALIBRATED AGE: cal AD 15
cal BP 1935

Sample σ and cal AD(cal BP) ranges:

σ	Ranges	
σ = 20	cal BC 3-cal AD 53(1952-1897)	
σ = 40	cal BC 37-cal AD 67(1986-1883)	
σ = 60	cal BC 56-cal AD 78(2005-1872)	
σ = 80	cal BC 97-cal AD 88(2046-1862)	
σ = 100	cal BC 110-cal AD 120(2060-1830)	
σ = 120	cal BC 151-149(2100-2098)	cal BC 120-cal AD 130(2070-1820)
σ = 160	cal BC 190-cal AD 210(2140-1740)	
σ = 200	cal BC 340-322(2289-2271)	cal BC 200-cal AD 240(2150-1710)

RADIOCARBON AGE BP 2000 CALIBRATED AGE: cal BC 1
cal BP 1950

Sample σ and cal BC(cal BP) ranges:

σ	Ranges	
σ = 20	cal BC 37-cal AD 16(1986-1934)	
σ = 40	cal BC 58-cal AD 28(2007-1922)	cal AD 40-52(1910-1898)
σ = 60	cal BC 97-cal AD 66(2046-1884)	
σ = 80	cal BC 105-cal AD 78(2054-1872)	
σ = 100	151-149(2100-2098)	cal BC 120-cal AD 90(2070-1860)
σ = 120	cal BC 170-cal AD 120(2120-1830)	
σ = 160	cal BC 200-cal AD 140(2150-1810)	
σ = 200	353-306(2302-2255)	cal BC 240-cal AD 230(2190-1720)

RADIOCARBON AGE BP 2020 CALIBRATED AGE: cal BC 36
cal BP 1985

Sample σ and cal BC(cal BP) ranges:

σ	Ranges	
σ = 20	cal BC 65-cal AD 1(2014-1949)	
σ = 40	cal BC 97-cal AD 16(2046-1934)	
σ = 60	cal BC 105-cal AD 28(2054-1922)	cal AD 42-52(1908-1898)
σ = 80	151-149(2100-2098)	cal BC 117-cal AD 66(2066-1884)
σ = 100	cal BC 170-cal AD 80(2120-1870)	
σ = 120	cal BC 190-cal AD 90(2140-1860)	
σ = 160	340-322(2289-2271)	cal BC 200-cal AD 130(2150-1820)
σ = 200	362-282(2311-2231)	cal BC 260-cal AD 210(2210-1740)

RADIOCARBON AGE BP 2040 CALIBRATED AGE: cal BC 50
cal BP 1999

Sample σ and cal BC(cal BP) ranges:

σ	Ranges	
σ = 20	97-34(2046-1983)	
σ = 40	cal BC 106-cal AD 1(2055-1949)	
σ = 60	151-148(2100-2097)	cal BC 117-cal AD 16(2066-1934)
σ = 80	cal BC 169-cal AD 28(2118-1922)	cal AD 42-51(1908-1899)
σ = 100	cal BC 190-cal AD 70(2140-1880)	
σ = 120	cal BC 200-cal AD 80(2150-1870)	
σ = 160	353-306(2302-2255)	cal BC 240-cal AD 120(2190-1830)
σ = 200	cal BC 370-cal AD 140(2320-1810)	

Table 3-Z

RADIOCARBON AGE BP 2060 CALIBRATED AGE: cal BC 96
cal BP 2045

Sample σ and cal BC(cal BP) ranges:

σ	Ranges	
σ = 20	106-49(2055-1998)	
σ = 40	152-148(2101-2097)	117-35(2066-1984)
σ = 60	169-1(2118-1950)	
σ = 80	cal BC 187-cal AD 16(2136-1934)	
σ = 100	cal BC 200-cal AD 30(2150-1920)	cal AD 42-51(1908-1899)
σ = 120	340-322(2289-2271)	cal BC 200-cal AD 70(2150-1880)
σ = 160	362-282(2311-2231)	cal BC 260-cal AD 90(2210-1860)
σ = 200	cal BC 380-cal AD 130(2330-1820)	

RADIOCARBON AGE BP 2080 CALIBRATED AGE: cal BC 105
cal BP 2054

Sample σ and cal BC(cal BP) ranges:

σ	Ranges	
σ = 20	153-147(2102-2096)	118-95(2067-2044)
σ = 40	169-49(2118-1998)	
σ = 60	187-35(2136-1984)	
σ = 80	196-1(2145-1950)	
σ = 100	340-322(2289-2271)	cal BC 200-cal AD 20(2150-1930)
σ = 120	353-305(2302-2254)	cal BC 240-cal AD 30(2190-1920)
	cal AD 43-51(1907-1899)	
σ = 160	cal BC 370-cal AD 80(2320-1870)	
σ = 200	cal BC 390-cal AD 120(2340-1830)	

RADIOCARBON AGE BP 2100 CALIBRATED AGES: cal BC 151, 149, 117
cal BP 2100, 2098, 2066

Sample σ and cal BC(cal BP) ranges:

σ	Ranges	
σ = 20	171-104(2120-2053)	
σ = 40	188-96(2137-2045)	
σ = 60	196-49(2145-1998)	
σ = 80	340-322(2289-2271)	204-35(2153-1984)
σ = 100	354-305(2303-2254)	240-1(2190-1950)
σ = 120	362-282(2311-2231)	cal BC 260-cal AD 20(2210-1930)
σ = 160	cal BC 380-cal AD 70(2330-1880)	
σ = 200	cal BC 390-cal AD 90(2340-1860)	

RADIOCARBON AGE BP 2120 CALIBRATED AGE: cal BC 168
cal BP 2117

Sample σ and cal BC(cal BP) ranges:

σ	Ranges	
σ = 20	189-114(2138-2063)	
σ = 40	197-104(2146-2053)	
σ = 60	340-322(2289-2271)	204-96(2153-2045)
σ = 80	354-305(2303-2254)	238-49(2187-1998)
σ = 100	362-282(2311-2231)	260-40(2210-1990)
σ = 120	370-1(2320-1950)	
σ = 160	cal BC 390-cal AD 30(2340-1920)	cal AD 43-51(1907-1899)
σ = 200	cal BC 400-cal AD 80(2350-1870)	

Table 3-AA

RADIOCARBON AGE BP 2140 CALIBRATED AGE: cal BC 187
cal BP 2136

Sample σ and cal BC(cal BP) ranges:

σ = 20	197-166(2146-2115)	131-129(2080-2078)
σ = 40	341-322(2290-2271)	204-116(2153-2065)
σ = 60	354-304(2303-2253)	238-105(2187-2054)
σ = 80	362-282(2311-2231)	258-96(2207-2045)
σ = 100	370-50(2320-2000)	
σ = 120	380-40(2330-1990)	
σ = 160	cal BC 390-cal AD 20(2340-1930)	
σ = 200	cal BC 400-cal AD 70(2350-1880)	

RADIOCARBON AGE BP 2160 CALIBRATED AGE: cal BC 196
cal BP 2145

Sample σ and cal BC(cal BP) ranges:

σ = 20	342-321(2291-2270)	204-184(2153-2133)
σ = 40	354-303(2303-2252)	239-167(2188-2116)
σ = 60	362-282(2311-2231)	259-116(2208-2065)
σ = 80	370-105(2319-2054)	
σ = 100	380-100(2330-2050)	
σ = 120	390-50(2340-2000)	
σ = 160	400-1(2350-1950)	
σ = 200	cal BC 400-cal AD 30(2350-1920)	cal AD 43-51(1907-1899)

RADIOCARBON AGE BP 2180 CALIBRATED AGES: cal BC 339, 323, 203
cal BP 2288, 2272, 2152

Sample σ and cal BC(cal BP) ranges:

σ = 20	355-300(2304-2249)	242-195(2191-2144)
σ = 40	362-281(2311-2230)	259-185(2208-2134)
σ = 60	371-167(2320-2116)	
σ = 80	379-116(2328-2065)	
σ = 100	390-100(2340-2050)	
σ = 120	390-100(2340-2050)	
σ = 160	400-40(2350-1990)	
σ = 200	cal BC 410-cal AD 20(2360-1930)	

RADIOCARBON AGE BP 2200 CALIBRATED AGES: cal BC 353, 306, 236
cal BP 2302, 2255, 2185

Sample σ and cal BC(cal BP) ranges:

σ = 20	363-337(2312-2286)	325-280(2274-2229)	260-202(2209-2151)
σ = 40	371-195(2320-2144)		
σ = 60	379-186(2328-2135)		
σ = 80	388-168(2337-2117)		
σ = 100	390-120(2340-2070)		
σ = 120	400-100(2350-2050)		
σ = 160	400-50(2350-2000)		
σ = 200	410-1(2360-1950)		

Table 3-BB

RADIOCARBON AGE BP 2220 CALIBRATED AGES: cal BC 362, 282, 258
cal BP 2311, 2231, 2207

Sample σ and cal BC(cal BP) ranges:

σ = 20	371-352(2320-2301)	311-210(2260-2159)
σ = 40	380-338(2329-2287)	324-203(2273-2152)
σ = 60	388-196(2337-2145)	
σ = 80	392-186(2341-2135)	
σ = 100	400-170(2350-2120)	
σ = 120	400-120(2350-2070)	
σ = 160	410-100(2360-2050)	
σ = 200	485-437(2434-2386)	420-40(2370-1990)

RADIOCARBON AGE BP 2240 CALIBRATED AGE: cal BC 370
cal BP 2319

Sample σ and cal BC(cal BP) ranges:

σ = 20	380-361(2329-2310)	284-256(2233-2205)
σ = 40	388-353(2337-2302)	309-233(2258-2182)
σ = 60	392-338(2341-2287)	323-203(2272-2152)
σ = 80	396-196(2345-2145)	
σ = 100	400-190(2350-2140)	
σ = 120	400-170(2350-2120)	
σ = 160	410-110(2360-2060)	
σ = 200	520-50(2470-2000)	

RADIOCARBON AGE BP 2260 CALIBRATED AGE: cal BC 379
cal BP 2328

Sample σ and cal BC(cal BP) ranges:

σ = 20	389-369(2338-2318)	271-269(2220-2218)
σ = 40	393-361(2342-2310)	283-257(2232-2206)
σ = 60	396-353(2345-2302)	308-234(2257-2183)
σ = 80	399-339(2348-2288)	323-203(2272-2152)
σ = 100	400-200(2350-2150)	
σ = 120	410-190(2360-2140)	
σ = 160	485-437(2434-2386)	420-120(2370-2070)
σ = 200	755-698(2704-2647)	540-100(2490-2050)

RADIOCARBON AGE BP 2280 CALIBRATED AGE: cal BC 388
cal BP 2337

Sample σ and cal BC(cal BP) ranges:

σ = 20	393-378(2342-2327)		
σ = 40	396-370(2345-2319)		
σ = 60	399-361(2348-2310)	283-257(2232-2206)	
σ = 80	402-353(2351-2302)	308-235(2257-2184)	
σ = 100	405-339(2354-2288)	320-200(2270-2150)	
σ = 120	410-200(2360-2150)		
σ = 160	520-170(2470-2120)		
σ = 200	760-683(2709-2632)	657-638(2606-2587)	592-586(2541-2535)
	550-110(2500-2060)		

TABLE 3-CC

RADIOCARBON AGE BP 2300 CALIBRATED AGE: cal BC 392
cal BP 2341

Sample σ and cal BC(cal BP) ranges:

σ = 20	396-386(2345-2335)		
σ = 40	399-378(2348-2327)		
σ = 60	402-370(2351-2319)		
σ = 80	405-361(2354-2310)	283-257(2232-2206)	
σ = 100	408-353(2357-2302)	308-235(2257-2184)	
σ = 120	486-437(2435-2386)	424-339(2373-2288)	320-200(2270-2150)
σ = 160	755-698(2704-2647)	540-190(2490-2140)	
σ = 200	760-120(2710-2070)		

RADIOCARBON AGE BP 2320 CALIBRATED AGE: cal BC 395
cal BP 2344

Sample σ and cal BC(cal BP) ranges:

σ = 20	399-392(2348-2341)		
σ = 40	402-387(2351-2336)		
σ = 60	405-378(2354-2327)		
σ = 80	408-370(2357-2319)		
σ = 100	486-437(2435-2386)	424-361(2373-2310)	283-258(2232-2207)
σ = 120	520-350(2470-2300)	307-235(2256-2184)	
σ = 160	760-683(2709-2632)	657-637(2606-2586)	592-586(2541-2535)
	550-200(2500-2150)		
σ = 200	770-170(2720-2120)		

RADIOCARBON AGE BP 2340 CALIBRATED AGE: cal BC 399
cal BP 2348

Sample σ and cal BC(cal BP) ranges:

σ = 20	402-395(2351-2344)		
σ = 40	405-392(2354-2341)		
σ = 60	408-387(2357-2336)		
σ = 80	487-436(2436-2385)	425-378(2374-2327)	
σ = 100	520-370(2470-2320)		
σ = 120	755-698(2704-2647)	540-360(2490-2310)	283-258(2232-2207)
σ = 160	760-340(2710-2290)	320-200(2270-2150)	
σ = 200	790-190(2740-2140)		

RADIOCARBON AGE BP 2360 CALIBRATED AGE: cal BC 402
cal BP 2351

Sample σ and cal BC(cal BP) ranges:

σ = 20	406-398(2355-2347)		
σ = 40	408-395(2357-2344)		
σ = 60	488-436(2437-2385)	425-392(2374-2341)	
σ = 80	524-387(2473-2336)		
σ = 100	755-698(2704-2647)	540-380(2490-2330)	
σ = 120	760-683(2709-2632)	657-637(2606-2586)	592-586(2541-2535)
	550-370(2500-2320)		
σ = 160	770-350(2720-2300)	307-235(2256-2184)	
σ = 200	790-200(2740-2150)		

TABLE 3-DD

RADIOCARBON AGE BP 2380 CALIBRATED AGE: cal BC 405
cal BP 2354

Sample σ and cal BC(cal BP) ranges:

σ = 20	409-401(2358-2350)		
σ = 40	489-398(2438-2347)		
σ = 60	524-395(2473-2344)		
σ = 80	755-698(2704-2647)	537-392(2486-2341)	
σ = 100	760-683(2709-2632)	657-637(2606-2586)	592-586(2541-2535)
	550-390(2500-2340)		
σ = 120	760-380(2710-2330)		
σ = 160	790-360(2740-2310)	283-258(2232-2207)	
σ = 200	800-340(2750-2290)	320-200(2270-2150)	

RADIOCARBON AGE BP 2400 CALIBRATED AGE: cal BC 408
cal BP 2357

Sample σ and cal BC(cal BP) ranges:

σ = 20	511-405(2460-2354)		
σ = 40	750-730(2699-2679)	524-402(2473-2351)	
σ = 60	755-697(2704-2646)	538-398(2487-2347)	
σ = 80	760-683(2709-2632)	657-637(2606-2586)	592-585(2541-2534)
	553-395(2502-2344)		
σ = 100	760-390(2710-2340)		
σ = 120	770-390(2720-2340)		
σ = 160	790-370(2740-2320)		
σ = 200	800-350(2750-2300)	307-235(2256-2184)	

RADIOCARBON AGE BP 2420 CALIBRATED AGES: cal BC 484, 438, 423
cal BP 2433, 2387, 2372

Sample σ and cal BC(cal BP) ranges:

σ = 20	750-726(2699-2675)	525-408(2474-2357)	
σ = 40	755-697(2704-2646)	538-405(2487-2354)	
σ = 60	760-683(2709-2632)	657-637(2606-2586)	592-585(2541-2534)
	553-402(2502-2351)		
σ = 80	765-399(2714-2348)		
σ = 100	770-400(2720-2350)		
σ = 120	790-390(2740-2340)		
σ = 160	800-380(2750-2330)		
σ = 200	810-360(2760-2310)	283-258(2232-2207)	

RADIOCARBON AGE BP 2440 CALIBRATED AGE: cal BC 523
cal BP 2472

Sample σ and cal BC(cal BP) ranges:

σ = 20	755-696(2704-2645)	538-478(2487-2427)	442-420(2391-2369)
σ = 40	760-683(2709-2632)	657-637(2606-2586)	592-585(2541-2534)
	553-408(2502-2357)		
σ = 60	765-405(2714-2354)		
σ = 80	770-402(2719-2351)		
σ = 100	790-400(2740-2350)		
σ = 120	790-400(2740-2350)		
σ = 160	800-390(2750-2340)		
σ = 200	810-370(2760-2320)		

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HIGH-PRECISION CALIBRATION OF THE RADIOCARBON TIME SCALE, 500–2500 BC

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INTRODUCTION

This paper is a twin paper to that of Stuiver and Pearson (1986) which covers the time period AD 1950–500 BC. The combined radiocarbon ages of dendrochronologically dated wood presented in this paper covers the time period 500–2500 BC.

Specific discussion of detail effecting only one of the two laboratories is given in the paper which has, as the premier author, the person responsible for the particular laboratory's measurement. Factors effecting both laboratories can be in either paper, but are carefully referenced to the other; outline details are given in both papers.

The construction of a calibration curve from ^{14}C ages with statistically limited precision is not a simple matter. Not only should the standard error in the determination be as small as possible, but the calculation of this error also has to be realistic in that it should account for all variability encountered in the laboratory procedures. Independent dendrochronologic calibration of the samples is also a must. Proof of accuracy has to come from a comparison of the results obtained in two or more facilities. It will be shown that the results obtained in Seattle and in Belfast on wood of the same age, but from different regions, give consistent replication within the quoted error over the entire interval. The aspects of replication are first discussed, and are followed by the details of calibration (Fig 1, Tables 1, 2).

The problems of quoted errors and the use and limitations of error multipliers are discussed, and recommendations are given for the inclusion of such errors in the reported ^{14}C age.

DENDROCHRONOLOGY AND SAMPLE TREATMENT

The wood samples used for the Belfast radiocarbon calibration came from deciduous oaks (*Quercus petraea* and *Quercus robur*) growing at altitudes <200m, in Ireland, Scotland, and England (Pilcher *et al*, 1984). The 7272-year Belfast chronology consists of the ring patterns of 1035 trees. Replication was the keystone to the production of the absolute dates for the radiocarbon samples; no year is spanned by <6 trees; most years are spanned by 20–30 trees. External cross-dating between the Irish chronology and those from England and Germany provided independent checks on its validity (Brown *et al*, 1986). The samples measured by the Seattle Laboratory were either Douglas Fir from the northwestern United States, Sequoia from California, or German Oak (Table 2) (Stuiver & Pearson, 1986, twin paper).

The treatment of oak wood samples at Belfast was to first plane the 20-year blocks of wood (some 180g) into thin shavings. These were then bleached using sodium chlorite in 0.018N HCl raised to a tempertaure of ca 70°C. This treatment left the samples free from tannins and lignins and close to pure cellulose. Following cellulose preparation samples were charred at 500°C to leave a carbon-rich residue ready for combustion to CO_2.

The treatment of the Seattle samples (mainly pine) followed one of two different methods detailed in Stuiver and Pearson (1986, twin paper).

TECHNIQUE AND LABORATORY REPRODUCIBILITY

Two different techniques were employed at the Belfast and Seattle laboratories. In Belfast, the oak wood samples were converted to CO_2 by combustion and sub-sampled for mass spectrometric measurement of the stable carbon isotope ratio. Benzene was then synthesized from sample CO_2 following the conversion path CO_2—LiC→C_2H_2—C_6H_6 using the method of Barker (1953). The benzene was then measured using a Philips PW4510 automatic liquid scintillation counter set up as previously described in Pearson (1979, 1983). Various corrections were applied to the observed count-rates based on the careful monitoring of internal and external parameters. The application of these corrections simulate a constant counting efficiency such that only one reference standard count-rate was used for the calculation of all the ^{14}C ages reported herein although measured over a period of 10 years. The system did not allow a constant background to be used over this period but corrections applied to the observed background count-rate gave an inaccuracy of $< \pm 0.5‰$ when used to evaluate a ^{14}C age of about one half-life.

The method used in Seattle was the proportional counting of CO_2 and is described more fully in Stuiver and Pearson (1986, twin paper).

The reproducibility of Belfast data is proven by a set of 55 replicate analyses measured over a period of 10 years, some replicates being done within months, others repeated years later. The actual standard deviation $\hat{\sigma}$ in a single measurement (assumed to be all of equal weight) based on 55 replicate analyses was calculated using the relationship $\hat{\sigma} = \sqrt{SS/2(n-1)}$ where SS = Sum of the (difference between duplicates)^2, n = 55, and $\hat{\sigma}$ is the derived single measurement standard deviation which can then be compared to the mean standard deviation ($\bar{\sigma}$) quoted on the 110 individual measurements. The actual calculated standard deviation value was $\hat{\sigma} = 19.0$ yr. The mean quoted error on the individual measurements was evaluated from $\bar{\sigma} = \Sigma_{i=1}^{n} \sigma_i/n$, and gave a value of $\bar{\sigma} = 15.4$ yr, thus suggesting that the quoted error is underestimated by ca 23%, or an error multiplier of 1.23 is required.

The error multiplier of the Seattle laboratory was also determined experimentally in two ways: 1) from the comparison of 30 pairs of wood samples from different trees giving an error multiplier of 1.53, and 2) repeated measurement on outlying samples yielded an error multiplication of 1.62. Both of these values were demonstrated to be maximum values, and a value of 1.60 was taken to be a reasonable estimate and perhaps still rather generous. Additional details are given in Stuiver and Pearson (1986).

SYSTEMATIC DIFFERENCES BETWEEN LABORATORIES AND COMPARISON OF VARIANCE

The systematic ^{14}C age differences between the Belfast and Seattle laboratories have a maximum difference of only a few years (Stuiver & Pearson, 1986, twin paper). The weighted mean ^{14}C age difference of the Belfast and Seattle bi-decadal data set is 0.6 ± 1.6 yr (number of comparisons n = 214). For the AD interval the difference is 2.6 ± 2.3 yr (n = 90) and for the BC portion it is 3.4 ± 2.1 (n = 124).

The ^{14}C ages of wood of the same age for Ireland, south Germany and northwestern United States differ on average by only a few years (Stuiver & Pearson, twin paper).

It is shown (Stuiver & Pearson, 1986, twin paper) that the quoted laboratory standard deviations account for almost all the differences found between the two data sets.

CONSTRUCTION OF RADIOCARBON AGE CALIBRATION CURVES

The calibration curves were constructed from the set of ^{14}C ages obtained for samples each spanning a 20-yr interval, with some exceptions as noted in the Table 1 heading. The cal AD/BC (or cal BP) ages follow the mid-points of the Belfast bi-decadal series whenever possible, starting in AD 1840. The AD 1940–AD 1860 data set is based on the Seattle data alone; all other ^{14}C ages are based on the weighted Belfast/Seattle averages except when Belfast skipped a decade. Here the gaps were filled by averaging 30-yr blocks of Seattle data (see Table 1).

As discussed previously, the standard deviations in the ^{14}C age determinations of each laboratory are based on the reproducibility of the measurements within each laboratory and are larger than the errors usually quoted by both laboratories. For Belfast, where additional factors are used to calculate the routinely reported standard deviation beyond the counting statistics, the reproducibility tests indicate an error multiplier of 1.23. For Seattle, where the routinely reported standard deviations include only the error derived from counting statistics, the error multiplier is 1.6.

The standard deviation assigned to the curve (the vertical difference between center and outer curve) accounts for nearly 90% of the demonstrated standard deviation in the ^{14}C age differences of both laboratories. The mean standard deviation reported with the curves is 12.1 yr and is solely based on the Belfast and Seattle measuring reproducibility. The variance in the differences in ^{14}C ages of contemporaneous samples measured independently in Belfast and Seattle indicate a measure of uncertainty that is equivalent with an average standard deviation of 13.4 yr.

The wood used for the ^{14}C measurements came from the western United States, Ireland, and southern Germany (Table 2). Oak wood was used for the European chronologies (Becker, 1983; Pilcher *et al*, 1984) and Douglas Fir and Sequoia for the US portion. In the preceding sections it was shown that contemporaneous wood from these trees differed, on average, by only a few ^{14}C years. Thus, although the curves are based on wood from different trees, identical results would have been obtained if all measurements had been made on a single tree from one locality.

THE AGE ERROR REPORTED WITH THE RADIOCARBON DATE

The international ^{14}C community follows strict calculation procedures when determining a conventional ^{14}C age (Stuiver & Polach, 1977). Unfortunately, age error calculations are much less bound by rules.

The error in any laboratory determination is a composite of 1) The Poisson statistical error based on the number of counts observed for sample and standards, assuming constant counting conditions, and 2) the errors associated with factors that cause deviation from the above constant counting conditions and other non-systematic errors which affect the reproducibility of the laboratory results. The latter can be derived from replicate sample measurements. Attempts to determine systematic errors are rarely made by the ^{14}C community. The reported sample age error (one standard deviation) is often based solely on Poisson statistics in the number of registered sample and standard counts. Such a substitute for a repeat-measurement derived standard deviation leads to an underestimate because it neglects other factors that add to the variance (Pearson, 1979, 1983).

When identical tree-ring samples (with approximate ages of ca 5000 ^{14}C yr) were measured by 20 laboratories (International Study Group, 1982) it was found that the reproducibility standard deviations in the submitted data set were substantially higher than the age errors reported by the laboratories. Systematic errors ranged from <20 yr (3 laboratories) to 200 yr (1 laboratory).

When comparing the reproducibility standard deviation (obtained after removal of off-sets from the data set) with the laboratory reported error σ it was found that σ has to be multiplied with 1.3 for $\sigma < 20$ yr, with ca 2.0 for σ in the 20- to 80-yr range, and with 1.0 for $\sigma > 80$ yr (International Study Group). These multipliers are strictly laboratory-related and in principle independent of the magnitude of σ. Additional information on systematic errors is available for a set of samples in the 7000 to 8000 ^{14}C yr range measured in Seattle, La Jolla, Heidelberg, and Tucson (Stuiver *et al*, 1986). Off-sets of 29 ± 10, 27 ± 12 and 52 ± 8 yr were found, respectively, for Seattle-La Jolla, Seattle-Heidelberg, and Seattle-Tucson comparisons.

The above studies indicate that systematic errors may exist, and that the reported standard deviation of a ^{14}C age measurement is usually too low. The degree of under-reporting has only been determined so far for 20 odd laboratories for samples ca 5000 ^{14}C yr old. Unfortunately, the error multipliers determined in the above international group study cannot be applied to all age ranges because the multiplier values are age dependent (Stuiver *et al*, 1986). Error multipliers also may change from year to year (or even day to day) at a specific laboratory with improving (or deteriorating) experimental conditions. It is recommended that the user of a ^{14}C date obtain additional information on reproducibility and systematic error determinations from the reporting laboratory. This information should lead to a realistic standard deviation in the age (based on repeat measurements of test samples) although care must be taken in its use particularly when determining 2σ and 3σ probabilities. Limitations on systematic error size also should be provided. A systematic error, of course, should not be part of the regular ± reported with the date.

In the absence of the above information, the user can only take as the ^{14}C age error the actual reported σ, with the understanding that this error is usually too small. In case the user would take twice the reported standard deviation it should be realized that 1) for some laboratories the actual error may be smaller than 2σ, and 2) statistical rules (such as stating that only 1 event out of 20 would be outside 2σ bounds) are not valid because, after all, the original σ is not a properly defined standard deviation in many instances.

CALIBRATION INSTRUCTIONS

The Figure 1 calibration curves consist of three lines. The center line is the actual calibration curve whereas the outer lines indicate the one sigma (standard deviation) uncertainty in the calibration curve. The calibration curve depicts the (non-linear) transformation of ^{14}C ages to calibrated AD/BC (or BP) ages. The nomenclature adopted for the dendro (calendar) year time scale is cal AD/BC or cal BP. The cal AD/BC ages are plotted along the lower horizontal axis and the cal BP ages along the upper one.

Cal BP ages are relative to the year AD 1950, with 0 cal BP equal to AD 1950. The relationship between cal AD/BC and cal BP ages is simple: cal BP = 1950 − cal AD, and cal BP = 1949 + cal BC. The switch from 1950 to 1949 when converting BC ages is caused by the absence of the zero year in the AD/BC chronology (when progressing from 1 BC to 1 AD, the cal BP ages should be without a gap).

The conversion of a ^{14}C age to a cal age is straightforward: 1) Draw a horizontal (parallel to the bottom axis) line (A) through the ^{14}C age to be converted, and 2) draw vertical lines through the intercept(s) of line A and the calibration curve (center line). The cal AD/BC ages can be read at the bottom axis, the cal BP ages at the top. A single ^{14}C age can correspond with multiple cal ages, due to past changes in atmospheric ^{14}C levels (see Stuiver, 1982 for illustration).

The user has to determine the calibrated ages from the Figure 1 graphs by drawing lines. An alternate approach is the use of Table 2, where the cal ages are listed for ^{14}C ages that increase by 20-yr steps. Obviously, the user has to interpolate between the 20-yr steps of ^{14}C ages and sigmas if further fine tuning is desired.

The conversion of the standard error in the ^{14}C age into a range of cal AD/BC (BP) ages is more complicated. The user should first determine whether he/she wants to use 1) the laboratory quoted error (see previous section for a discussion) or 2) increase the quoted error by a known "error multiplier." Once the sample σ has been targeted, the curve σ (one standard deviation) should be read from the calibration curve by taking the difference in radiocarbon years between center curve and outer curve(s) in Figure 1. The curve σ and sample σ should then be used to calculate total $\sigma = \sqrt{(\text{sample } \sigma)^2 + (\text{curve } \sigma)^2}$ (Stuiver, 1982).

Horizontal lines should now be drawn through the ^{14}C age + total σ, and ^{14}C age − total σ value. The vertical lines, drawn through the intercepts with the CENTRAL curve, yield the outer limits of possible cal AD/BC (or BP) ages that are compatible with the sample standard deviation.

The above procedure was used to derive the "ranges" of cal AD/BC (BP) ages listed in Table 2.

The conversion procedure yields 1) single or multiple cal AD/BC (BP) ages that are compatible with a certain ^{14}C age, and 2) the range(s) of cal ages that corresponds to the standard deviation in the ^{14}C age. The probability that a certain cal age is the actual sample age may be quite variable within the cal age range. Higher probabilities are encountered around the intercept ages. Low, or near zero probabilities are encountered when part of the calibration curve 'snakes' outside the total σ boundaries. The non-linear transform of a Gaussian standard deviation around a ^{14}C age into cal AD/BC (BP) ages leads to a very complex probability distribution that can only be calculated with the aid of computers. We are currently developing suitable programs for these probability calculations, and plan to make these programs available in the near future.

The calibration data presented in this paper are to be used for samples formed in isotopic (^{14}C) equilibrium with atmospheric CO_2. Although the wood samples were collected from specific regions (Ireland, Germany, and western USA) the calibration data can be used for a large part of the Northern Hemisphere (Stuiver, 1982). However, systematic age differences are possible for Southern Hemispheric samples where ^{14}C ages of wood samples tend to be ca 30 yr older (Lerman, Mook & Vogel, 1970; Vogel, Fuls & Visser, 1986). Thus, ^{14}C ages of Southern Hemispheric samples should be reduced by 30 years before being converted into a cal AD/BC (BP) age.

SMOOTHING OF THE CALIBRATION CURVE

The Figure 1 points have a 20-yr time separation, *ie*, the calibration points are the mid-points of wood samples spanning 20 years. Samples submitted for dating may cover shorter (eg, seed samples) or longer intervals (eg, lake sediment samples). The decadal calibration results of the Seattle laboratory are available when better time resolution is needed (Stuiver & Becker, 1986). If less resolution is desired, the Figure 2 curves can be used. Here, a 5-point moving average (usually identical with a 100-yr moving average of the Figure 1 data set) was used to construct the curves. A single line is given in Figure 2 because the uncertainty in the 5 point moving average is only a few radiocarbon years. The instructions for determining the cal AD/BC (BP) ages are listed in the preceding section. Samples falling outside the ranges covered by the twin papers (Stuiver & Pearson, 1986; Pearson & Stuiver, 1986) can be provisionally converted using the curves provided by Pearson *et al* (1986) employing the same method outlined above.

MARINE SAMPLE AGES

The calibraton curves should be applied only for age conversion of samples that were formed in equilibrium with atmospheric CO_2. Conventional ^{14}C ages of materials not in equilibrium with atmospheric reservoirs do not take into account the off-set in ^{14}C age that may occur (Stuiver & Polach, 1977). This off-set, or reservoir deficiency, has to be deducted from the reported ^{14}C age before any attempt can be made to convert to cal AD/BC (BP) ages. The reservoir deficiency is time dependent for the mixed layer of the ocean. Model calculated calibration curves for marine samples are listed separately in this volume (Stuiver, Pearson & Braziunas, 1986).

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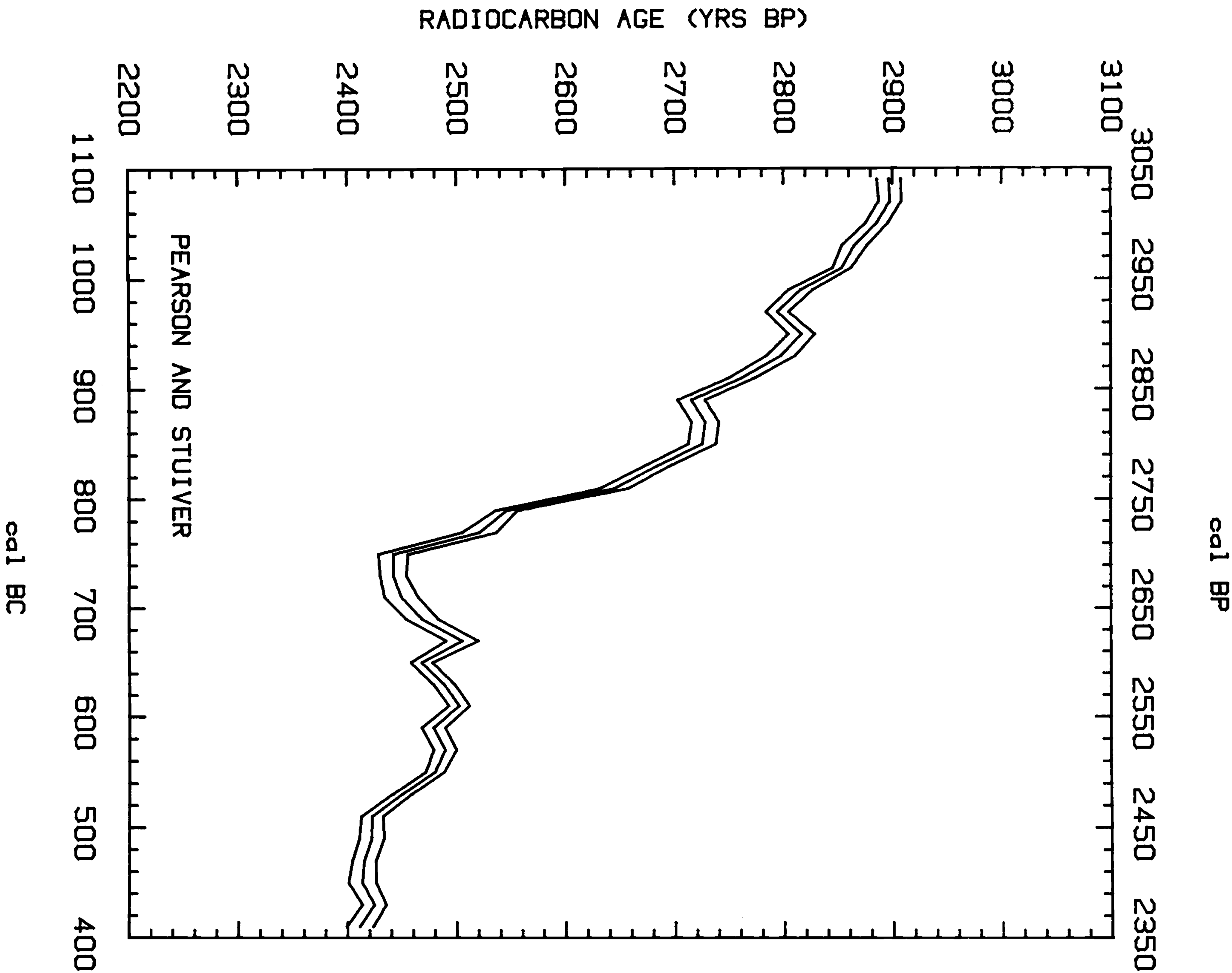

RADIOCARBON AGE (YRS BP)
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
cal BP
3050
2950
2850
2750
2650
2550
2450
2350
cal BC
1100
1000
900
800
700
600
500
400
PEARSON AND STUIVER

Fig 1A

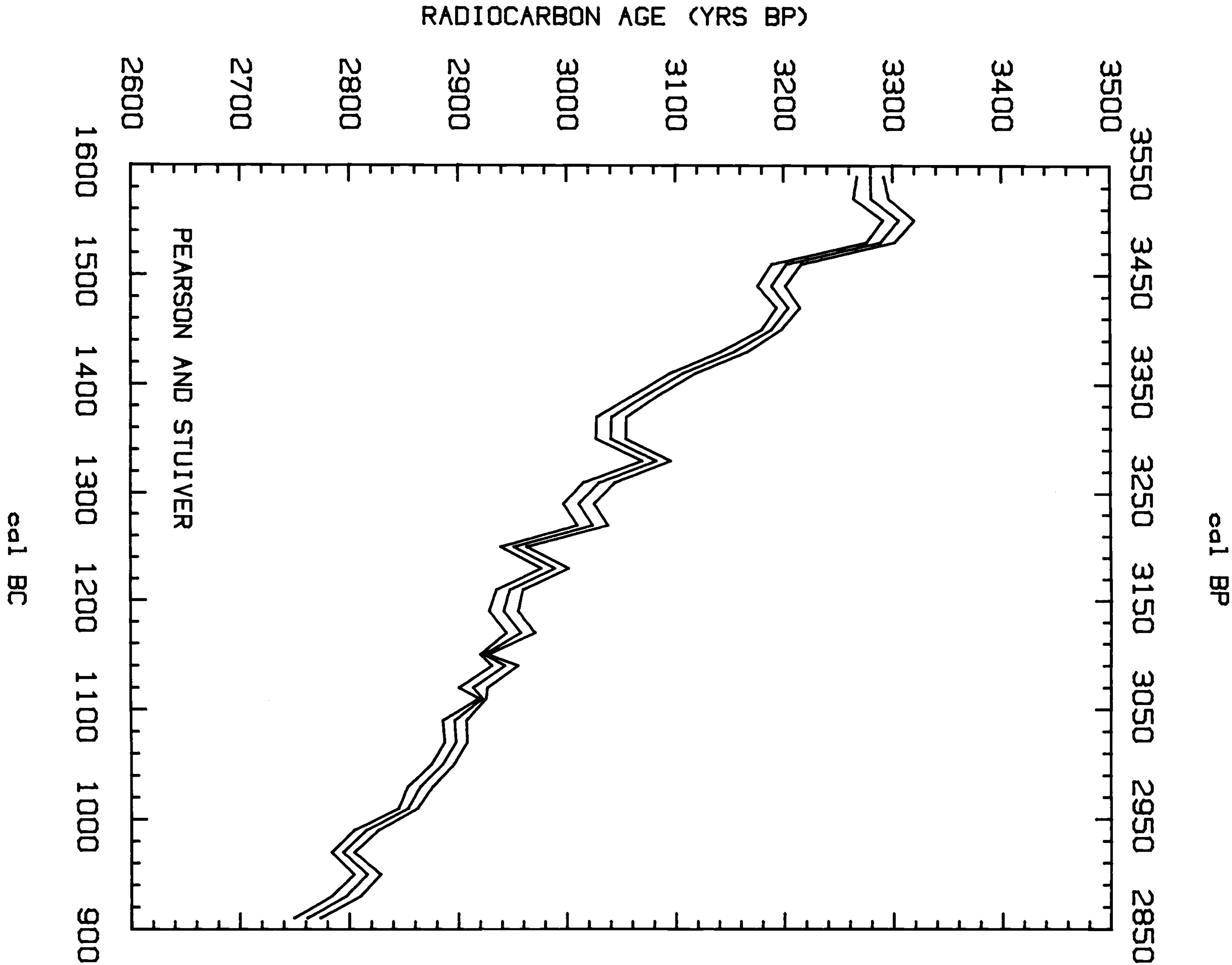
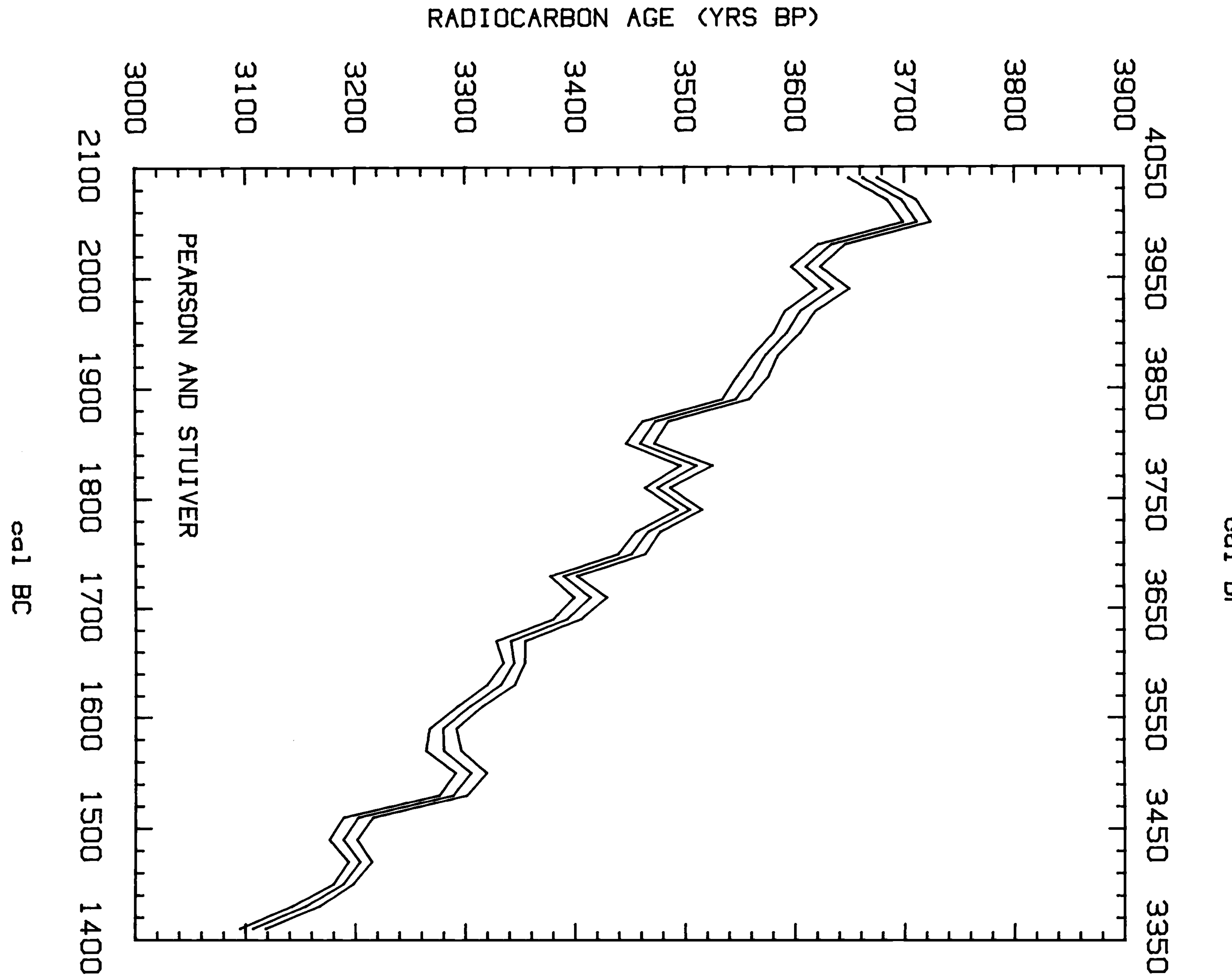

RADIOCARBON AGE (YRS BP)
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
cal BP
3550
3450
3350
3250
3150
3050
2950
2850
cal BC
1600
1500
1400
1300
1200
1100
1000
900
PEARSON AND STUIVER

Fig 1B



RADIOCARBON AGE (YRS BP)
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
cal BP
4050
3950
3850
3750
3650
3550
3450
3350
PEARSON AND STUIVER
2100
2000
1900
1800
1700
1600
1500
1400
cal BC

Fig 1C

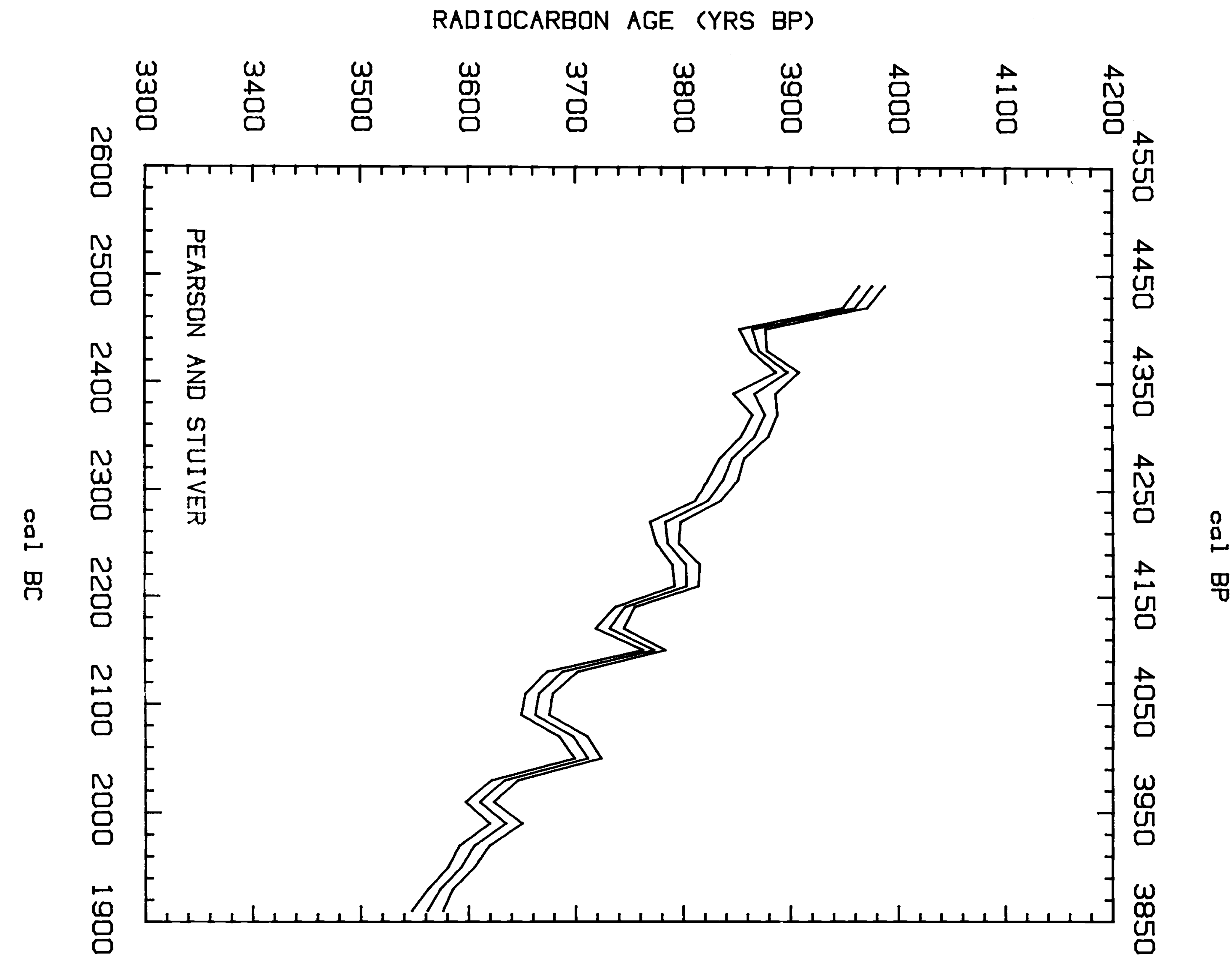

RADIOCARBON AGE (YRS BP)
cal BP
cal BC
PEARSON AND STUIVER
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
4550
4450
4350
4250
4150
4050
3950
3850
2600
2500
2400
2300
2200
2100
2000
1900

Fig 1D

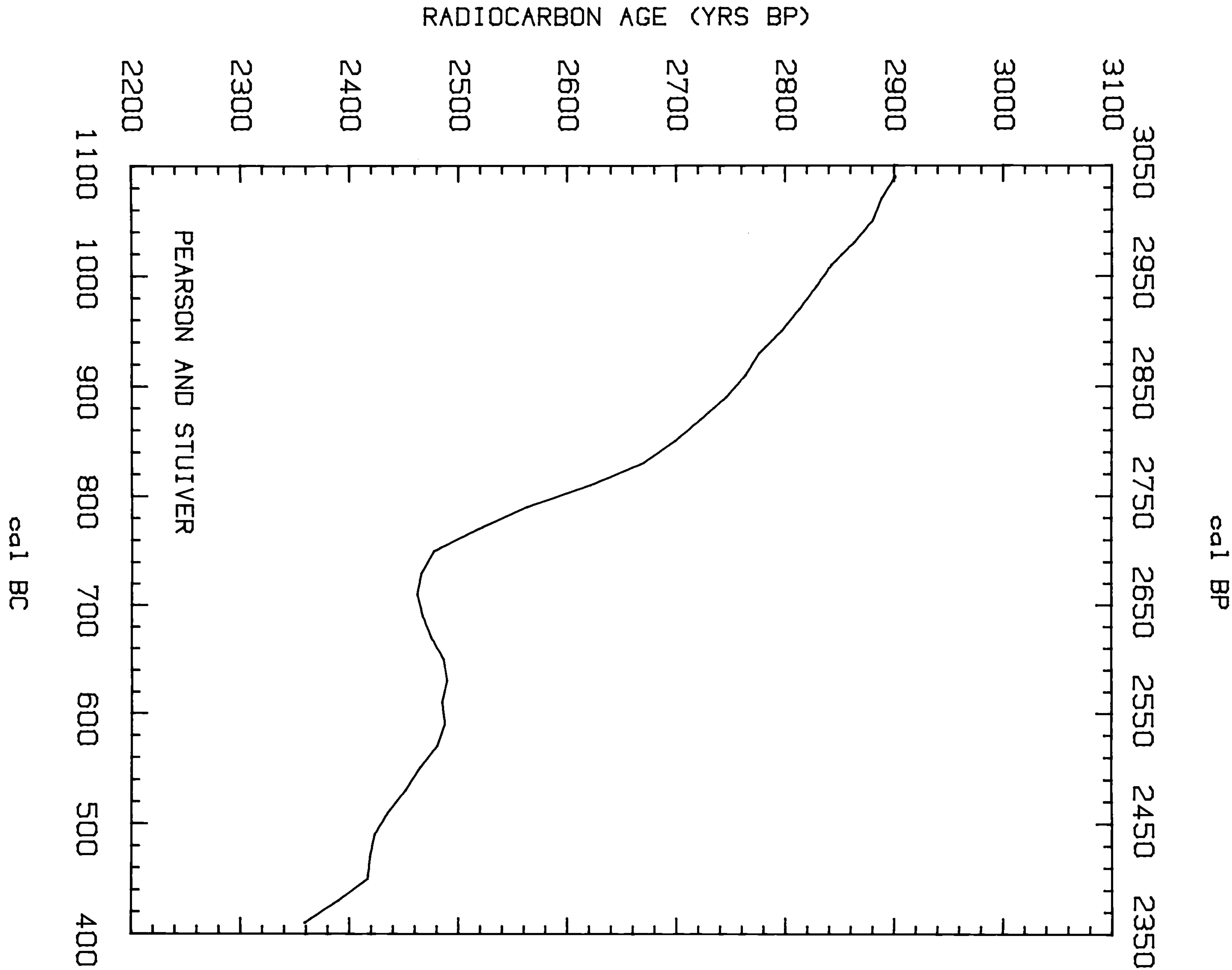
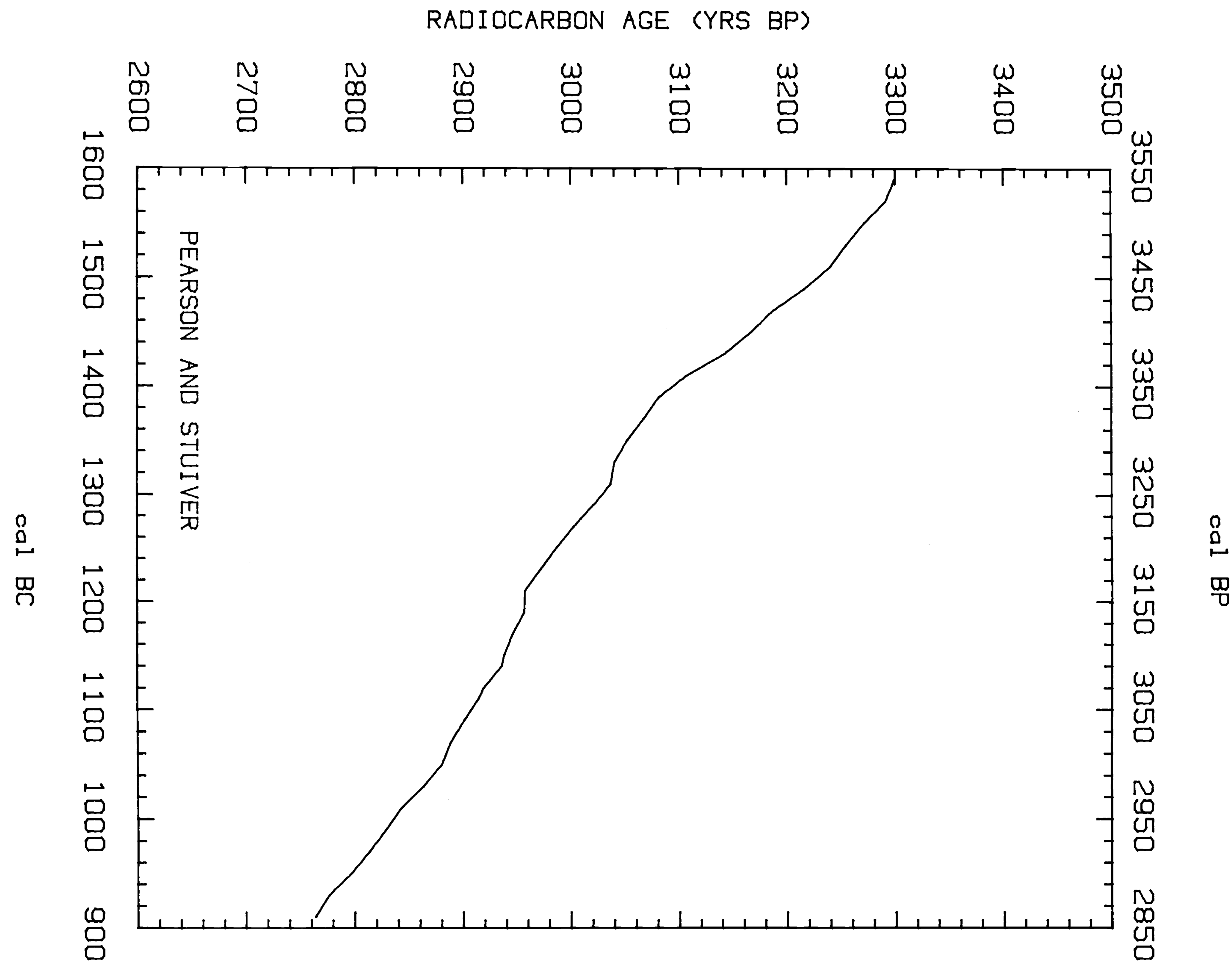

RADIOCARBON AGE (YRS BP)
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
cal BP
3050
2950
2850
2750
2650
2550
2450
2350
cal BC
1100
1000
900
800
700
600
500
400
PEARSON AND STUIVER

Fig 2A



RADIOCARBON AGE (YRS BP)
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
cal BP
3550
3450
3350
3250
3150
3050
2950
2850
cal BC
1600
1500
1400
1300
1200
1100
1000
900
PEARSON AND STUIVER

Fig 2B

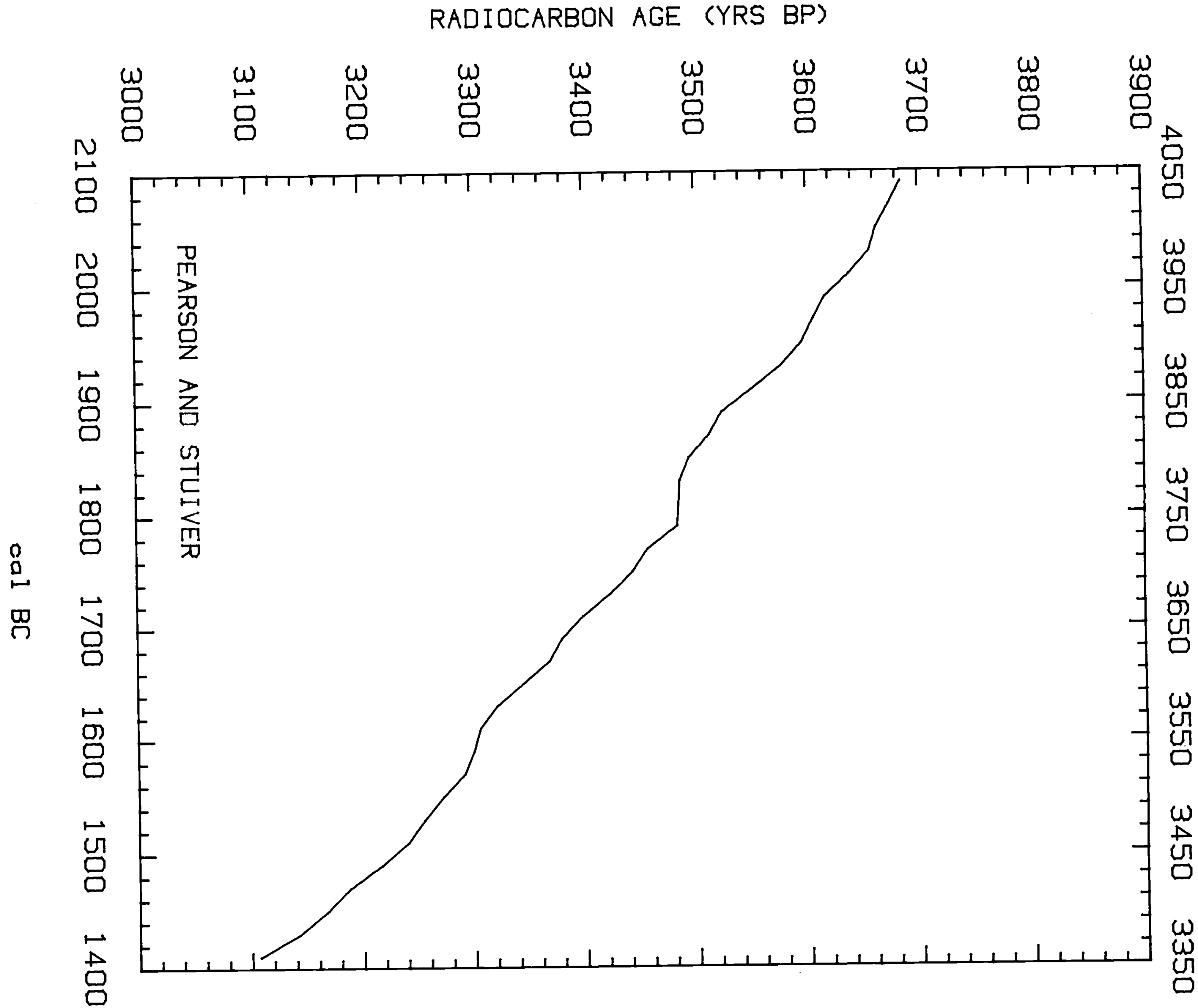

RADIOCARBON AGE (YRS BP)
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
cal BP
4050
3950
3850
3750
3650
3550
3450
3350
2100
2000
1900
1800
1700
1600
1500
1400
cal BC
PEARSON AND STUIVER

Fig 2C

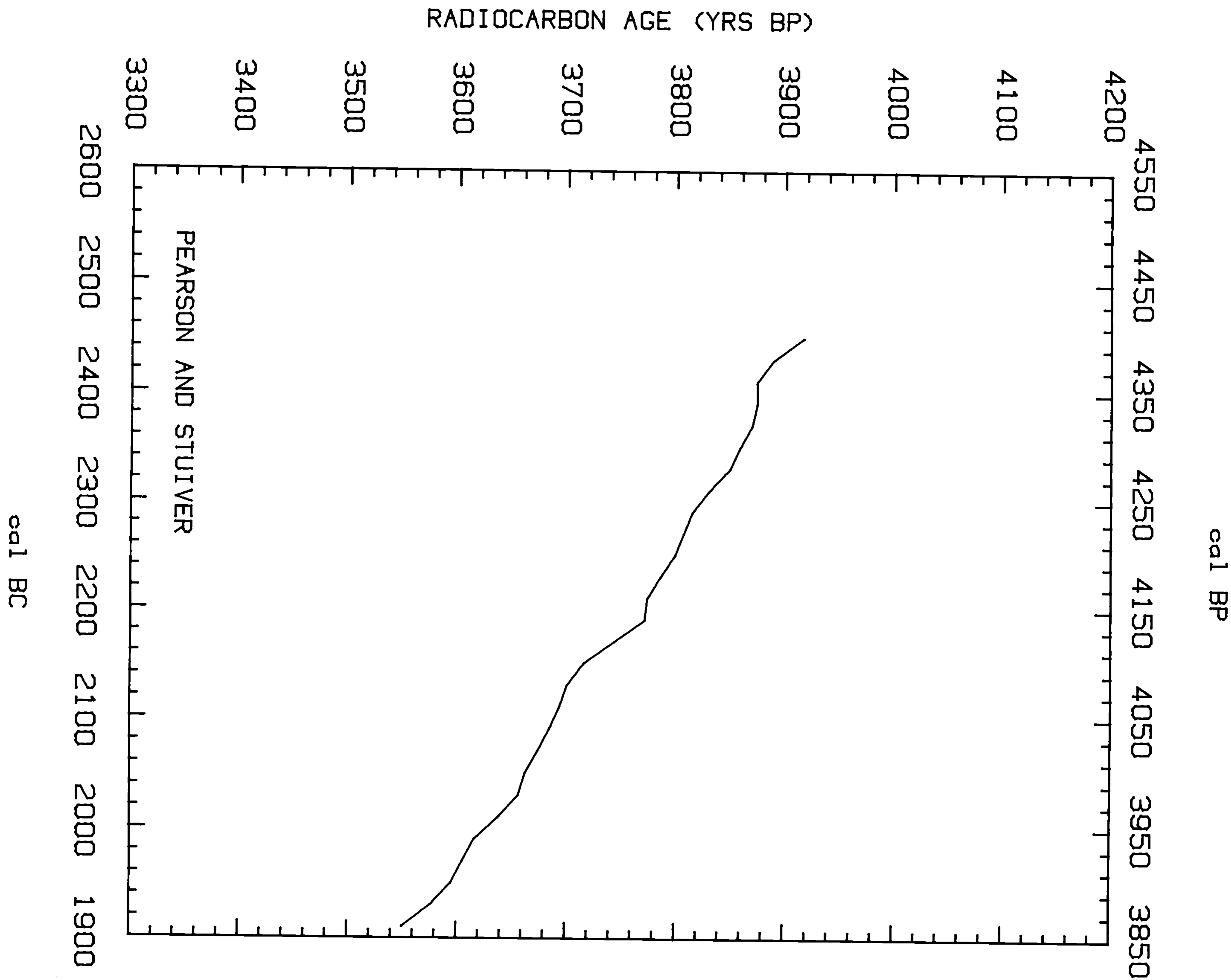

RADIOCARBON AGE (YRS BP)
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
cal BP
4550
4450
4350
4250
4150
4050
3950
3850
PEARSON AND STUIVER
cal BC
2600
2500
2400
2300
2200
2100
2000
1900

Fig 2D

TABLE 1-A

The radiocarbon ages are the averages of age determinations made at the University of Belfast and the University of Washington (Seattle). The cal AD/BC (or cal BP) ages represent the mid-points of bi-decadal wood sections. Belfast data only were used for 670 BC, 690 BC, 2390 BC, and 2450 BC because Seattle decade measurements were incomplete for these ages.

The cal AD/BC ages follow the mid-points of the Belfast bi-decadal series whenever possible, starting at 510 BC. The actual midpoints of the averages were occasionally slightly different. The differences have been neglected because the mid-points of the Seattle sample were always within 1.5 years of the mid-point of the corresponding Belfast sample. The standard deviation in the ages and Δ values include lab error multipliers of 1.23 for Belfast and 1.6 for Seattle. The trees used and sample treatments are listed in Table 2 (Stuiver & Pearson, 1986).

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 510 BP 2459	-4.1 ± 1.2	2422 ± 10	BC 870 BP 2819	1.5 ± 1.6	2728 ± 12
BC 530 BP 2479	-5.0 ± 1.1	2450 ± 9	BC 890 BP 2839	5.5 ± 1.6	2715 ± 12
BC 550 BP 2499	-6.3 ± 1.0	2480 ± 8	BC 910 BP 2859	2.1 ± 1.5	2761 ± 12
BC 570 BP 2519	-5.1 ± 1.3	2489 ± 10	BC 930 BP 2879	.1 ± 1.6	2797 ± 13
BC 590 BP 2539	-1.4 ± 1.3	2478 ± 11	BC 950 BP 2899	.1 ± 1.5	2816 ± 12
BC 610 BP 2559	-1.9 ± 1.2	2502 ± 10	BC 970 BP 2919	5.3 ± 1.3	2794 ± 10
BC 630 BP 2579	2.3 ± 1.2	2488 ± 10	BC 990 BP 2939	5.1 ± 1.4	2815 ± 11
BC 650 BP 2599	7.3 ± 1.2	2468 ± 10	BC 1010 BP 2959	2.7 ± 1.1	2854 ± 9
BC 670 BP 2619	5.0 ± 1.8	2505 ± 15	BC 1030 BP 2979	3.7 ± 1.4	2865 ± 12
BC 690 BP 2639	12.1 ± 1.8	2468 ± 15	BC 1050 BP 2999	3.6 ± 1.3	2886 ± 10
BC 710 BP 2659	16.9 ± 1.9	2449 ± 15	BC 1070 BP 3019	4.5 ± 1.3	2898 ± 10
BC 730 BP 2679	20.4 ± 1.5	2442 ± 12	BC 1090 BP 3039	7.1 ± 1.4	2897 ± 11
BC 750 BP 2699	22.8 ± 1.7	2442 ± 14	BC 1110 BP 3059	6.3 ± .4	2923 ± 3
BC 770 BP 2719	15.3 ± 1.9	2521 ± 16	BC 1120 BP 3069	8.6 ± 1.6	2914 ± 13
BC 790 BP 2739	14.6 ± 1.2	2545 ± 10	BC 1140 BP 3089	7.3 ± 1.5	2943 ± 12
BC 810 BP 2759	4.6 ± 1.6	2644 ± 13	BC 1150 BP 3099	11.0 ± .4	2924 ± 3
BC 830 BP 2779	2.2 ± 1.4	2683 ± 12	BC 1170 BP 3119	9.2 ± 1.6	2958 ± 13
BC 850 BP 2799	-.6 ± 1.6	2725 ± 13	BC 1190 BP 3139	13.6 ± 1.7	2942 ± 13

TABLE 1-B

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 1210 BP 3159	15.3 ± 1.5	2948 ± 12	BC 1710 BP 3659	17.8 ± 1.8	3414 ± 15
BC 1230 BP 3179	12.5 ± 1.6	2989 ± 13	BC 1730 BP 3679	23.4 ± 1.5	3389 ± 12
BC 1250 BP 3199	19.8 ± 1.5	2951 ± 12	BC 1750 BP 3699	18.0 ± 1.5	3452 ± 12
BC 1270 BP 3219	13.1 ± 1.7	3024 ± 14	BC 1770 BP 3719	18.6 ± 1.4	3466 ± 11
BC 1290 BP 3239	17.1 ± 1.8	3011 ± 14	BC 1790 BP 3739	16.2 ± 1.4	3505 ± 11
BC 1310 BP 3259	17.3 ± 1.8	3030 ± 14	BC 1810 BP 3759	22.4 ± 1.4	3475 ± 11
BC 1330 BP 3279	13.0 ± 1.6	3083 ± 13	BC 1830 BP 3779	20.3 ± 1.8	3511 ± 15
BC 1350 BP 3299	20.8 ± 1.7	3041 ± 14	BC 1850 BP 3799	29.4 ± 1.6	3459 ± 13
BC 1370 BP 3319	23.2 ± 1.7	3041 ± 14	BC 1870 BP 3819	30.1 ± 1.5	3473 ± 12
BC 1390 BP 3339	21.6 ± 1.4	3073 ± 12	BC 1890 BP 3839	23.2 ± 1.5	3546 ± 12
BC 1410 BP 3359	19.8 ± 1.5	3107 ± 12	BC 1910 BP 3859	23.8 ± 1.8	3562 ± 15
BC 1430 BP 3379	16.2 ± 1.5	3155 ± 12	BC 1930 BP 3879	24.7 ± 1.4	3574 ± 12
BC 1450 BP 3399	14.3 ± 1.1	3189 ± 9	BC 1950 BP 3899	24.7 ± 1.5	3593 ± 12
BC 1470 BP 3419	14.8 ± 1.3	3204 ± 11	BC 1970 BP 3919	25.6 ± 1.7	3606 ± 14
BC 1490 BP 3439	19.3 ± 1.6	3189 ± 13	BC 1990 BP 3939	24.3 ± 1.9	3635 ± 15
BC 1510 BP 3459	20.0 ± 1.7	3203 ± 14	BC 2010 BP 3959	30.0 ± 1.6	3610 ± 13
BC 1530 BP 3479	11.5 ± 1.6	3289 ± 13	BC 2030 BP 3979	29.4 ± 1.5	3634 ± 12
BC 1550 BP 3499	11.9 ± 1.8	3305 ± 14	BC 2050 BP 3999	22.0 ± 1.5	3711 ± 12
BC 1570 BP 3519	17.5 ± 2.0	3280 ± 16	BC 2070 BP 4019	26.2 ± 1.6	3698 ± 13
BC 1590 BP 3539	20.1 ± 1.5	3280 ± 12	BC 2090 BP 4039	33.2 ± 1.6	3662 ± 13
BC 1610 BP 3559	19.4 ± 1.4	3304 ± 11	BC 2110 BP 4059	35.3 ± 1.6	3666 ± 13
BC 1630 BP 3579	18.3 ± 1.6	3333 ± 13	BC 2130 BP 4079	35.0 ± 1.8	3688 ± 14
BC 1650 BP 3599	19.2 ± 1.2	3344 ± 10	BC 2150 BP 4099	26.5 ± 1.3	3773 ± 10
BC 1670 BP 3619	22.1 ± 1.6	3341 ± 13	BC 2170 BP 4119	34.3 ± 1.6	3732 ± 13
BC 1690 BP 3639	18.0 ± 1.6	3393 ± 13	BC 2190 BP 4139	35.0 ± 1.1	3746 ± 9

TABLE 1-C

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 2210 BP 4159	30.1 ± 1.4	3803 ± 11
BC 2230 BP 4179	32.7 ± 1.6	3803 ± 13
BC 2250 BP 4199	37.4 ± 1.3	3786 ± 10
BC 2270 BP 4219	40.2 ± 1.8	3784 ± 14
BC 2290 BP 4239	37.6 ± 1.5	3823 ± 12
BC 2310 BP 4259	38.2 ± 1.8	3838 ± 14
BC 2330 BP 4279	39.6 ± 1.4	3846 ± 12
BC 2350 BP 4299	39.4 ± 1.6	3867 ± 13
BC 2370 BP 4319	40.7 ± 1.4	3877 ± 12
BC 2390 BP 4339	44.5 ± 2.4	3867 ± 20
BC 2410 BP 4359	43.0 ± 1.3	3898 ± 11
BC 2430 BP 4379	49.0 ± .9	3871 ± 8
BC 2450 BP 4399	52.4 ± 1.5	3865 ± 12
BC 2470 BP 4419	42.5 ± 1.4	3960 ± 11
BC 2490 BP 4439	43.0 ± 1.5	3976 ± 12

TABLE 2

The conversion of the radiocarbon ages to a series of ranges of cal AD/BC (*and* BP) dates is determined by the AD/BC intercepts of the sample radiocarbon age ± $\sqrt{(\text{sample } \sigma)^2 + (\text{curve } \sigma)^2}$ and the calibration curve. Intercepts of the radiocarbon age with the calibration curve are listed to the right. Sample σ is the standard error in the radiocarbon age.

For sample sigmas and ranges larger or equal to 100 years the data were rounded to the nearest decade. When the gap between two successive ranges was less than 10 years, the two ranges were combined to a single one.

Illustrations of the above are given below.

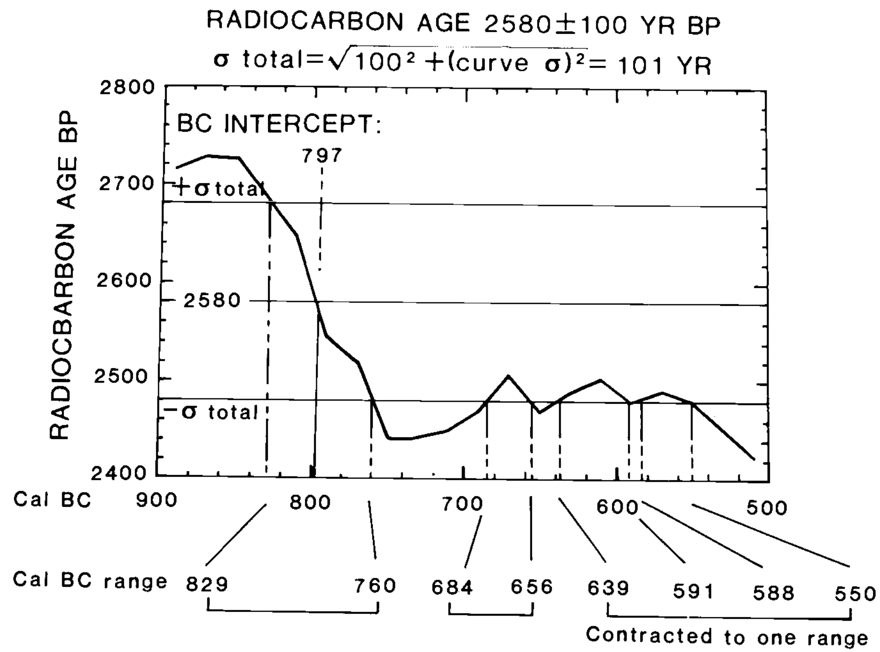


TABLE 2 (continued)

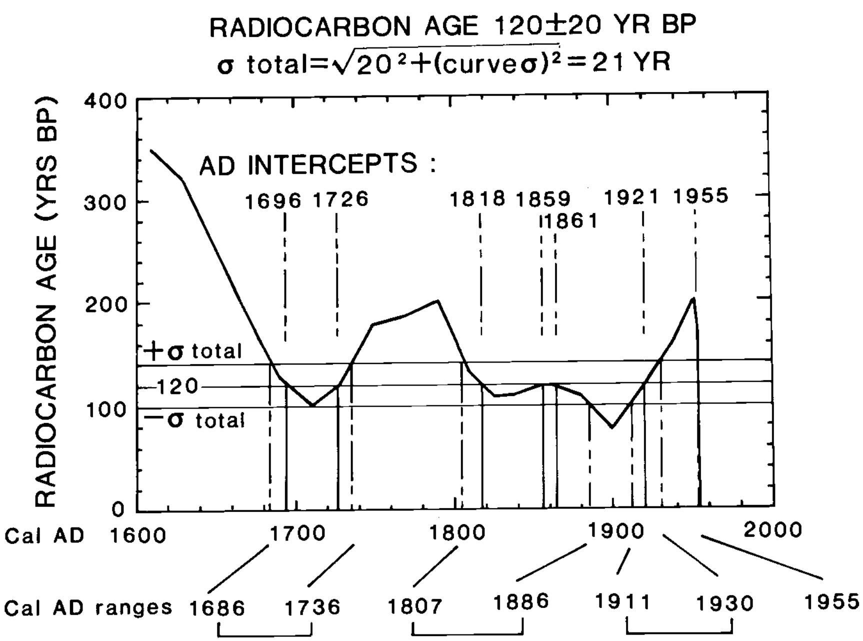


TABLE 2-A

RADIOCARBON AGE BP 2460 CALIBRATED AGES: cal BC 755, 699, 537
cal BP 2704, 2648, 2486

Sample σ and cal BC(cal BP) ranges:

σ = 20	761-682(2710-2631) 559-520(2508-2469)	659-634(2608-2583)	594-580(2543-2529)
σ = 40	765-478(2714-2427)	442-420(2391-2369)	
σ = 60	771-408(2720-2357)		
σ = 80	787-405(2736-2354)		
σ = 100	790-400(2740-2350)		
σ = 120	800-400(2750-2350)		
σ = 160	810-390(2760-2340)		
σ = 200	820-380(2770-2330)		

RADIOCARBON AGE BP 2480 CALIBRATED AGES: cal BC 760, 684, 657, 638, 591, 587, 551
cal BP 2709, 2633, 2606, 2587, 2540, 2536, 2500

Sample σ and cal BC(cal BP) ranges:

σ = 20	766-754(2715-2703)	702-535(2651-2484)
σ = 40	771-522(2720-2471)	
σ = 60	787-481(2736-2430)	440-422(2389-2371)
σ = 80	793-408(2742-2357)	
σ = 100	800-400(2750-2350)	
σ = 120	800-400(2750-2350)	
σ = 160	810-400(2760-2350)	
σ = 200	830-390(2780-2340)	

RADIOCARBON AGE BP 2500 CALIBRATED AGES: cal BC 765, 673, 667, 613, 608
cal BP 2714, 2622, 2616, 2562, 2557

Sample σ and cal BC(cal BP) ranges:

σ = 20	772-759(2721-2708)	685-655(2634-2604)	641-548(2590-2497)
σ = 40	787-754(2736-2703)	700-536(2649-2485)	
σ = 60	793-522(2742-2471)		
σ = 80	797-481(2746-2430)	440-422(2389-2371)	
σ = 100	800-410(2750-2360)		
σ = 120	810-400(2760-2350)		
σ = 160	820-400(2770-2350)		
σ = 200	840-390(2790-2340)		

RADIOCARBON AGE BP 2520 CALIBRATED AGE: cal BC 770
cal BP 2719

Sample σ and cal BC(cal BP) ranges:

σ = 20	790-764(2739-2713)	675-665(2624-2614)	620-604(2569-2553)
σ = 40	793-759(2742-2708)	685-655(2634-2604)	640-548(2589-2497)
σ = 60	797-754(2746-2703)	700-536(2649-2485)	
σ = 80	801-522(2750-2471)		
σ = 100	810-480(2760-2430)	440-422(2389-2371)	
σ = 120	810-410(2760-2360)		
σ = 160	830-400(2780-2350)		
σ = 200	892-881(2841-2830)	850-400(2800-2350)	

Table 2-B

RADIOCARBON AGE BP 2540 CALIBRATED AGE: cal BC 786
cal BP 2735

Sample σ and cal BC(cal BP) ranges:

σ = 20	794-769(2743-2718)		
σ = 40	797-764(2746-2713)	674-666(2623-2615)	616-607(2565-2556)
σ = 60	801-759(2750-2708)	684-656(2633-2605)	639-549(2588-2498)
σ = 80	805-754(2754-2703)	700-536(2649-2485)	
σ = 100	810-520(2760-2470)		
σ = 120	820-480(2770-2430)	439-422(2388-2371)	
σ = 160	840-400(2790-2350)		
σ = 200	900-400(2850-2350)		

RADIOCARBON AGE BP 2560 CALIBRATED AGE: cal BC 793
cal BP 2742

Sample σ and cal BC(cal BP) ranges:

σ = 20	798-783(2747-2732)		
σ = 40	801-769(2750-2718)		
σ = 60	805-765(2754-2714)	673-667(2622-2616)	615-607(2564-2556)
σ = 80	809-760(2758-2709)	684-656(2633-2605)	639-550(2588-2499)
σ = 100	818-754(2767-2703)	700-540(2650-2490)	
σ = 120	830-520(2780-2470)		
σ = 160	892-882(2841-2831)	850-410(2800-2360)	
σ = 200	910-400(2860-2350)		

RADIOCARBON AGE BP 2580 CALIBRATED AGE: cal BC 797
cal BP 2746

Sample σ and cal BC(cal BP) ranges:

σ = 20	802-792(2751-2741)		
σ = 40	805-784(2754-2733)		
σ = 60	809-770(2758-2719)		
σ = 80	819-765(2768-2714)	673-667(2622-2616)	614-608(2563-2557)
σ = 100	829-760(2778-2709)	684-656(2633-2605)	639-550(2588-2499)
σ = 120	838-755(2787-2704)	700-540(2650-2490)	
σ = 160	900-480(2850-2430)	439-423(2388-2372)	
σ = 200	920-400(2870-2350)		

RADIOCARBON AGE BP 2600 CALIBRATED AGE: cal BC 801
cal BP 2750

Sample σ and cal BC(cal BP) ranges:

σ = 20	806-796(2755-2745)		
σ = 40	809-793(2758-2742)		
σ = 60	819-785(2768-2734)		
σ = 80	829-770(2778-2719)		
σ = 100	838-765(2787-2714)	673-667(2622-2616)	614-608(2563-2557)
σ = 120	892-881(2841-2830)	848-760(2797-2709)	684-656(2633-2605)
	638-550(2587-2499)		
σ = 160	910-520(2860-2470)		
σ = 200	976-964(2925-2913)	930-410(2880-2360)	

Table 2-C

RADIOCARBON AGE BP 2620 CALIBRATED AGE: cal BC 805
cal BP 2754

Sample σ and cal BC(cal BP) ranges:

σ = 20	810-800(2759-2749)		
σ = 40	819-797(2768-2746)		
σ = 60	829-793(2778-2742)		
σ = 80	838-785(2787-2734)		
σ = 100	892-881(2841-2830)	848-770(2797-2719)	
σ = 120	900-760(2850-2710)	673-667(2622-2616)	614-608(2563-2557)
σ = 160	920-750(2870-2700)	700-540(2650-2490)	
σ = 200	990-480(2940-2430)	439-423(2388-2372)	

RADIOCARBON AGE BP 2640 CALIBRATED AGE: cal BC 809
cal BP 2758

Sample σ and cal BC(cal BP) ranges:

σ = 20	820-804(2769-2753)		
σ = 40	829-801(2778-2750)		
σ = 60	839-797(2788-2746)		
σ = 80	893-881(2842-2830)	848-793(2797-2742)	
σ = 100	900-790(2850-2740)		
σ = 120	910-770(2860-2720)		
σ = 160	976-964(2925-2913)	930-760(2880-2710)	684-656(2633-2605)
	638-550(2587-2499)		
σ = 200	1000-520(2950-2470)		

RADIOCARBON AGE BP 2660 CALIBRATED AGE: cal BC 818
cal BP 2767

Sample σ and cal BC(cal BP) ranges:

σ = 20	830-808(2779-2757)		
σ = 40	839-805(2788-2754)		
σ = 60	893-880(2842-2829)	848-801(2797-2750)	
σ = 80	901-797(2850-2746)		
σ = 100	910-790(2860-2740)		
σ = 120	920-790(2870-2740)		
σ = 160	990-760(2940-2710)	673-667(2622-2616)	614-608(2563-2557)
σ = 200	1020-750(2970-2700)	700-540(2650-2490)	

RADIOCARBON AGE BP 2680 CALIBRATED AGE: cal BC 828
cal BP 2777

Sample σ and cal BC(cal BP) ranges:

σ = 20	840-816(2789-2765)		
σ = 40	893-879(2842-2828)	848-809(2797-2758)	
σ = 60	901-805(2850-2754)		
σ = 80	910-801(2859-2750)		
σ = 100	920-800(2870-2750)		
σ = 120	976-964(2925-2913)	930-790(2880-2740)	
σ = 160	1000-770(2950-2720)		
σ = 200	1040-760(2990-2710)	684-656(2633-2605)	638-550(2587-2499)

TABLE 2-D

```
RADIOCARBON AGE BP 2700   CALIBRATED AGE:   cal BC  838
                                            cal BP 2787
Sample σ and cal BC(cal BP) ranges:
σ =  20    894-877(2843-2826)    849-827(2798-2776)
σ =  40    902-817(2851-2766)
σ =  60    910-809(2859-2758)
σ =  80    921-805(2870-2754)
σ = 100    976-964(2925-2913)    930-800(2880-2750)
σ = 120    990-800(2940-2750)
σ = 160    1020-790(2970-2740)
σ = 200    1090-760(3040-2710)   673-667(2622-2616)    614-608(2563-2557)
```

```
RADIOCARBON AGE BP 2720   CALIBRATED AGES:  cal BC  892,  882,  848
                                            cal BP 2841, 2831, 2797
Sample σ and cal BC(cal BP) ranges:
σ =  20    902-836(2851-2785)
σ =  40    910-827(2859-2776)
σ =  60    921-817(2870-2766)
σ =  80    976-964(2925-2913)    934-809(2883-2758)
σ = 100    990-800(2940-2750)
σ = 120    1000-800(2950-2750)
σ = 160    1050-790(3000-2740)
σ = 200    1120-770(3070-2720)
```

```
RADIOCARBON AGE BP 2740   CALIBRATED AGE:   cal BC  901
                                            cal BP 2850
Sample σ and cal BC(cal BP) ranges:
σ =  20    911-846(2860-2795)
σ =  40    921-837(2870-2786)
σ =  60    977-964(2926-2913)    934-828(2883-2777)
σ =  80    993-818(2942-2767)
σ = 100    1000-810(2950-2760)
σ = 120    1020-800(2970-2750)
σ = 160    1090-800(3040-2750)
σ = 200    1160-790(3110-2740)
```

```
RADIOCARBON AGE BP 2760   CALIBRATED AGE:   cal BC  909
                                            cal BP 2858
Sample σ and cal BC(cal BP) ranges:
σ =  20    922-899(2871-2848)
σ =  40    977-963(2926-2912)    935-847(2884-2796)
σ =  60    993-837(2942-2786)
σ =  80    1003-828(2952-2777)
σ = 100    1020-820(2970-2770)
σ = 120    1050-810(3000-2760)
σ = 160    1120-800(3070-2750)
σ = 200    1252-1245(3201-3194)  1220-790(3170-2740)
```

TABLE 2-E

```
RADIOCARBON AGE BP 2780   CALIBRATED AGE:   cal BC  920
                                            cal BP 2869
Sample σ and cal BC(cal BP) ranges:
σ =  20    979-961(2928-2910)    937-908(2886-2857)
σ =  40    993-900(2942-2849)
σ =  60    1004-847(2953-2796)
σ =  80    1023-838(2972-2787)
σ = 100    1050-830(3000-2780)
σ = 120    1090-820(3040-2770)
σ = 160    1160-810(3110-2760)
σ = 200    1260-800(3210-2750)
```

```
RADIOCARBON AGE BP 2800   CALIBRATED AGES:  cal BC  976,  965,  933
                                            cal BP 2925, 2914, 2882
Sample σ and cal BC(cal BP) ranges:
σ =  20    994-919(2943-2868)
σ =  40    1004-909(2953-2858)
σ =  60    1023-900(2972-2849)
σ =  80    1045-847(2994-2796)
σ = 100    1090-840(3040-2790)
σ = 120    1120-830(3070-2780)
σ = 160    1252-1245(3201-3194)  1220-810(3170-2760)
σ = 200    1260-800(3210-2750)
```

```
RADIOCARBON AGE BP 2820   CALIBRATED AGE:   cal BC  992
                                            cal BP 2941
Sample σ and cal BC(cal BP) ranges:
σ =  20    1004-931(2953-2880)
σ =  40    1023-920(2972-2869)
σ =  60    1045-909(2994-2858)
σ =  80    1093-901(3042-2850)
σ = 100    1120-850(3070-2800)
σ = 120    1160-840(3110-2790)
σ = 160    1260-820(3210-2770)
σ = 200    1300-810(3250-2760)
```

```
RADIOCARBON AGE BP 2840   CALIBRATED AGE:   cal BC 1003
                                            cal BP 2952
Sample σ and cal BC(cal BP) ranges:
σ =  20    1025-991(2974-2940)
σ =  40    1046-932(2995-2881)
σ =  60    1093-920(3042-2869)
σ =  80    1125-909(3074-2858)
σ = 100    1160-900(3110-2850)
σ = 120    1252-1245(3201-3194)  1220-850(3170-2800)
σ = 160    1260-830(3210-2780)
σ = 200    1310-810(3260-2760)
```

Table 2-F

RADIOCARBON AGE BP 2860 CALIBRATED AGE: cal BC 1021
cal BP 2970

Sample σ and cal BC(cal BP) ranges:
σ = 20 1047-1002(2996-2951)
σ = 40 1094-992(3043-2941)
σ = 60 1125-932(3074-2881)
σ = 80 1160-920(3109-2869)
σ = 100 1253-1245(3202-3194) 1220-910(3170-2860)
σ = 120 1260-900(3210-2850)
σ = 160 1300-840(3250-2790)
σ = 200 1382-1341(3331-3290) 1320-820(3270-2770)

RADIOCARBON AGE BP 2880 CALIBRATED AGE: cal BC 1045
cal BP 2994

Sample σ and cal BC(cal BP) ranges:
σ = 20 1095-1016(3044-2965)
σ = 40 1125-1002(3074-2951)
σ = 60 1160-992(3109-2941)
σ = 80 1253-1245(3202-3194) 1216-932(3165-2881)
σ = 100 1260-920(3210-2870)
σ = 120 1260-910(3210-2860)
σ = 160 1310-850(3260-2800)
σ = 200 1390-830(3340-2780)

RADIOCARBON AGE BP 2900 CALIBRATED AGE: cal BC 1093
cal BP 3042

Sample σ and cal BC(cal BP) ranges:
σ = 20 1125-1043(3074-2992)
σ = 40 1160-1020(3109-2969)
σ = 60 1252-1245(3201-3194) 1216-1003(3165-2952)
σ = 80 1258-992(3207-2941)
σ = 100 1260-980(3210-2930) 965-933(2914-2882)
σ = 120 1300-920(3250-2870)
σ = 160 1382-1341(3331-3290) 1320-900(3270-2850)
σ = 200 1410-840(3360-2790)

RADIOCARBON AGE BP 2920 CALIBRATED AGES: cal BC 1124, 1113, 1108
cal BP 3073, 3062, 3057

Sample σ and cal BC(cal BP) ranges:
σ = 20 1161-1091(3110-3040)
σ = 40 1253-1245(3202-3194) 1216-1044(3165-2993)
σ = 60 1258-1020(3207-2969)
σ = 80 1264-1003(3213-2952)
σ = 100 1300-990(3250-2940)
σ = 120 1310-980(3260-2930) 965-933(2914-2882)
σ = 160 1390-910(3340-2860)
σ = 200 1420-850(3370-2800)

Table 2-G

RADIOCARBON AGE BP 2940 CALIBRATED AGES: cal BC 1159, 1142, 1138
cal BP 3108, 3091, 3087

Sample σ and cal BC(cal BP) ranges:
σ = 20 1253-1244(3202-3193) 1217-1106(3166-3055)
σ = 40 1258-1092(3207-3041)
σ = 60 1264-1044(3213-2993)
σ = 80 1300-1020(3249-2969)
σ = 100 1310-1000(3260-2950)
σ = 120 1382-1341(3331-3290) 1320-990(3270-2940)
σ = 160 1410-920(3360-2870)
σ = 200 1420-900(3370-2850)

RADIOCARBON AGE BP 2960 CALIBRATED AGES: cal BC 1252, 1245, 1216
cal BP 3201, 3194, 3165

Sample σ and cal BC(cal BP) ranges:
σ = 20 1259-1157(3208-3106) 1144-1135(3093-3084)
σ = 40 1264-1107(3213-3056)
σ = 60 1301-1092(3250-3041)
σ = 80 1357-1350(3306-3299) 1314-1044(3263-2993)
σ = 100 1382-1340(3331-3289) 1320-1020(3270-2970)
σ = 120 1390-1000(3340-2950)
σ = 160 1420-930(3370-2880)
σ = 200 1430-910(3380-2860)

RADIOCARBON AGE BP 2980 CALIBRATED AGES: cal BC 1258, 1235, 1226
cal BP 3207, 3184, 3175

Sample σ and cal BC(cal BP) ranges:
σ = 20 1264-1214(3213-3163) 1172-1169(3121-3118)
σ = 40 1302-1158(3251-3107) 1143-1136(3092-3085)
σ = 60 1368-1350(3317-3299) 1314-1107(3263-3056)
σ = 80 1382-1340(3331-3289) 1322-1092(3271-3041)
σ = 100 1390-1040(3340-2990)
σ = 120 1410-1020(3360-2970)
σ = 160 1420-990(3370-2940)
σ = 200 1450-920(3400-2870)

RADIOCARBON AGE BP 3000 CALIBRATED AGE: cal BC 1263
cal BP 3212

Sample σ and cal BC(cal BP) ranges:
σ = 20 1304-1257(3253-3206) 1237-1224(3186-3173)
σ = 40 1370-1349(3319-3298) 1315-1215(3264-3164)
σ = 60 1383-1340(3332-3289) 1322-1159(3271-3108) 1142-1137(3091-3086)
σ = 80 1395-1107(3344-3056)
σ = 100 1410-1090(3360-3040)
σ = 120 1420-1040(3370-2990)
σ = 160 1430-1000(3380-2950)
σ = 200 1507-1475(3456-3424) 1470-980(3420-2930) 965-933(2914-2882)

TABLE 2-H

RADIOCARBON AGE BP 3020 CALIBRATED AGES: cal BC 1300, 1276, 1269
cal BP 3249, 3225, 3218

Sample σ and cal BC(cal BP) ranges:

σ = 20	1372-1348(3321-3297)	1316-1262(3265-3211)	
σ = 40	1383-1340(3332-3289)	1322-1257(3271-3206)	1236-1224(3185-3173)
σ = 60	1395-1215(3344-3164)		
σ = 80	1407-1159(3356-3108)	1142-1137(3091-3086)	
σ = 100	1420-1110(3370-3060)		
σ = 120	1420-1090(3370-3040)		
σ = 160	1450-1020(3400-2970)		
σ = 200	1510-990(3460-2940)		

RADIOCARBON AGE BP 3040 CALIBRATED AGE: cal BC 1314
cal BP 3263

Sample σ and cal BC(cal BP) ranges:

σ = 20	1384-1339(3333-3288)	1323-1295(3272-3244)	1283-1268(3232-3217)
σ = 40	1395-1263(3344-3212)		
σ = 60	1407-1257(3356-3206)	1236-1225(3185-3174)	
σ = 80	1416-1215(3365-3164)		
σ = 100	1420-1160(3370-3110)	1142-1137(3091-3086)	
σ = 120	1430-1110(3380-3060)		
σ = 160	1510-1040(3460-2990)		
σ = 200	1520-1000(3470-2950)		

RADIOCARBON AGE BP 3060 CALIBRATED AGES: cal BC 1382, 1341, 1321
cal BP 3331, 3290, 3270

Sample σ and cal BC(cal BP) ranges:

σ = 20	1397-1312(3346-3261)	
σ = 40	1407-1297(3356-3246)	1280-1268(3229-3217)
σ = 60	1416-1263(3365-3212)	
σ = 80	1424-1258(3373-3207)	1236-1225(3185-3174)
σ = 100	1430-1220(3380-3170)	
σ = 120	1450-1160(3400-3110)	1142-1137(3091-3086)
σ = 160	1510-1090(3460-3040)	
σ = 200	1520-1020(3470-2970)	

RADIOCARBON AGE BP 3080 CALIBRATED AGES: cal BC 1394, 1331, 1329
cal BP 3343, 3280, 3278

Sample σ and cal BC(cal BP) ranges:

σ = 20	1408-1379(3357-3328)	1343-1320(3292-3269)
σ = 40	1416-1313(3365-3262)	
σ = 60	1424-1298(3373-3247)	1278-1268(3227-3217)
σ = 80	1434-1263(3383-3212)	
σ = 100	1450-1260(3400-3210)	1235-1225(3184-3174)
σ = 120	1510-1220(3460-3170)	
σ = 160	1520-1120(3470-3070)	1113-1108(3062-3057)
σ = 200	1591-1570(3540-3519)	1530-1040(3480-2990)

TABLE 2-I

RADIOCARBON AGE BP 3100 CALIBRATED AGE: cal BC 1406
cal BP 3355

Sample σ and cal BC(cal BP) ranges:

σ = 20	1417-1392(3366-3341)	1333-1328(3282-3277)
σ = 40	1425-1381(3374-3330)	1342-1321(3291-3270)
σ = 60	1434-1313(3383-3262)	
σ = 80	1445-1299(3394-3248)	1278-1269(3227-3218)
σ = 100	1510-1260(3460-3210)	
σ = 120	1510-1260(3460-3210)	1235-1225(3184-3174)
σ = 160	1520-1160(3470-3110)	1142-1137(3091-3086)
σ = 200	1607-1554(3556-3503)	1540-1090(3490-3040)

RADIOCARBON AGE BP 3120 CALIBRATED AGE: cal BC 1416
cal BP 3365

Sample σ and cal BC(cal BP) ranges:

σ = 20	1425-1404(3374-3353)	
σ = 40	1434-1393(3383-3342)	1332-1328(3281-3277)
σ = 60	1446-1381(3395-3330)	1341-1321(3290-3270)
σ = 80	1508-1314(3457-3263)	
σ = 100	1510-1300(3460-3250)	1277-1269(3226-3218)
σ = 120	1520-1260(3470-3210)	
σ = 160	1591-1570(3540-3519)	1530-1220(3480-3170)
σ = 200	1620-1120(3570-3070)	1113-1108(3062-3057)

RADIOCARBON AGE BP 3140 CALIBRATED AGE: cal BC 1424
cal BP 3373

Sample σ and cal BC(cal BP) ranges:

σ = 20	1435-1414(3384-3363)	
σ = 40	1446-1405(3395-3354)	
σ = 60	1508-1393(3457-3342)	1332-1329(3281-3278)
σ = 80	1514-1381(3463-3330)	1341-1321(3290-3270)
σ = 100	1520-1310(3470-3260)	
σ = 120	1520-1300(3470-3250)	1277-1269(3226-3218)
σ = 160	1610-1260(3560-3210)	1235-1225(3184-3174)
σ = 200	1640-1160(3590-3110)	1142-1138(3091-3087)

RADIOCARBON AGE BP 3160 CALIBRATED AGE: cal BC 1433
cal BP 3382

Sample σ and cal BC(cal BP) ranges:

σ = 20	1446-1423(3395-3372)	
σ = 40	1508-1415(3457-3364)	
σ = 60	1514-1405(3463-3354)	
σ = 80	1519-1394(3468-3343)	1332-1329(3281-3278)
σ = 100	1520-1380(3470-3330)	1341-1321(3290-3270)
σ = 120	1591-1570(3540-3519)	1530-1310(3480-3260)
σ = 160	1620-1260(3570-3210)	
σ = 200	1680-1220(3630-3170)	

Table 2-J

RADIOCARBON AGE BP 3180 CALIBRATED AGE: cal BC 1445
cal BP 3394

Sample σ and cal BC(cal BP) ranges:

σ = 20	1510-1432(3459-3381)		
σ = 40	1514-1423(3463-3372)		
σ = 60	1519-1415(3468-3364)		
σ = 80	1523-1406(3472-3355)		
σ = 100	1591-1570(3540-3519)	1530-1390(3480-3340)	1332-1329(3281-3278)
σ = 120	1610-1380(3560-3330)	1341-1321(3290-3270)	
σ = 160	1640-1300(3590-3250)	1277-1269(3226-3218)	
σ = 200	1690-1260(3640-3210)	1235-1225(3184-3174)	

RADIOCARBON AGE BP 3200 CALIBRATED AGES: cal BC 1506, 1476, 1464
cal BP 3455, 3425, 3413

Sample σ and cal BC(cal BP) ranges:

σ = 20	1515-1443(3464-3392)	
σ = 40	1519-1432(3468-3381)	
σ = 60	1524-1423(3473-3372)	
σ = 80	1591-1570(3540-3519)	1528-1415(3477-3364)
σ = 100	1610-1410(3560-3360)	
σ = 120	1620-1390(3570-3340)	1332-1329(3281-3278)
σ = 160	1680-1310(3630-3260)	
σ = 200	1734-1721(3683-3670)	1700-1260(3650-3210)

RADIOCARBON AGE BP 3220 CALIBRATED AGE: cal BC 1514
cal BP 3463

Sample σ and cal BC(cal BP) ranges:

σ = 20	1520-1500(3469-3449)	1481-1459(3430-3408)
σ = 40	1524-1444(3473-3393)	
σ = 60	1591-1569(3540-3518)	1528-1432(3477-3381)
σ = 80	1607-1423(3556-3372)	
σ = 100	1620-1420(3570-3370)	
σ = 120	1640-1410(3590-3360)	
σ = 160	1690-1380(3640-3330)	1341-1321(3290-3270)
σ = 200	1740-1300(3690-3250)	1277-1269(3226-3218)

RADIOCARBON AGE BP 3240 CALIBRATED AGE: cal BC 1519
cal BP 3468

Sample σ and cal BC(cal BP) ranges:

σ = 20	1524-1513(3473-3462)		
σ = 40	1592-1569(3541-3518)	1528-1503(3477-3452)	1478-1462(3427-3411)
σ = 60	1608-1444(3557-3393)		
σ = 80	1622-1433(3571-3382)		
σ = 100	1640-1420(3590-3370)		
σ = 120	1680-1420(3630-3370)		
σ = 160	1734-1721(3683-3670)	1700-1390(3650-3340)	1332-1329(3281-3278)
σ = 200	1750-1310(3700-3260)		

Table 2-K

RADIOCARBON AGE BP 3260 CALIBRATED AGE: cal BC 1523
cal BP 3472

Sample σ and cal BC(cal BP) ranges:

σ = 20	1593-1567(3542-3516)	1529-1518(3478-3467)	
σ = 40	1608-1514(3557-3463)		
σ = 60	1622-1504(3571-3453)	1477-1463(3426-3412)	
σ = 80	1644-1444(3593-3393)		
σ = 100	1680-1430(3630-3380)		
σ = 120	1690-1420(3640-3370)		
σ = 160	1740-1410(3690-3360)		
σ = 200	1852-1850(3801-3799)	1760-1380(3710-3330)	1341-1321(3290-3270)

RADIOCARBON AGE BP 3280 CALIBRATED AGES: cal BC 1590, 1579, 1528
cal BP 3539, 3528, 3477

Sample σ and cal BC(cal BP) ranges:

σ = 20	1610-1522(3559-3471)		
σ = 40	1623-1518(3572-3467)		
σ = 60	1645-1514(3594-3463)		
σ = 80	1678-1505(3627-3454)	1477-1463(3426-3412)	
σ = 100	1690-1440(3640-3390)		
σ = 120	1734-1721(3683-3670)	1700-1430(3650-3380)	
σ = 160	1750-1420(3700-3370)		
σ = 200	1872-1842(3821-3791)	1813-1806(3762-3755)	1780-1390(3730-3340)
	1331-1329(3280-3278)		

RADIOCARBON AGE BP 3300 CALIBRATED AGES: cal BC 1607, 1554, 1543
cal BP 3556, 3503, 3492

Sample σ and cal BC(cal BP) ranges:

σ = 20	1624-1527(3573-3476)		
σ = 40	1670-1665(3619-3614)	1646-1523(3595-3472)	
σ = 60	1678-1518(3627-3467)		
σ = 80	1685-1514(3634-3463)		
σ = 100	1734-1721(3683-3670)	1700-1500(3650-3450)	1477-1463(3426-3412)
σ = 120	1740-1440(3690-3390)		
σ = 160	1852-1849(3801-3798)	1760-1420(3710-3370)	
σ = 200	1880-1410(3830-3360)		

RADIOCARBON AGE BP 3320 CALIBRATED AGE: cal BC 1621
cal BP 3570

Sample σ and cal BC(cal BP) ranges:

σ = 20	1671-1604(3620-3553)	1557-1540(3506-3489)	
σ = 40	1678-1528(3627-3477)		
σ = 60	1685-1523(3634-3472)		
σ = 80	1734-1721(3683-3670)	1698-1518(3647-3467)	
σ = 100	1740-1510(3690-3460)		
σ = 120	1750-1510(3700-3460)	1476-1464(3425-3413)	
σ = 160	1872-1842(3821-3791)	1813-1806(3762-3755)	1780-1430(3730-3380)
σ = 200	1880-1420(3830-3370)		

TABLE 2-L

RADIOCARBON AGE BP 3340 CALIBRATED AGE: cal BC 1643
cal BP 3592

Sample o and cal BC(cal BP) ranges:

o = 20	1678-1619(3627-3568)	
o = 40	1686-1605(3635-3554)	1556-1542(3505-3491)
o = 60	1734-1721(3683-3670)	1698-1528(3647-3477)
o = 80	1740-1523(3689-3472)	
o = 100	1750-1520(3700-3470)	
o = 120	1852-1850(3801-3799)	1760-1510(3710-3460)
o = 160	1880-1440(3830-3390)	
o = 200	1890-1420(3840-3370)	

RADIOCARBON AGE BP 3360 CALIBRATED AGE: cal BC 1677
cal BP 3626

Sample o and cal BC(cal BP) ranges:

o = 20	1686-1636(3635-3585)		
o = 40	1734-1720(3683-3669)	1699-1620(3648-3569)	
o = 60	1740-1605(3689-3554)	1555-1542(3504-3491)	
o = 80	1747-1528(3696-3477)		
o = 100	1852-1849(3801-3798)	1760-1520(3710-3470)	
o = 120	1872-1842(3821-3791)	1813-1806(3762-3755)	1780-1520(3730-3470)
o = 160	1880-1510(3830-3460)	1476-1464(3425-3413)	
o = 200	1910-1430(3860-3380)		

RADIOCARBON AGE BP 3380 CALIBRATED AGE: cal BC 1685
cal BP 3634

Sample o and cal BC(cal BP) ranges:

o = 20	1735-1718(3684-3667)	1700-1676(3649-3625)	
o = 40	1741-1639(3690-3588)		
o = 60	1747-1620(3696-3569)		
o = 80	1853-1849(3802-3798)	1763-1606(3712-3555)	1555-1542(3504-3491)
o = 100	1872-1842(3821-3791)	1813-1806(3762-3755)	1780-1530(3730-3480)
o = 120	1880-1520(3830-3470)		
o = 160	1890-1510(3840-3460)		
o = 200	1940-1440(3890-3390)		

RADIOCARBON AGE BP 3400 CALIBRATED AGES: cal BC 1733, 1721, 1697
cal BP 3682, 3670, 3646

Sample o and cal BC(cal BP) ranges:

o = 20	1741-1683(3690-3632)		
o = 40	1747-1676(3696-3625)		
o = 60	1853-1849(3802-3798)	1763-1640(3712-3589)	
o = 80	1872-1842(3821-3791)	1813-1806(3762-3755)	1778-1620(3727-3569)
o = 100	1880-1610(3830-3560)	1555-1542(3504-3491)	
o = 120	1880-1530(3830-3480)		
o = 160	1910-1520(3860-3470)		
o = 200	1960-1510(3910-3460)	1476-1464(3425-3413)	

TABLE 2-M

RADIOCARBON AGE BP 3420 CALIBRATED AGE: cal BC 1740
cal BP 3689

Sample o and cal BC(cal BP) ranges:

o = 20	1747-1693(3696-3642)		
o = 40	1854-1849(3803-3798)	1764-1684(3713-3633)	
o = 60	1872-1841(3821-3790)	1813-1806(3762-3755)	1778-1677(3727-3626)
o = 80	1878-1641(3827-3590)		
o = 100	1880-1620(3830-3570)		
o = 120	1890-1610(3840-3560)	1555-1543(3504-3492)	
o = 160	1940-1520(3890-3470)		
o = 200	2019-2002(3968-3951)	1980-1510(3930-3460)	

RADIOCARBON AGE BP 3440 CALIBRATED AGE: cal BC 1746
cal BP 3695

Sample o and cal BC(cal BP) ranges:

o = 20	1856-1848(3805-3797)	1766-1739(3715-3688)	
o = 40	1872-1841(3821-3790)	1814-1805(3763-3754)	1778-1695(3727-3644)
o = 60	1878-1685(3827-3634)		
o = 80	1883-1677(3832-3626)		
o = 100	1890-1640(3840-3590)		
o = 120	1910-1620(3860-3570)		
o = 160	1960-1530(3910-3480)		
o = 200	2030-1520(3980-3470)		

RADIOCARBON AGE BP 3460 CALIBRATED AGES: cal BC 1851, 1850, 1761
cal BP 3800, 3799, 3710

Sample o and cal BC(cal BP) ranges:

o = 20	1873-1841(3822-3790)	1815-1804(3764-3753)	1779-1745(3728-3694)
o = 40	1878-1739(3827-3688)		
o = 60	1883-1733(3832-3682)	1722-1696(3671-3645)	
o = 80	1889-1685(3838-3634)		
o = 100	1910-1680(3860-3630)		
o = 120	1940-1640(3890-3590)		
o = 160	2019-2002(3968-3951)	1980-1610(3930-3560)	1555-1543(3504-3492)
o = 200	2040-1520(3990-3470)		

RADIOCARBON AGE BP 3480 CALIBRATED AGES: cal BC 1872, 1842, 1813, 1807, 1777
cal BP 3821, 3791, 3762, 3756, 3726

Sample o and cal BC(cal BP) ranges:

o = 20	1878-1757(3827-3706)	
o = 40	1883-1746(3832-3695)	
o = 60	1889-1739(3838-3688)	
o = 80	1909-1733(3858-3682)	1722-1696(3671-3645)
o = 100	1940-1680(3890-3630)	
o = 120	1960-1680(3910-3630)	
o = 160	2030-1620(3980-3570)	
o = 200	2123-2080(4072-4029)	2040-1530(3990-3480)

Table 2-N

RADIOCARBON AGE BP 3500 CALIBRATED AGES: cal BC 1877, 1834, 1824, 1793, 1788
cal BP 3826, 3783, 3773, 3742, 3737

Sample σ and cal BC(cal BP) ranges:

σ = 20	1884-1871(3833-3820)	1843-1775(3792-3724)	
σ = 40	1889-1759(3838-3708)		
σ = 60	1909-1746(3858-3695)		
σ = 80	1937-1740(3886-3689)		
σ = 100	1960-1730(3910-3680)	1722-1696(3671-3645)	
σ = 120	2019-2002(3968-3951)	1980-1680(3930-3630)	
σ = 160	2040-1640(3990-3590)		
σ = 200	2133-2066(4082-4015)	2050-1610(4000-3560)	1555-1543(3504-3492)

RADIOCARBON AGE BP 3520 CALIBRATED AGE: cal BC 1883
cal BP 3832

Sample σ and cal BC(cal BP) ranges:

σ = 20	1889-1876(3838-3825)	1835-1822(3784-3771)	1795-1786(3744-3735)
σ = 40	1910-1871(3859-3820)	1843-1776(3792-3725)	
σ = 60	1938-1760(3887-3709)		
σ = 80	1962-1746(3911-3695)		
σ = 100	2019-2002(3968-3951)	1980-1740(3930-3690)	
σ = 120	2030-1730(3980-3680)	1722-1696(3671-3645)	
σ = 160	2123-2080(4072-4029)	2040-1680(3990-3630)	
σ = 200	2140-1620(4090-3570)		

RADIOCARBON AGE BP 3540 CALIBRATED AGE: cal BC 1888
cal BP 3837

Sample σ and cal BC(cal BP) ranges:

σ = 20	1913-1882(3862-3831)		
σ = 40	1938-1877(3887-3826)	1835-1823(3784-3772)	1794-1787(3743-3736)
σ = 60	1963-1872(3912-3821)	1842-1776(3791-3725)	
σ = 80	2019-2001(3968-3950)	1980-1760(3929-3709)	
σ = 100	2030-1750(3980-3700)		
σ = 120	2040-1740(3990-3690)		
σ = 160	2133-2066(4082-4015)	2050-1680(4000-3630)	
σ = 200	2182-2166(4131-4115)	2140-1640(4090-3590)	

RADIOCARBON AGE BP 3560 CALIBRATED AGE: cal BC 1908
cal BP 3857

Sample σ and cal BC(cal BP) ranges:

σ = 20	1941-1887(3890-3836)			
σ = 40	1964-1882(3913-3831)			
σ = 60	2019-2001(3968-3950)	1981-1877(3930-3826)	1835-1823(3784-3772)	1794-1787(3743-3736)
σ = 80	2032-1872(3981-3821)	1842-1777(3791-3726)		
σ = 100	2040-1760(3990-3710)			
σ = 120	2123-2080(4072-4029)	2040-1750(3990-3700)		
σ = 160	2140-1730(4090-3680)	1722-1696(3671-3645)		
σ = 200	2190-1680(4140-3630)			

Table 2-O

RADIOCARBON AGE BP 3580 CALIBRATED AGE: cal BC 1936
cal BP 3885

Sample σ and cal BC(cal BP) ranges:

σ = 20	1966-1904(3915-3853)		
σ = 40	2020-2001(3969-3950)	1981-1888(3930-3837)	
σ = 60	2032-1882(3981-3831)		
σ = 80	2037-1877(3986-3826)	1835-1823(3784-3772)	1794-1787(3743-3736)
σ = 100	2123-2080(4072-4029)	2040-1870(3990-3820)	1842-1777(3791-3726)
σ = 120	2133-2066(4082-4015)	2050-1760(4000-3710)	
σ = 160	2182-2166(4131-4115)	2140-1740(4090-3690)	
σ = 200	2200-1680(4150-3630)		

RADIOCARBON AGE BP 3600 CALIBRATED AGE: cal BC 1961
cal BP 3910

Sample σ and cal BC(cal BP) ranges:

σ = 20	2022-1999(3971-3948)	1982-1932(3931-3881)		
σ = 40	2032-1905(3981-3854)			
σ = 60	2037-1888(3986-3837)			
σ = 80	2124-2079(4073-4028)	2042-1883(3991-3832)		
σ = 100	2133-2065(4082-4014)	2050-1880(4000-3830)	1834-1824(3783-3773)	1794-1787(3743-3736)
σ = 120	2140-1870(4090-3820)	1842-1777(3791-3726)		
σ = 160	2200-1750(4150-3700)			
σ = 200	2278-2233(4227-4182)	2210-1730(4160-3680)	1722-1696(3671-3645)	

RADIOCARBON AGE BP 3620 CALIBRATED AGES: cal BC 2018, 2002, 1980
cal BP 3967, 3951, 3929

Sample σ and cal BC(cal BP) ranges:

σ = 20	2033-1954(3982-3903)			
σ = 40	2037-1934(3986-3883)			
σ = 60	2124-2079(4073-4028)	2042-1906(3991-3855)		
σ = 80	2133-2065(4082-4014)	2047-1888(3996-3837)		
σ = 100	2140-1880(4090-3830)			
σ = 120	2183-2166(4132-4115)	2140-1880(4090-3830)	1834-1824(3783-3773)	1794-1787(3743-3736)
σ = 160	2200-1760(4150-3710)			
σ = 200	2290-1740(4240-3690)			

RADIOCARBON AGE BP 3640 CALIBRATED AGE: cal BC 2032
cal BP 3981

Sample σ and cal BC(cal BP) ranges:

σ = 20	2096-2089(4045-4038)	2038-2015(3987-3964)	2005-1977(3954-3926)
σ = 40	2125-2079(4074-4028)	2042-1958(3991-3907)	
σ = 60	2133-2065(4082-4014)	2047-1935(3996-3884)	
σ = 80	2138-1907(4087-3856)		
σ = 100	2182-2166(4131-4115)	2140-1890(4090-3840)	
σ = 120	2200-1880(4150-3830)		
σ = 160	2278-2233(4227-4182)	2210-1870(4160-3820)	1842-1777(3791-3726)
σ = 200	2320-1750(4270-3700)		

Table 2-P

RADIOCARBON AGE BP 3660 CALIBRATED AGE: cal BC 2037
cal BP 3986

Sample σ and cal BC(cal BP) ranges:

σ = 20	2126-2078(4075-4027)	2043-2031(3992-3980)	
σ = 40	2133-2064(4082-4013)	2048-2017(3997-3966)	2004-1978(3953-3927)
σ = 60	2138-1959(4087-3908)		
σ = 80	2183-2166(4132-4115)	2142-1935(4091-3884)	
σ = 100	2200-1910(4150-3860)		
σ = 120	2200-1890(4150-3840)		
σ = 160	2290-1880(4240-3830)	1834-1824(3783-3773)	1794-1787(3743-3736)
σ = 200	2340-1760(4290-3710)		

RADIOCARBON AGE BP 3680 CALIBRATED AGES: cal BC 2123, 2080, 2042
cal BP 4072, 4029, 3991

Sample σ and cal BC(cal BP) ranges:

σ = 20	2134-2061(4083-4010)	2048-2036(3997-3985)	
σ = 40	2138-2031(4087-3980)		
σ = 60	2183-2165(4132-4114)	2143-2017(4092-3966)	2003-1979(3952-3928)
σ = 80	2195-1959(4144-3908)		
σ = 100	2200-1940(4150-3890)		
σ = 120	2279-2233(4228-4182)	2210-1910(4160-3860)	
σ = 160	2320-1880(4270-3830)		
σ = 200	2453-2423(4402-4372)	2400-1870(4350-3820)	1842-1777(3791-3726)

RADIOCARBON AGE BP 3700 CALIBRATED AGES: cal BC 2133, 2067, 2047
cal BP 4082, 4016, 3996

Sample σ and cal BC(cal BP) ranges:

σ = 20	2138-2119(4087-4068)	2082-2041(4031-3990)	
σ = 40	2184-2165(4133-4114)	2143-2036(4092-3985)	
σ = 60	2195-2031(4144-3980)		
σ = 80	2202-2017(4151-3966)	2003-1979(3952-3928)	
σ = 100	2279-2232(4228-4181)	2210-1960(4160-3910)	
σ = 120	2290-1940(4240-3890)		
σ = 160	2340-1890(4290-3840)		
σ = 200	2460-1880(4410-3830)	1834-1824(3783-3773)	1793-1787(3742-3736)

RADIOCARBON AGE BP 3720 CALIBRATED AGE: cal BC 2138
cal BP 4087

Sample σ and cal BC(cal BP) ranges:

σ = 20	2186-2164(4135-4113)	2143-2132(4092-4081)	2071-2046(4020-3995)
σ = 40	2195-2121(4144-4070)	2081-2041(4030-3990)	
σ = 60	2202-2036(4151-3985)		
σ = 80	2279-2232(4228-4181)	2209-2031(4158-3980)	
σ = 100	2290-2020(4240-3970)	2003-1979(3952-3928)	
σ = 120	2320-1960(4270-3910)		
σ = 160	2453-2423(4402-4372)	2400-1910(4350-3860)	
σ = 200	2460-1880(4410-3830)		

Table 2-Q

RADIOCARBON AGE BP 3740 CALIBRATED AGES: cal BC 2181, 2166, 2142
cal BP 4130, 4115, 4091

Sample σ and cal BC(cal BP) ranges:

σ = 20	2196-2137(4145-4086)		
σ = 40	2202-2132(4151-4081)	2069-2047(4018-3996)	
σ = 60	2279-2232(4228-4181)	2209-2122(4158-4071)	2081-2042(4030-3991)
σ = 80	2289-2037(4238-3986)		
σ = 100	2320-2030(4270-3980)		
σ = 120	2340-2020(4290-3970)	2003-1979(3952-3928)	
σ = 160	2460-1940(4410-3890)		
σ = 200	2470-1890(4420-3840)		

RADIOCARBON AGE BP 3760 CALIBRATED AGES: cal BC 2195, 2156, 2147
cal BP 4144, 4105, 4096

Sample σ and cal BC(cal BP) ranges:

σ = 20	2203-2142(4152-4091)	
σ = 40	2279-2232(4228-4181)	2209-2137(4158-4086)
σ = 60	2289-2133(4238-4082)	2068-2047(4017-3996)
σ = 80	2317-2122(4266-4071)	2081-2042(4030-3991)
σ = 100	2340-2040(4290-3990)	
σ = 120	2453-2423(4402-4372)	2400-2030(4350-3980)
σ = 160	2460-1960(4410-3910)	
σ = 200	2470-1910(4420-3860)	

RADIOCARBON AGE BP 3780 CALIBRATED AGE: cal BC 2202
cal BP 4151

Sample σ and cal BC(cal BP) ranges:

σ = 20	2279-2231(4228-4180)	2210-2194(4159-4143)	2158-2146(4107-4095)
σ = 40	2289-2180(4238-4129)	2167-2142(4116-4091)	
σ = 60	2318-2137(4267-4086)		
σ = 80	2344-2133(4293-4082)	2068-2047(4017-3996)	
σ = 100	2453-2423(4402-4372)	2400-2120(4350-4070)	2080-2042(4029-3991)
σ = 120	2460-2040(4410-3990)		
σ = 160	2470-2020(4420-3970)	2002-1980(3951-3929)	
σ = 200	>2490-1940(>4440-3890)		

RADIOCARBON AGE BP 3800 CALIBRATED AGES: cal BC 2278, 2233, 2209
cal BP 4227, 4182, 4158

Sample σ and cal BC(cal BP) ranges:

σ = 20	2290-2201(4239-4150)	
σ = 40	2320-2194(4269-4143)	2157-2146(4106-4095)
σ = 60	2344-2180(4293-4129)	2167-2142(4116-4091)
σ = 80	2453-2423(4402-4372)	2399-2137(4348-4086)
σ = 100	2460-2130(4410-4080)	2068-2047(4017-3996)
σ = 120	2460-2120(4410-4070)	2080-2042(4029-3991)
σ = 160	2470-2030(4420-3980)	
σ = 200	>2490-1960(>4440-3910)	

TABLE 2-R

RADIOCARBON AGE BP 3820   CALIBRATED AGE: cal BC 2288
cal BP 4237

Sample o and cal BC(cal BP) ranges:
o = 20   2325-2276(4274-4225) 2238-2207(4187-4156)
o = 40   2345-2201(4294-4150)
o = 60   2453-2422(4402-4371) 2399-2194(4348-4143) 2157-2147(4106-4096)
o = 80   2458-2180(4407-4129) 2167-2142(4116-4091)
o = 100   2460-2140(4410-4090)
o = 120   2470-2130(4420-4080) 2068-2047(4017-3996)
o = 160   >2490-2040(>4440-3990)
o = 200   >2490-2020(>4440-3970) 2003-1979(3952-3928)

RADIOCARBON AGE BP 3840   CALIBRATED AGE: cal BC 2316
cal BP 4265

Sample o and cal BC(cal BP) ranges:
o = 20   2347-2286(4296-4235)
o = 40   2454-2422(4403-4371) 2400-2277(4349-4226) 2236-2208(4185-4157)
o = 60   2458-2201(4407-4150)
o = 80   2462-2194(4411-4143) 2157-2147(4106-4096)
o = 100   2470-2180(4420-4130) 2166-2142(4115-4091)
o = 120   2470-2140(4420-4090)
o = 160   >2490-2120(>4440-4070) 2080-2042(4029-3991)
o = 200   >2490-2030(>4440-3980)

RADIOCARBON AGE BP 3860   CALIBRATED AGE: cal BC 2343
cal BP 4292

Sample o and cal BC(cal BP) ranges:
o = 20   2454-2421(4403-4370) 2401-2309(4350-4258)
o = 40   2458-2287(4407-4236)
o = 60   2462-2278(4411-4227) 2235-2208(4184-4157)
o = 80   2466-2201(4415-4150)
o = 100   2470-2190(4420-4140) 2157-2147(4106-4096)
o = 120   >2490-2180(>4440-4130) 2166-2142(4115-4091)
o = 160   >2490-2130(>4440-4080) 2067-2047(4016-3996)
o = 200   >2490-2040(>4440-3990)

RADIOCARBON AGE BP 3880   CALIBRATED AGES: cal BC 2453, 2423, 2398
cal BP 4402, 4372, 4347

Sample o and cal BC(cal BP) ranges:
o = 20   2458-2340(4407-4289)
o = 40   2462-2311(4411-4260)
o = 60   2466-2288(4415-4237)
o = 80   2471-2278(4420-4227) 2234-2208(4183-4157)
o = 100   >2490-2200(>4440-4150)
o = 120   >2490-2190(>4440-4140) 2157-2147(4106-4096)
o = 160   >2490-2140(>4440-4090)
o = 200   >2490-2120(>4440-4070) 2080-2042(4029-3991)

TABLE 2-S

RADIOCARBON AGE BP 3900   CALIBRATED AGE: cal BC 2457
cal BP 4406

Sample o and cal BC(cal BP) ranges:
o = 20   2462-2452(4411-4401) 2426-2396(4375-4345)
o = 40   2466-2342(4415-4291)
o = 60   2471-2313(4420-4262)
o = 80   >2490-2288(>4439-4237)
o = 100   >2490-2280(>4440-4230) 2234-2209(4183-4158)
o = 120   >2490-2200(>4440-4150)
o = 160   >2490-2180(>4440-4130) 2166-2142(4115-4091)
o = 200   >2490-2130(>4440-4080) 2067-2047(4016-3996)

RADIOCARBON AGE BP 3920   CALIBRATED AGE: cal BC 2462
cal BP 4411

Sample o and cal BC(cal BP) ranges:
o = 20   2466-2457(4415-4406) 2411-2409(4360-4358)
o = 40   2472-2453(4421-4402) 2425-2397(4374-4346)
o = 60   >2490-2342(>4439-4291)
o = 80   >2490-2314(>4439-4263)
o = 100   >2490-2290(>4440-4240)
o = 120   >2490-2280(>4440-4230) 2234-2209(4183-4158)
o = 160   >2490-2190(>4440-4140) 2157-2147(4106-4096)
o = 200   >2490-2140(>4440-4090)

RADIOCARBON AGE BP 3940   CALIBRATED AGE: cal BC 2466
cal BP 4415

Sample o and cal BC(cal BP) ranges:
o = 20   2474-2461(4423-4410)
o = 40   >2490-2457(>4439-4406)
o = 60   >2490-2453(>4439-4402) 2424-2398(4373-4347)
o = 80   >2490-2342(>4439-4291)
o = 100   >2490-2310(>4440-4260)
o = 120   >2490-2290(>4440-4240)
o = 160   >2490-2200(>4440-4150)
o = 200   >2490-2180(>4440-4130) 2166-2142(4115-4091)

RADIOCARBON AGE BP 3960   CALIBRATED AGE: cal BC 2470
cal BP 4419

Sample o and cal BC(cal BP) ranges:
o = 20   >2490-2465(>4439-4414)
o = 40   >2490-2461(>4439-4410)
o = 60   >2490-2457(>4439-4406)
o = 80   >2490-2453(>4439-4402) 2424-2398(4373-4347)
o = 100   >2490-2340(>4440-4290)
o = 120   >2490-2310(>4440-4260)
o = 160   >2490-2280(>4440-4230) 2234-2209(4183-4158)
o = 200   >2490-2190(>4440-4140) 2157-2147(4106-4096)

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HIGH-PRECISION DECADAL CALIBRATION OF THE RADIOCARBON TIME SCALE, AD 1950–2500 BC

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INTRODUCTION

The radiocarbon ages of dendrochronologically dated wood samples, each covering 10 years, are reported back to 2500 yr BC. The decadal calibration curve constructed from these data is an extension of the curve previously given for the AD interval (Stuiver, 1982). A major difference with the previous work, however, is the assessment of the error in the radiocarbon age determination. Whereas previously this error was only based on the Poisson counting statistics of the accumulated number of counts for the sample and standards, the current calibration error is based on an estimate of the reproducibility in the radiocarbon activity determination. As a consequence, the uncertainty in the current calibration curve is, on average, 1.6 times that of the AD curve previously given.

The radiocarbon ages obtained for the decadal wood samples (Fig 1 and Table 1) were used for the construction of the bi-decadal calibration curves also reported in this issue (Stuiver & Pearson, 1986; Pearson & Stuiver, 1986). Because the average ^{14}C age of a bi-decadal wood sample is determined from one 20-yr determination by the Belfast laboratory, and from two 10-yr determinations of the Seattle laboratory, the resulting bi-decadal calibration curve is more precisely defined than the decadal curve published here. For most purposes, therefore, the internationally recommended bi-decadal curves should be used. However, the decadal curve is important when investigators are interested in the fine structure of ^{14}C age calibration of samples formed during a short interval (*ie*, <2 decades).

DENDROCHRONOLOGY AND SAMPLE TREATMENT

The trees used for the AD interval were either Douglas Fir (Pseudotsuga menziesii) from the US Pacific Northwest, or Sequoia (*Sequioadendron giganteum*) from California. The dendrochronologic work on these materials is summarized in Table 2, and in Stuiver (1982) and Stuiver and Pearson (1986). Nearly all the BC material was dendro-dated by one of the authors (Becker, 1983). A limited number of samples from the Irish Oak chronology (Pilcher *et al*, 1984) was used near 500 BC.

Table 2 also lists the type of wood pretreatment. The de Vries method (Stuiver & Quay, 1980) was used for most of the AD wood samples, whereas alpha cellulose (Stuiver, Burk & Quay, 1984) was prepared for samples covering the BC interval. The de Vries method does not remove all components added after the year of growth, but our measurements show the influence of incomplete removal of late additions to be limited to 2 or 3 ^{14}C years (Stuiver & Quay, 1981).

TECHNIQUE AND LABORATORY REPRODUCIBILITY

The ^{14}C community has traditionally been satisfied with reporting age errors based on counting statistics alone. This clearly was an unwise choice as interlaboratory comparisons of results obtained for the same samples show substantial under-reporting of the ^{14}C age errors (International Study Group, 1982; Stuiver, 1982).

Repeat analyses of samples with ^{14}C ages <4000 yr yield an error for the Seattle laboratory equal to 1.6 times the Poisson counting error (Stuiver, 1982; Stuiver & Pearson, 1986). This 1.6 "error multiplier" is only valid for the age ranges given in this paper, and should not be applied to all samples measured in the Seattle laboratory (Stuiver, Pearson & Braziunas, 1986). The error reported with the ^{14}C ages in Table 1 is the actual reproducibility standard deviation. Suitable proof that this standard deviation indeed accounts for the entire uncertainty in the measuring process was derived from a comparison with the ^{14}C ages obtained by the Belfast laboratory (Pearson *et al*, 1986) on contemporaneous wood. The differences in ^{14}C ages of 214 sample pairs (Stuiver & Pearson, 1986, Fig 3) are fully compatible with the quoted errors of the Seattle and Belfast laboratories. Similar agreement is obtained when subdiving the paired samples of the AD 1950–2500 BC period in AD and BC intervals (Figs 2 and 3), and by comparing Belfast Irish Oak results with Seattle German Oak results (Fig 4). Four CO_2 gas proportional counters (Stuiver, Robinson & Yang, 1979) were used for the ^{14}C activity determinations. The counter volumes are ca 4L; when operated at a filling pressure of 3.0 to 3.5 atmospheres the count rates for 'old' NBS oxalic acid are 90 to 100 counts per minute. Background count rates are 1.5 to 2.5 counts per minute, depending on the counter.

SYSTEMATIC DIFFERENCES BETWEEN LABORATORIES

Systematic ^{14}C age differences are discussed in Stuiver (1982); Stuiver and Pearson (1986) and Stuiver *et al* (1986). It was shown that systematic offsets of the Seattle data are limited to a few years for the age ranges discussed here, and that ^{14}C ages of wood of the same age from Ireland, south Germany, and the northwest United States differed, on average, by a few years only. Thus, although our curves are based on wood from trees of different regions, identical results would have been obtained if all measurements had been made on one tree from one locality.

CALIBRATION INSTRUCTIONS

The calibration instructions are similar to those given in Stuiver and Pearson (1986) and Pearson and Stuiver (1986) and are repeated here. The Figure 1 calibration curves consist of three lines. The center line is the actual calibration curve whereas the outer lines indicate the one sigma (standard deviation) uncertainty in the calibration curve. The calibration curve depicts the (non-linear) transformation of ^{14}C ages to calibrated AD/BC (or BP) ages. The nomenclature adopted for the dendro (calendar) year time scale is cal AD/BC or cal BP. The cal AD/BC ages are plotted along the lower horizontal axis and the cal BP ages along the upper one.

Cal BP ages are relative to the year AD 1950, with 0 cal BP equal to AD 1950. The relationship between cal AD/BC and cal BP ages is simple: cal BP = 1950 − cal AD, and cal BP = 1949 + cal BC. The switch from 1950 to 1949 when converting BC ages is caused by the absence of the zero year in the AD/BC chronology (when progressing from 1 BC to AD 1, the cal BP ages should be without a gap).

The conversion of a ^{14}C age to cal age is straightforward: 1) draw a horizontal (parallel to the bottom axis) line (A) through the ^{14}C age to be converted, and 2) draw vertical lines through the intercept(s) of line A and the calibration curve (center line). The cal AD/BC ages can be read at the bottom axis, the cal BP ages at the top. A single ^{14}C age can correspond with multiple cal ages, due to past changes in atmospheric ^{14}C levels (see Stuiver, 1982 for illustration).

The user has to determine the calibrated ages from the Figure 1 graphs by drawing lines. An alternate approach is the use of Table 3, where the cal ages are listed for ^{14}C ages that increase by 20-year steps. Obviously the user has to interpolate between the 20-yr steps of ^{14}C ages and sigmas if further fine tuning is desired.

The conversion of the standard error in the ^{14}C age into a range of cal AD/BC (BP) ages is more complicated. The user should first determine whether he/she wants to use 1) the laboratory quoted error (see Stuiver & Pearson, 1986 for a discussion) or 2) increase the quoted error by a known "error multiplier." Once the sample σ has been targeted, the curve σ (one standard deviation) should be read from the calibration curve by taking the difference in ^{14}C years between center curve and outer curve(s) in Figure 1. The curve σ should then be used to calculate total

$$\sigma = \sqrt{(\text{sample } \sigma)^2 + (\text{curve } \sigma)^2}$$

(Stuiver, 1982).

Horizontal lines should now be drawn through the ^{14}C age + total σ, and ^{14}C age − total σ value. The vertical lines, drawn through the intercepts with the CENTRAL curve, yield the outer limits of possible cal AD/BC (or BP) ages that are compatible with the sample standard deviation.

The above procedure was used to derive the "ranges" of cal AD/BC (BP) ages listed in Table 3.

The conversion procedure yields 1) single or multiple cal AD/BC (BP) ages that are compatible with a certain ^{14}C age, and 2) the range(s) of cal ages that corresponds to the standard deviation in the ^{14}C age. The probability that a certain cal age is the actual sample age may be quite variable within the cal age range. Higher probabilities are encountered around the intercept ages. Low, or near zero probabilities are encountered when part of the calibration curve 'snakes' outside the total σ boundaries. The non-linear transform of a Gaussian standard deviation around a ^{14}C age into cal AD/BC (BP) ages leads to a very complex probability distribution that can only be calculated with the aid of computers. We are currently developing suitable programs for these probability calculations, and plan to make these programs available in the near future.

The calibration data presented in this paper are to be used for samples formed in isotopic (^{14}C) equilibrium with atmospheric CO_2. Although the wood samples were collected from specific regions (Ireland, Germany and western USA) the calibration data can be used for a large part of the Northern Hemisphere (Stuiver, 1982). However, systematic age differences are possible for Southern Hemispheric samples where ^{14}C ages of wood samples tend to be approximately 30 years older (Lerman, Mook & Vogel, 1970; Vogel, Fuls & Visser, 1986). Thus, ^{14}C ages of Southern Hemispheric samples should be reduced by 30 years before being converted into a cal AD/BC (BP) age.

MARINE SAMPLE AGES

The calibration curves should be applied only for age conversion of samples that were formed in equilibrium with atmospheric CO_2. Conventional ^{14}C ages of materials not in equilibrium with atmospheric reservoirs do not take into account the off-set in ^{14}C age that may occur (Stuiver & Polach, 1977). This off-set, or reservoir deficiency, has to be deducted from the reported ^{14}C age before any attempt can be made to convert to cal AD/BC (BP) ages. The reservoir deficiency is time-dependent for the mixed layer of the ocean. Model calculated calibration curves for marine samples are listed separately in this volume (Stuiver, Pearson & Braziunas, 1986). This paper also contains a plot of the Table 1 Δ ^{14}C values.

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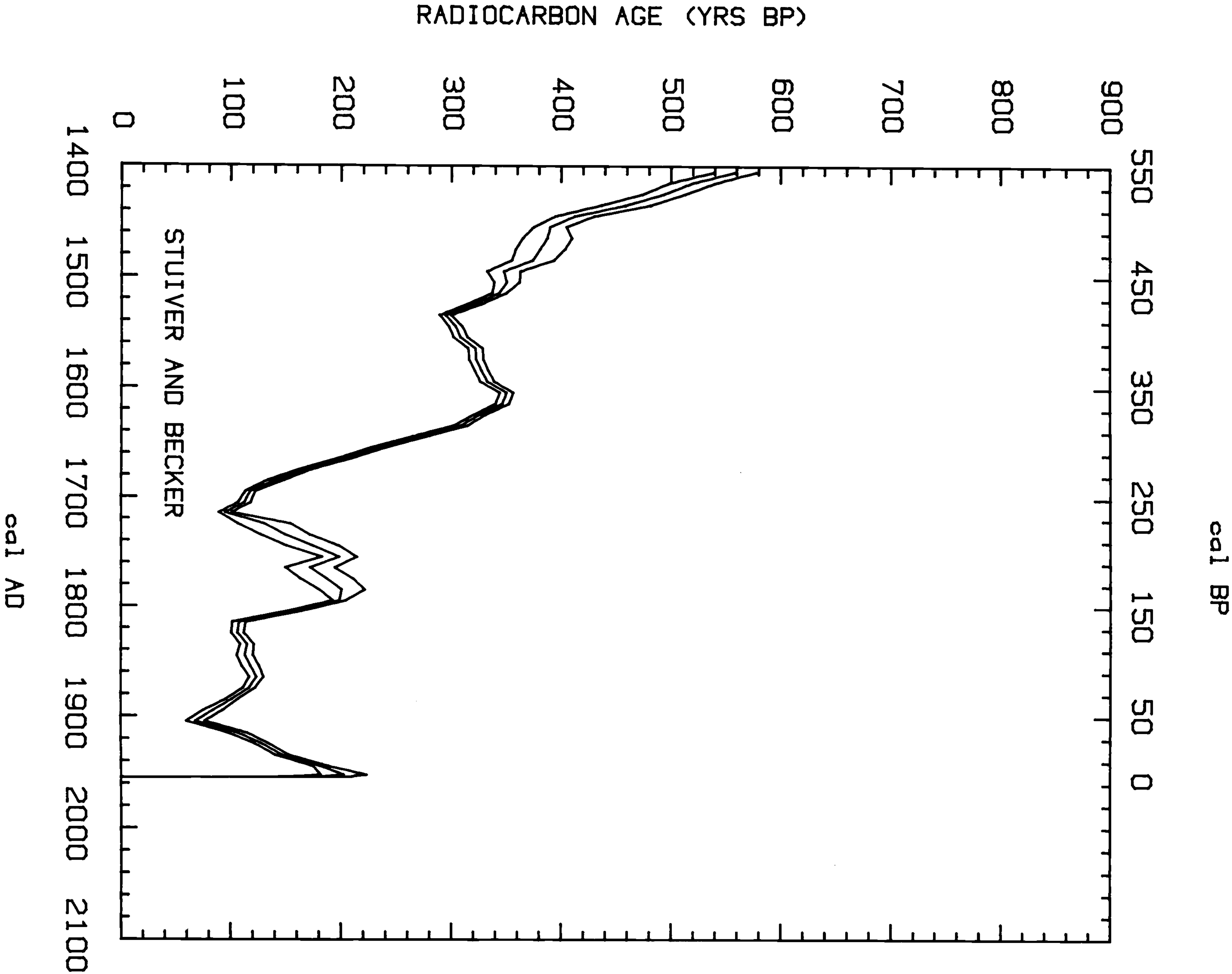
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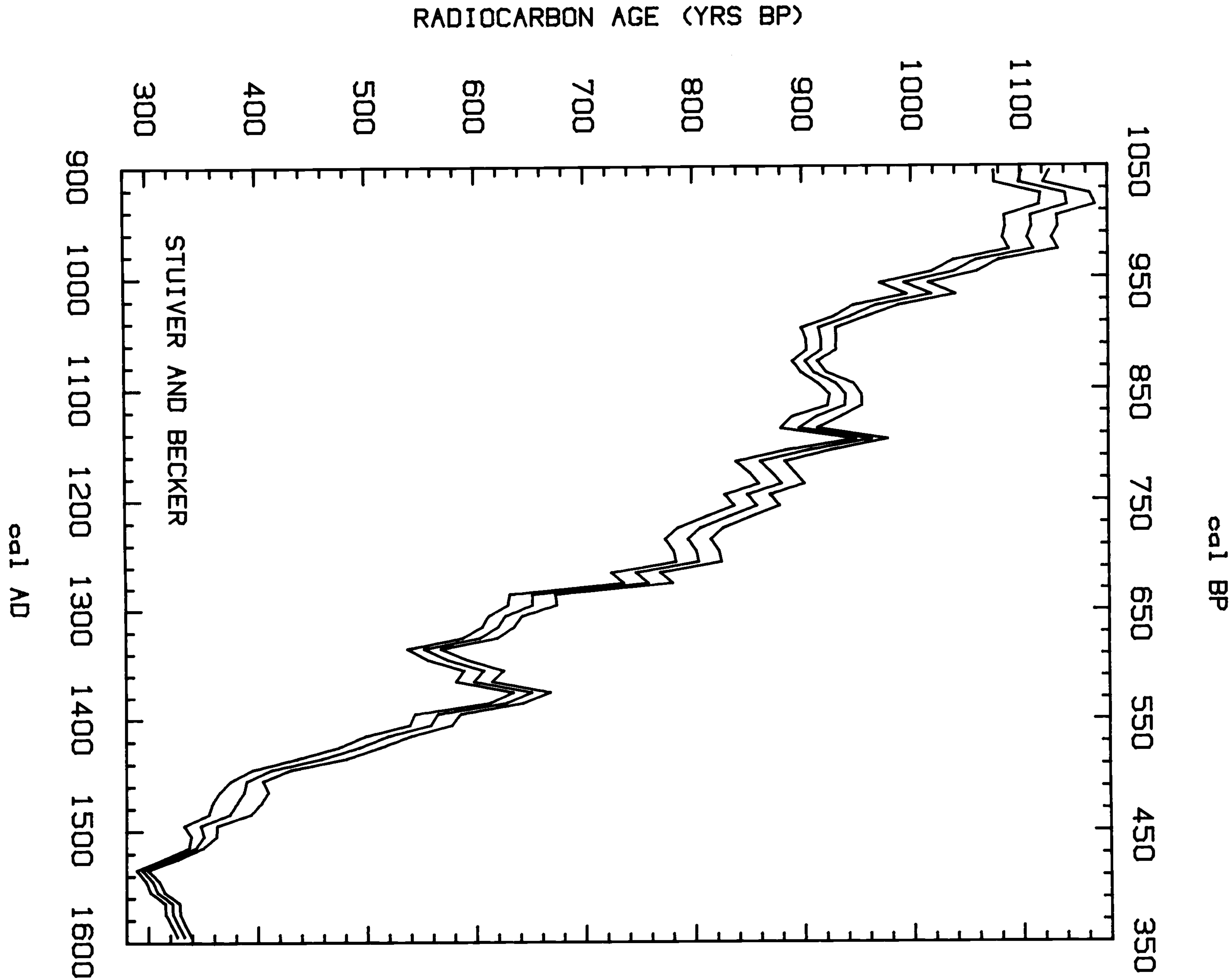
0
100
200
300
400
500
600
700
800
900
cal BP
550
450
350
250
150
50
0
STUIVER AND BECKER
cal AD
1400
1500
1600
1700
1800
1900
2000
2100
Fig 1A



RADIOCARBON AGE (YRS BP)
300
400
500
600
700
800
900
1000
1100
cal BP
1050
950
850
750
650
550
450
350
STUIVER AND BECKER
900
1000
1100
1200
1300
1400
1500
1600
cal AD

Fig 1B

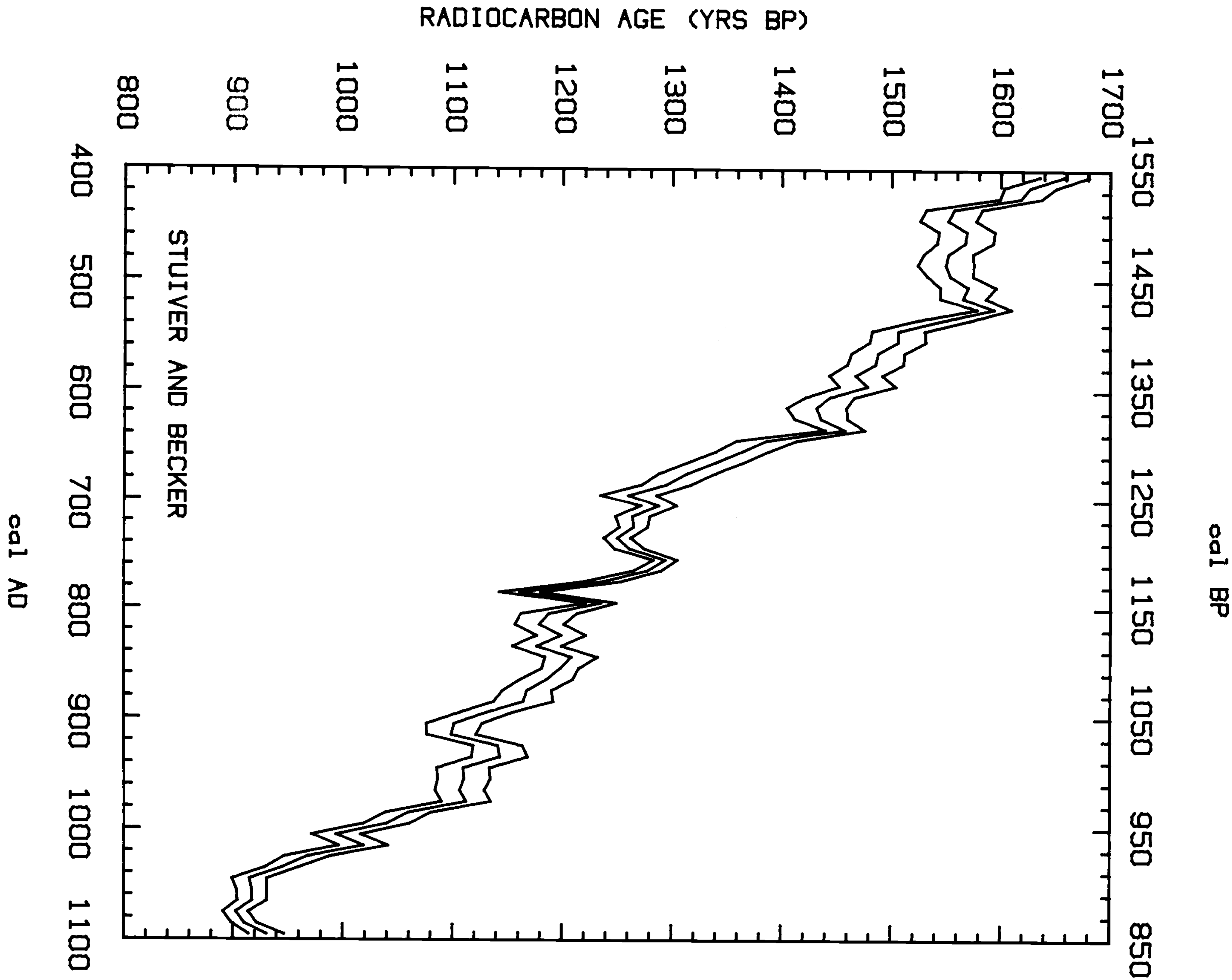
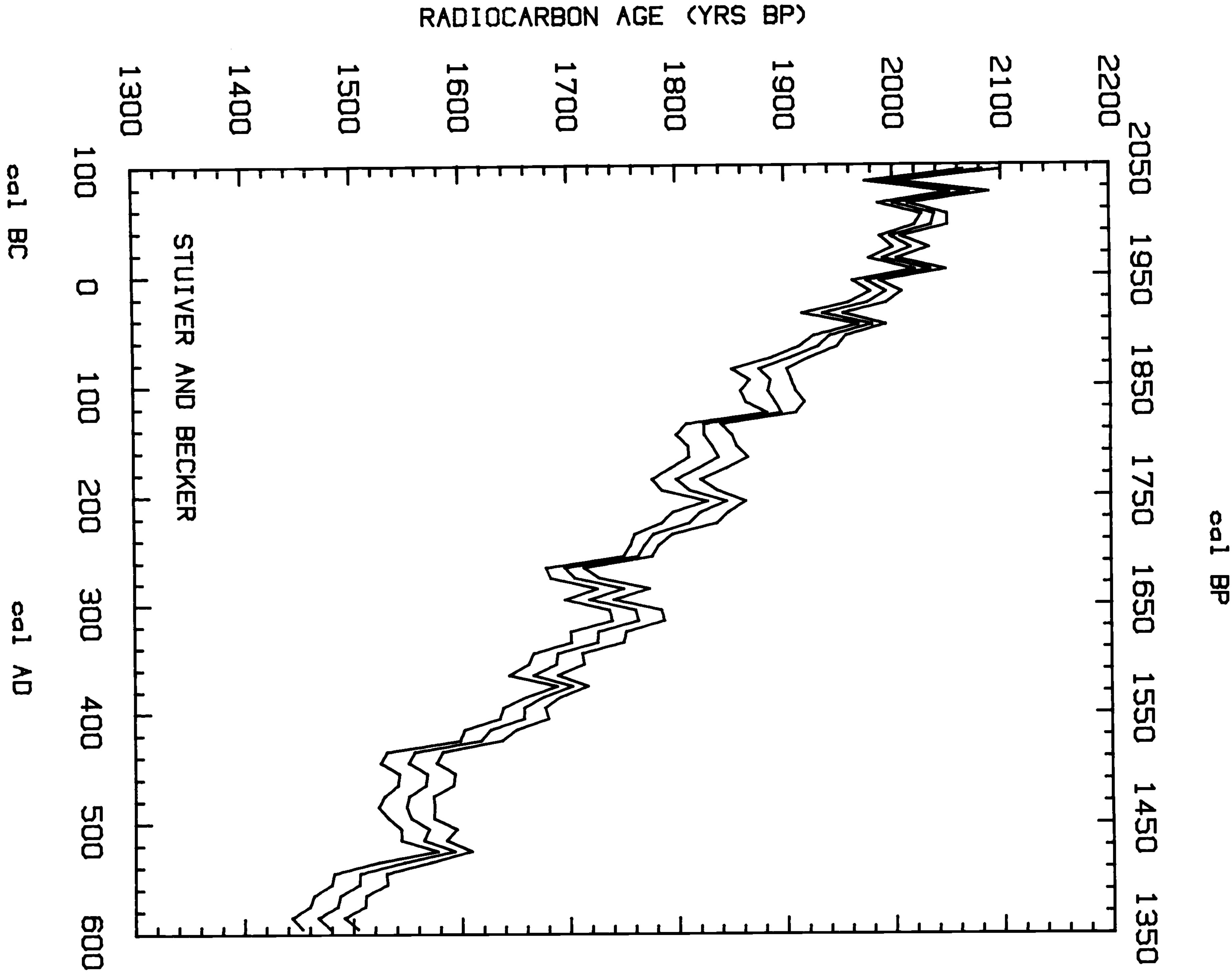
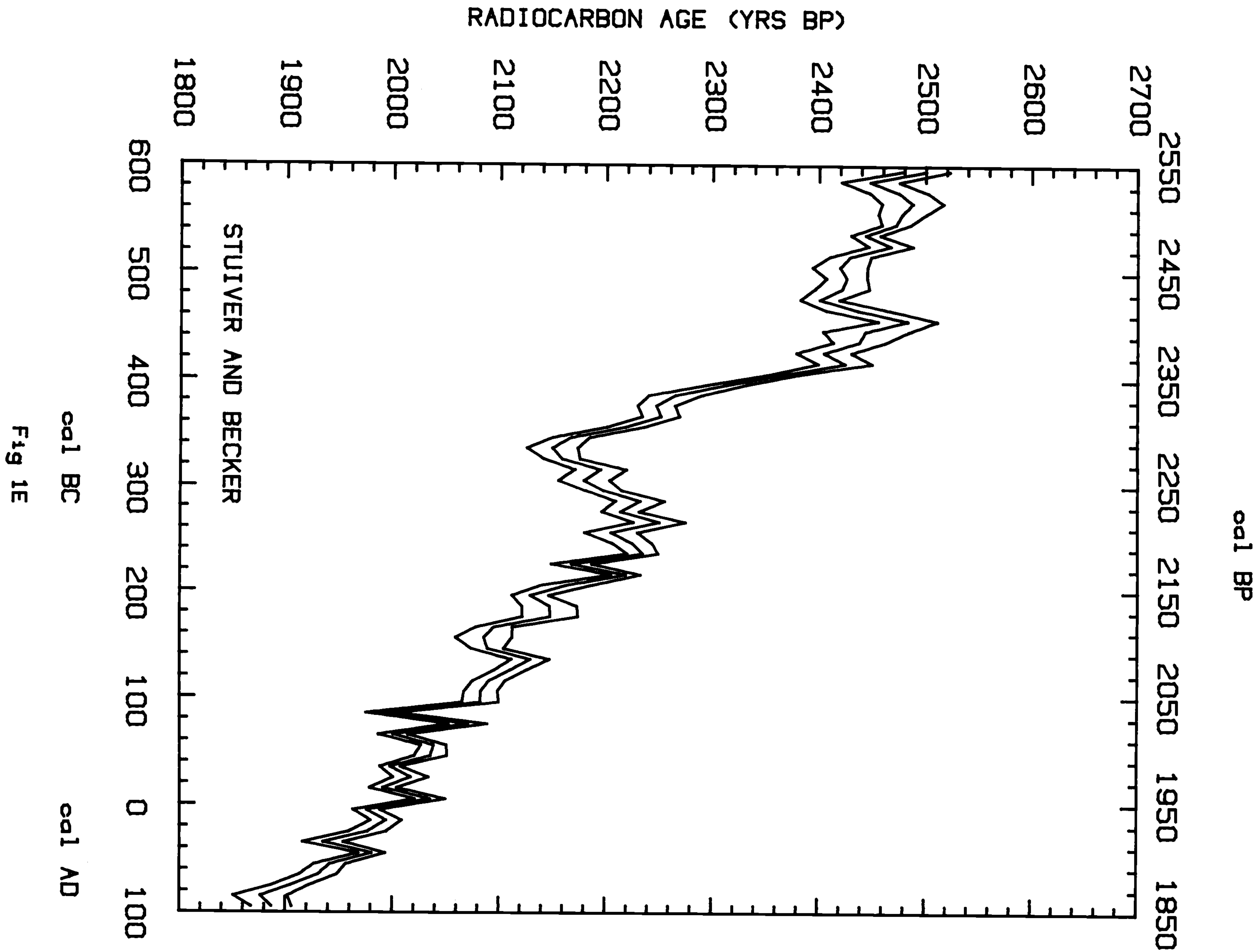

RADIOCARBON AGE (YRS BP)
1700
1600
1500
1400
1300
1200
1100
1000
900
800
1550
1450
1350
1250
1150
1050
950
850
cal BP
400
500
600
700
800
900
1000
1100
STUIVER AND BECKER
cal AD

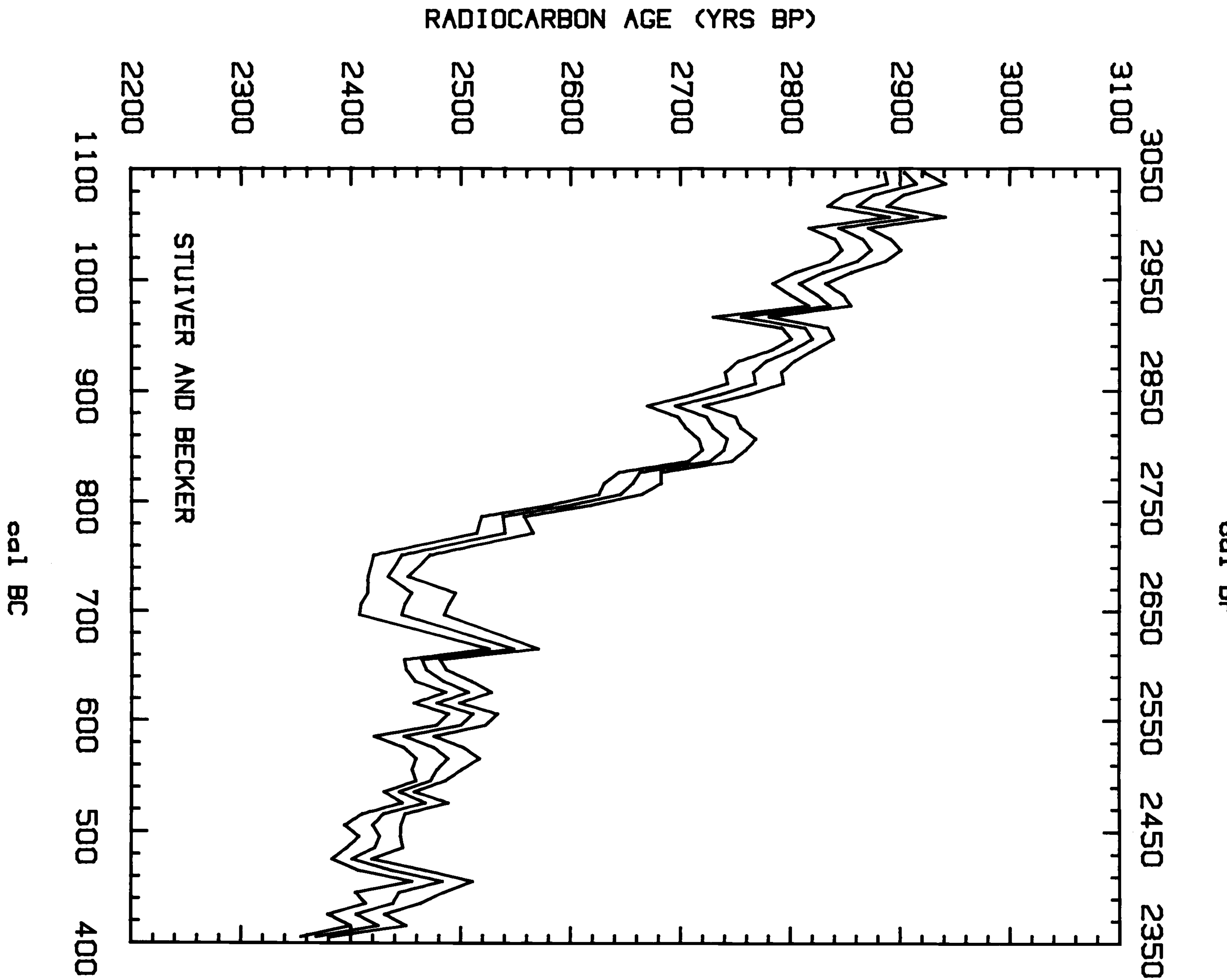
Fig 1C



RADIOCARBON AGE (YRS BP)
cal BP
cal BC
cal AD
STUIVER AND BECKER

Fig 1D


RADIOCARBON AGE (YRS BP)
cal BP
cal BC
cal AD
STUIVER AND BECKER
Fig 1E


RADIOCARBON AGE (YRS BP)
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2300
2400
2500
2600
2700
2800
2900
3000
3100
cal BP
3050
2950
2850
2750
2650
2550
2450
2350
cal BC
1100
1000
900
800
700
600
500
400
STUIVER AND BECKER

Fig 1F

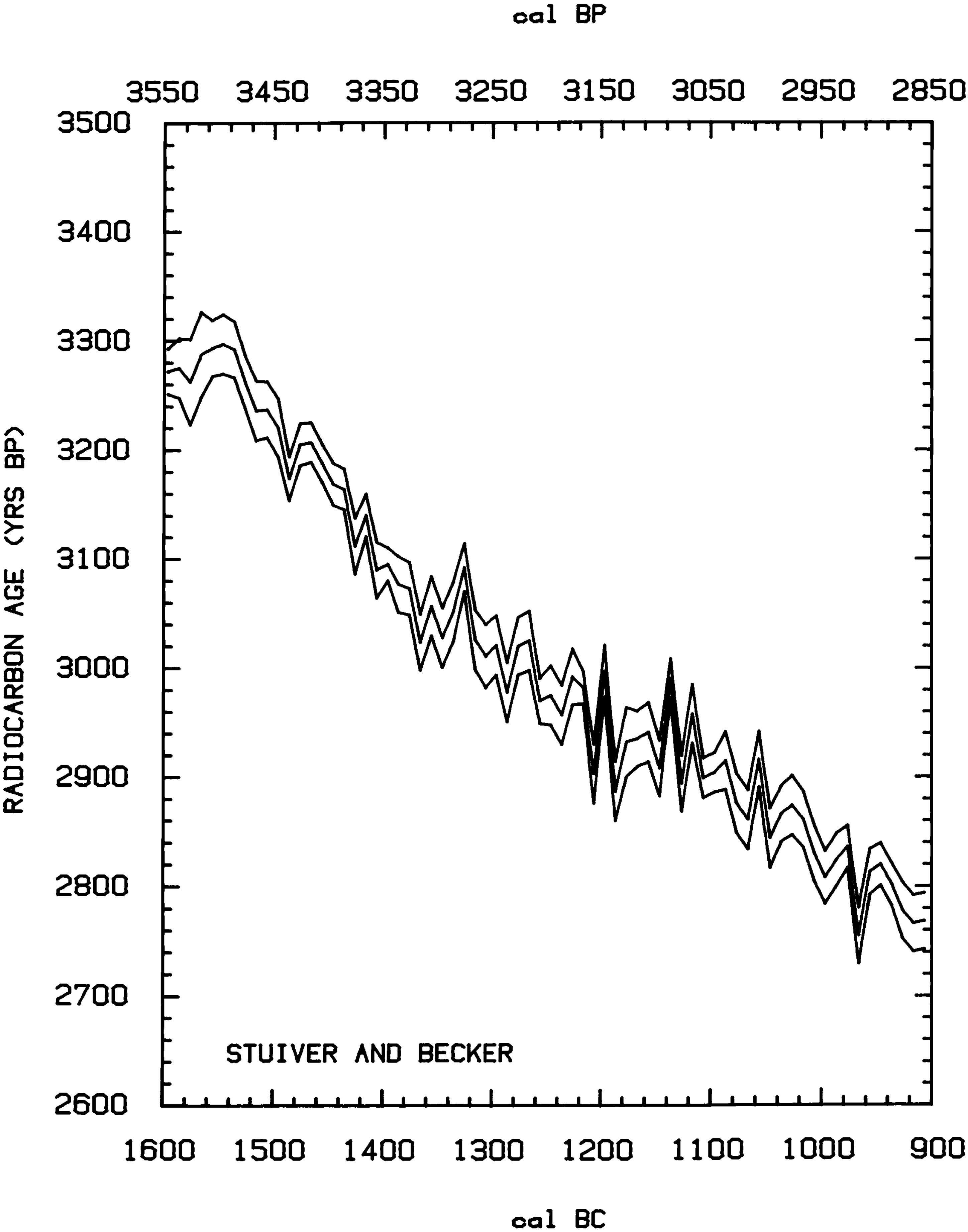

cal BP
3550
3450
3350
3250
3150
3050
2950
2850
RADIOCARBON AGE (YRS BP)
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
STUIVER AND BECKER
1600
1500
1400
1300
1200
1100
1000
900
cal BC

Fig 1G

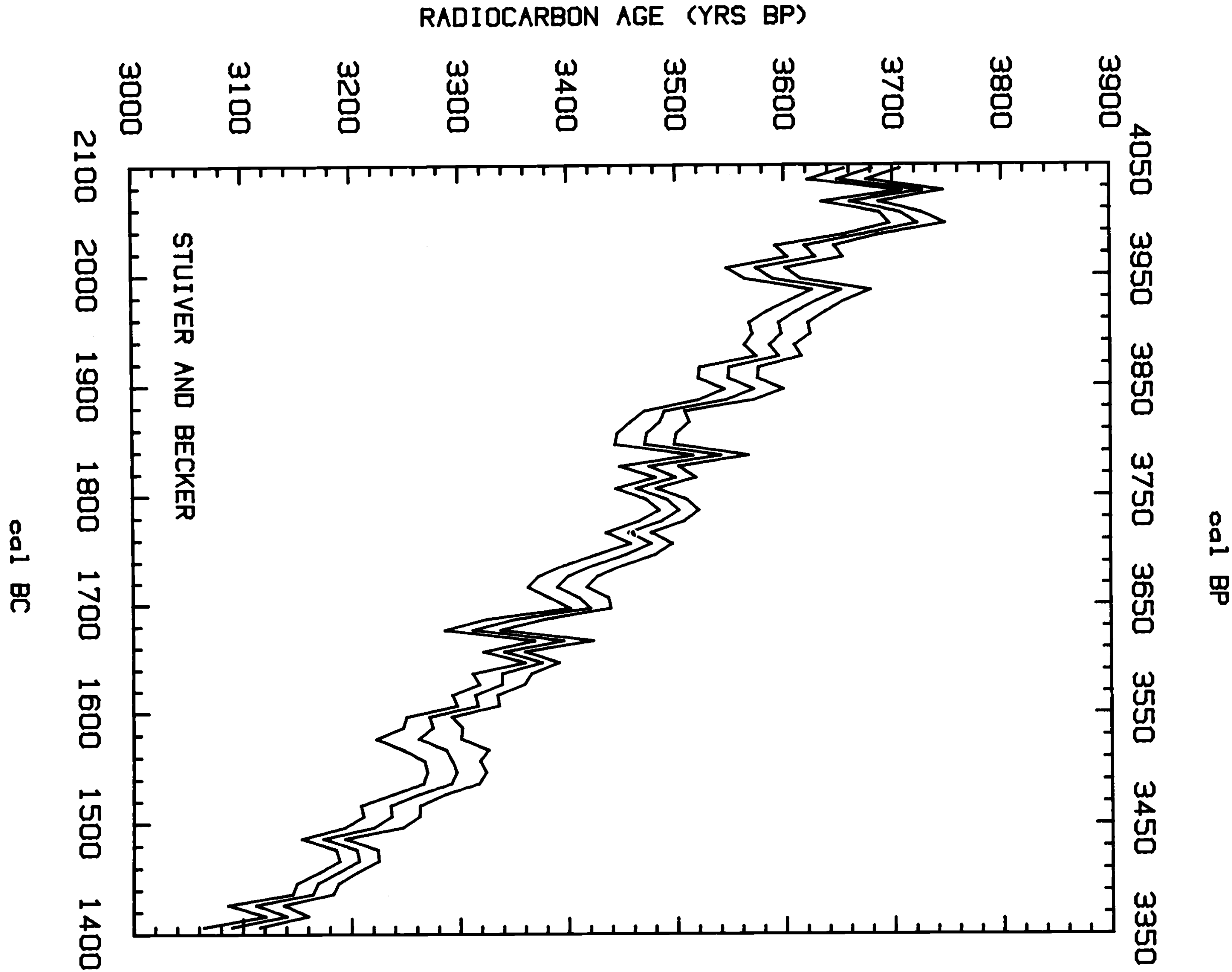

RADIOCARBON AGE (YRS BP)
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
cal BP
4050
3950
3850
3750
3650
3550
3450
3350
cal BC
2100
2000
1900
1800
1700
1600
1500
1400
STUIVER AND BECKER

Fig 1H

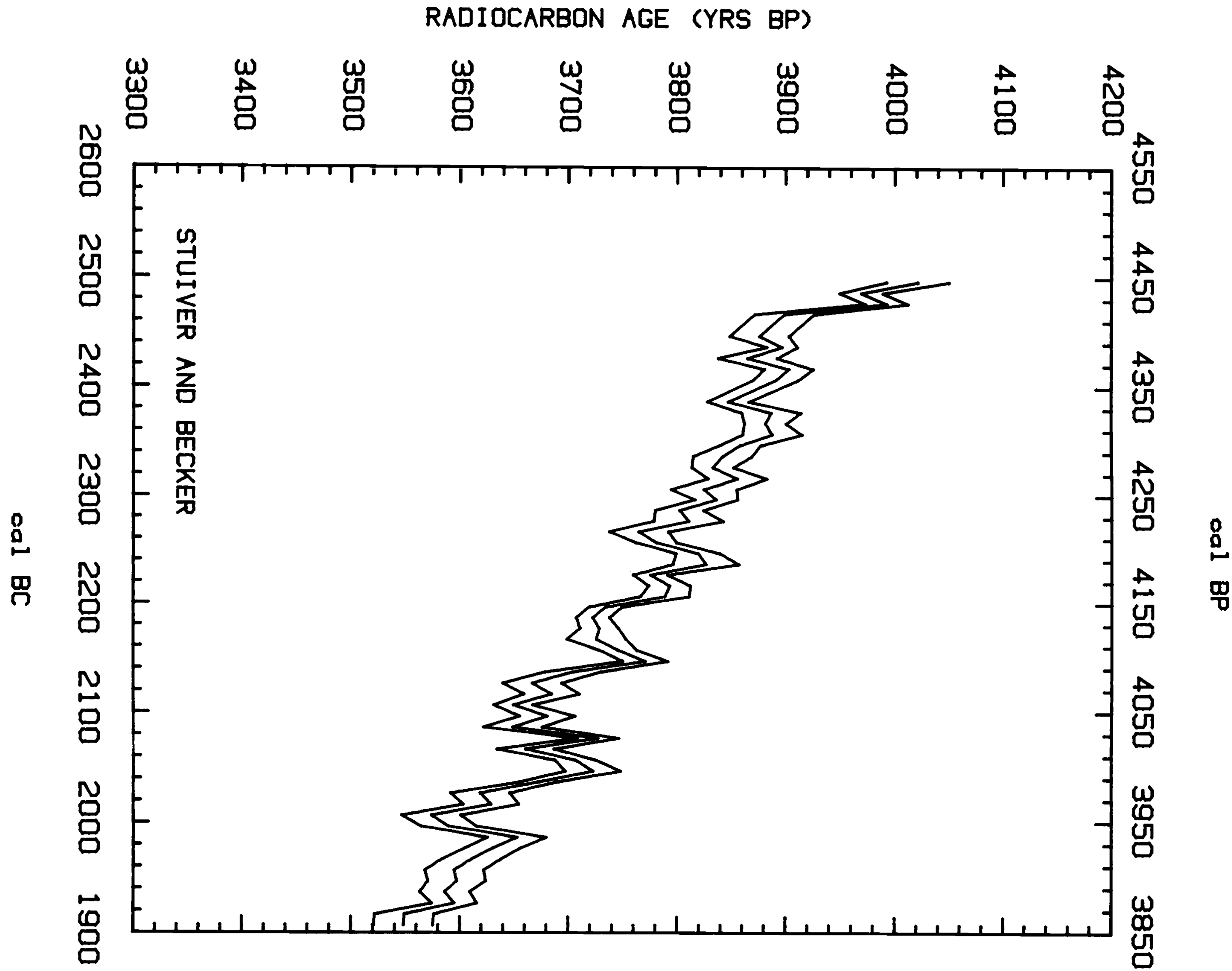

RADIOCARBON AGE (YRS BP)
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
4550
4450
4350
4250
4150
4050
3950
3850
cal BP
2600
2500
2400
2300
2200
2100
2000
1900
cal BC
STUIVER AND BECKER

Fig 11

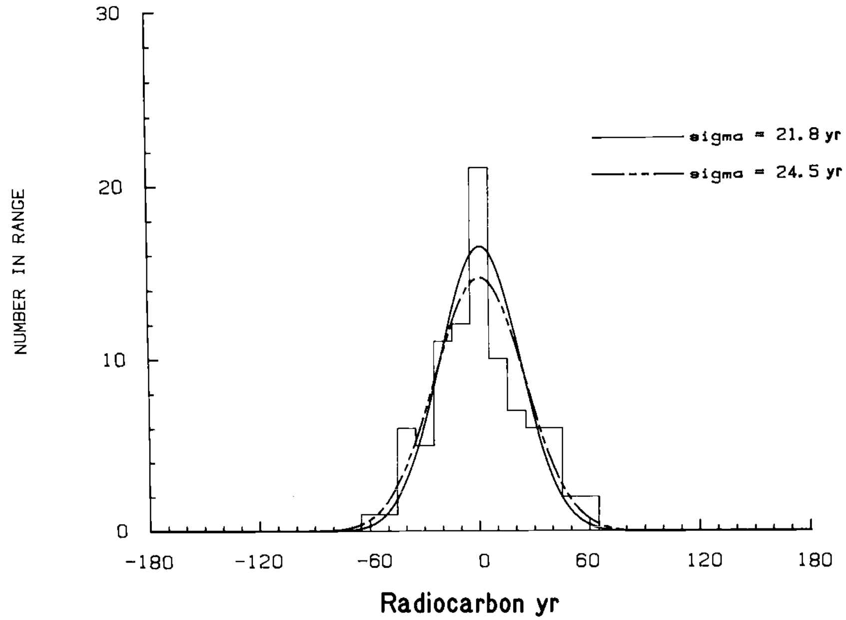


Fig 2. The distribution of ^{14}C age differences of contemporaneous sample pairs measured in Belfast and Seattle. All pairs are from the AD interval. Based on the laboratory precisions, the expected standard deviation is 21.8 yr, actual standard deviation is 24.5 yr.

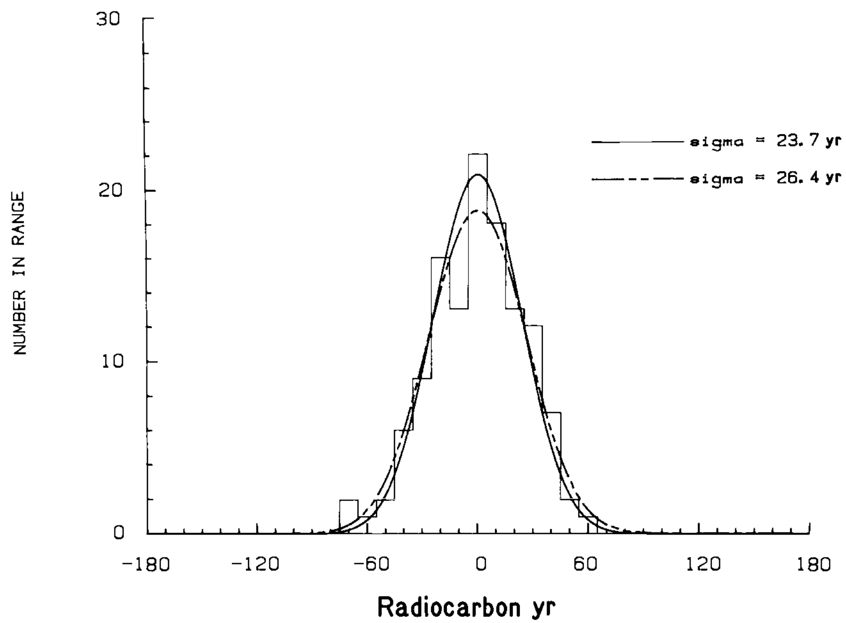


Fig 3. The distribution of ^{14}C age differences of contemporaneous sample pairs measured in Belfast and Seattle. All pairs are from the BC interval. The expected standard deviation, based on the precision quoted by the laboratories, is 23.7 yr. Actual standard deviation is 26.4 yr.

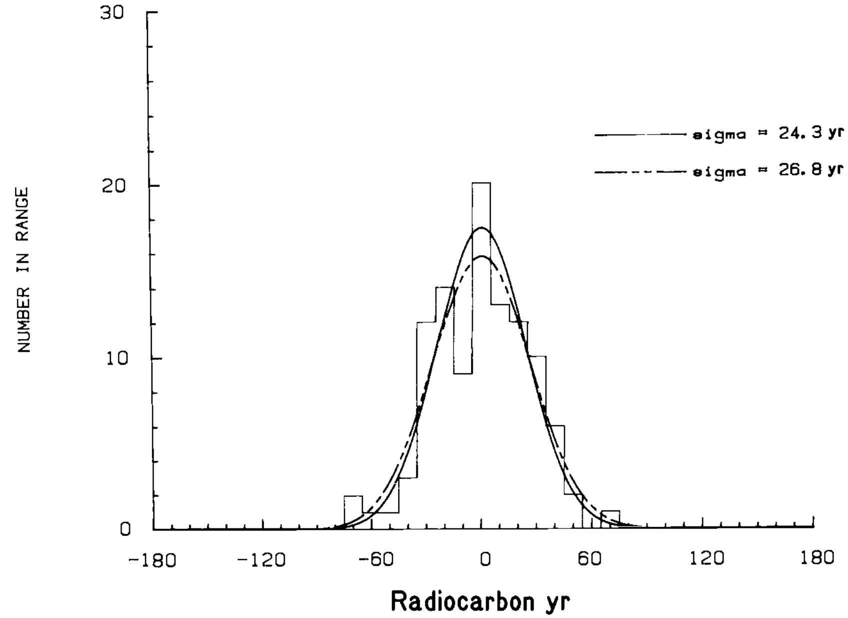


Fig 4. The distribution of ^{14}C age differences of contemporaneous sample pairs measured in Belfast (Irish Oak) and Seattle (South German Oak). Based on the laboratory precisions, the expected standard deviation in the age differences is 24.3 yr, actual standard deviation is 26.8 yr.

TABLE 1-A

The radiocarbon age determinations were made at the University of Washington (Seattle). The cal AD/BC ages (or cal BP) represent the mid-points of 10-year wood sections, except as noted with asterisks, when 20-year samples were needed to obtain the quantity of treated wood used for a measurement. The standard deviation of the age and Δ values includes a 1.6 lab error multiplier (see text). The trees and wood treatment are listed in Table 2. Overlapping decadal samples with mid-points no greater than one year apart were averaged. Single year data were averaged for the intervals AD 1510–1719 and AD 1790–1949.

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 1944.3 BP 5.7	-21.7 ± .9	181 ± 7
AD 1934.5 BP 15.5	-16.2 ± .8	146 ± 6
AD 1924.5 BP 25.5	-12.8 ± .8	128 ± 6
AD 1915 BP 35	-9.0 ± 1.1	106 ± 9
AD 1904.5 BP 45.5	-2.9 ± 1.0	68 ± 8
AD 1894.5 BP 55.5	-3.7 ± 1.1	84 ± 9
AD 1884.5 BP 65.5	-4.6 ± .7	101 ± 6
AD 1874.5 BP 75.5	-5.4 ± .7	116 ± 6
AD 1864.5 BP 85.5	-5.0 ± .8	123 ± 6
AD 1854.5 BP 95.5	-3.1 ± 1.0	118 ± 8
AD 1845 BP 105	-1.3 ± .9	113 ± 7
AD 1835.0 BP 115.0	-.3 ± .8	115 ± 6
AD 1824.5 BP 125.5	2.0 ± .7	106 ± 6
AD 1814.5 BP 135.5	3.0 ± .8	107 ± 6
AD 1804.5 BP 145.5	-1.9 ± .8	157 ± 6
AD 1794.5 BP 155.5	-5.9 ± .7	198 ± 6
AD 1784.5 BP 165.5	-4.9 ± 2.6	201 ± 21
AD 1774.5 BP 175.5	-2.0 ± 3.0	187 ± 24
AD 1764.5 BP 185.5	1.1 ± 2.8	172 ± 22
AD 1754.5 BP 195.5	-1.0 ± 2.0	198 ± 16
AD 1744.5 BP 205.5	3.2 ± 3.0	174 ± 24
AD 1734.5 BP 215.5	7.6 ± 2.8	149 ± 22
AD 1724.5 BP 225.5	11.2 ± 3.0	130 ± 24
AD 1714.5 BP 235.5	16.9 ± .7	94 ± 6
AD 1704.7 BP 245.3	15.9 ± .7	112 ± 6
AD 1694.5 BP 255.5	16.4 ± .6	118 ± 4
AD 1684.5 BP 265.5	14.7 ± .9	141 ± 7
AD 1674.6 BP 275.4	12.5 ± .7	168 ± 6
AD 1664.5 BP 285.5	9.3 ± .8	203 ± 6
AD 1654.6 BP 295.4	6.7 ± .8	234 ± 7
AD 1644.5 BP 305.5	3.3 ± .8	271 ± 6
AD 1634.5 BP 315.5	-.3 ± .8	309 ± 6
AD 1624.5 BP 325.5	-1.2 ± .7	326 ± 5
AD 1614.5 BP 335.5	-2.5 ± .8	346 ± 6
AD 1604.5 BP 345.5	-1.8 ± .8	350 ± 6
AD 1594.5 BP 355.5	1.6 ± .8	333 ± 6
AD 1584.5 BP 365.5	3.5 ± .8	327 ± 6
AD 1574.5 BP 375.5	5.3 ± .8	322 ± 7
AD 1564.5 BP 385.5	6.6 ± .8	322 ± 7
AD 1554.5 BP 395.5	9.5 ± .8	308 ± 6
AD 1544.5 BP 405.5	11.3 ± .8	304 ± 6
AD 1534.5 BP 415.5	13.7 ± .6	294 ± 5

TABLE 1-B

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 1524.5 BP 425.5	11.6 ± .8	321 ± 6
AD 1514.5 BP 435.5	10.0 ± .8	344 ± 7
AD 1504.8 BP 445.3	10.3 ± 1.4	351 ± 12
AD 1495 BP 455	11.8 ± 1.9	348 ± 15
AD 1485 BP 465	9.7 ± 2.4	374 ± 19
AD 1475 BP 475	10.1 ± 2.8	381 ± 22
AD 1465 BP 485	10.5 ± 2.8	387 ± 22
AD 1455 BP 495	11.4 ± 1.8	390 ± 15
AD 1445 BP 505	9.8 ± 2.2	412 ± 18
AD 1435 BP 515	5.2 ± 2.8	459 ± 22
AD 1425 BP 525	2.1 ± 2.4	493 ± 19
AD 1415 BP 535	.1 ± 2.6	519 ± 21
AD 1405 BP 545	-3.6 ± 2.4	559 ± 19
AD 1395 BP 555	-3.2 ± 2.6	565 ± 21
AD 1385 BP 565	-9.7 ± 1.9	628 ± 15
AD 1375 BP 575	-11.4 ± 2.1	651 ± 17
AD 1365 BP 585	-3.7 ± 2.0	598 ± 16
AD 1355 BP 595	-3.6 ± 2.3	607 ± 18
AD 1345 BP 605	1.7 ± 2.3	574 ± 18
AD 1335 BP 615	5.6 ± 1.9	553 ± 15
AD 1325 BP 625	.4 ± 2.0	604 ± 16
AD 1315 BP 635	-.4 ± 1.8	620 ± 15
AD 1305 BP 645	-.0 ± 1.9	627 ± 15
AD 1295 BP 655	-1.9 ± 2.8	652 ± 22
AD 1285 BP 665	-.7 ± 2.6	652 ± 21
AD 1275 BP 675	-12.6 ± 2.8	758 ± 22
AD 1265 BP 685	-10.0 ± 2.8	746 ± 22
AD 1255 BP 695	-15.9 ± 2.6	804 ± 21
AD 1245 BP 705	-14.4 ± 2.6	802 ± 21
AD 1235 BP 715	-12.3 ± 2.6	794 ± 21
AD 1225 BP 725	-12.5 ± 2.6	806 ± 21
AD 1215 BP 735	-14.4 ± 2.6	831 ± 21
AD 1205 BP 745	-16.5 ± 2.6	858 ± 21
AD 1195 BP 755	-14.2 ± 2.6	849 ± 21
AD 1185 BP 765	-16.9 ± 2.6	880 ± 21
AD 1175 BP 775	-14.6 ± 2.6	871 ± 21
AD 1165 BP 785	-12.1 ± 2.8	861 ± 22
AD 1155 BP 795	-16.3 ± 2.6	905 ± 21
AD 1145 BP 805	-22.3 ± 1.8	963 ± 15
AD 1135.3 BP 814.8	-12.9 ± 2.1	896 ± 17
AD 1125 BP 825	-13.7 ± 2.8	913 ± 22
AD 1115.3 BP 834.8	-15.7 ± 2.0	939 ± 16
AD 1105.3 BP 844.8	-14.6 ± 1.8	939 ± 15
AD 1095.3 BP 854.8	-12.3 ± 2.0	930 ± 16
AD 1085.3 BP 864.8	-8.6 ± 1.4	910 ± 12
AD 1075.3 BP 874.8	-6.4 ± 1.4	902 ± 12
AD 1065.3 BP 884.8	-7.1 ± 1.7	917 ± 13
AD 1055.3 BP 894.8	-5.9 ± 1.7	917 ± 14
AD 1045.3 BP 904.8	-4.4 ± 2.0	915 ± 16
AD 1035.3 BP 914.8	-6.8 ± 1.9	944 ± 15

TABLE 1-C

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 1025 / BP 925	-8.5 ± 2.6	968 ± 21	AD 775 / BP 1175	-11.7 ± 2.1	1236 ± 17
AD 1015 / BP 935	-13.6 ± 2.8	1019 ± 22	AD 764.8 / BP 1185.2	-15.5 ± 1.6	1277 ± 13
AD 1005 / BP 945	-9.3 ± 2.8	993 ± 22	AD 754.8 / BP 1195.2	-16.4 ± 1.4	1294 ± 11
AD 995 / BP 955	-13.8 ± 2.6	1040 ± 21	AD 744.8 / BP 1205.2	-11.1 ± 1.7	1261 ± 14
AD 985 / BP 965	-15.0 ± 2.6	1059 ± 21	AD 734.8 / BP 1215.2	-8.6 ± 1.5	1250 ± 12
AD 975 / BP 975	-20.3 ± 2.8	1112 ± 22	AD 724.8 / BP 1225.3	-9.2 ± 1.6	1265 ± 13
AD 965 / BP 985	-18.4 ± 2.8	1106 ± 22	AD 714.8 / BP 1235.3	-7.9 ± 2.0	1264 ± 16
AD 955 / BP 995	-17.7 ± 3.0	1110 ± 24	AD 704.8 / BP 1245.3	-9.6 ± 2.0	1288 ± 16
AD 945 / BP 1005	-16.4 ± 3.0	1110 ± 24	AD 695 / BP 1255	-5.0 ± 3.2	1260 ± 26
AD 935 / BP 1015	-19.3 ± 3.2	1143 ± 26	AD 685 / BP 1265	-8.1 ± 2.8	1295 ± 22
AD 925 / BP 1025	-17.9 ± 2.8	1141 ± 22	AD 675 / BP 1275	-9.2 ± 3.2	1313 ± 26
AD 915 / BP 1035	-11.5 ± 2.8	1099 ± 22	AD 665 / BP 1285	-11.2 ± 3.2	1339 ± 26
AD 905 / BP 1045	-10.6 ± 3.2	1101 ± 26	AD 655 / BP 1295	-13.0 ± 3.0	1364 ± 24
AD 895 / BP 1055	-13.0 ± 3.0	1130 ± 24	AD 645 / BP 1305	-14.6 ± 3.4	1386 ± 27
AD 885 / BP 1065	-16.0 ± 3.4	1165 ± 27	AD 635 / BP 1315	-22.2 ± 2.2	1458 ± 18
AD 875 / BP 1075	-15.2 ± 2.8	1168 ± 22	AD 625 / BP 1325	-18.3 ± 3.0	1436 ± 24
AD 865 / BP 1085	-16.2 ± 3.0	1186 ± 24	AD 615 / BP 1335	-16.6 ± 3.4	1432 ± 27
AD 855 / BP 1095	-16.5 ± 2.1	1198 ± 17	AD 605 / BP 1345	-16.9 ± 2.8	1444 ± 22
AD 845 / BP 1105	-16.6 ± 3.0	1208 ± 24	AD 595 / BP 1355	-19.9 ± 3.2	1478 ± 26
AD 835 / BP 1115	-11.5 ± 2.8	1176 ± 22	AD 585 / BP 1365	-17.4 ± 3.0	1468 ± 24
AD 825 / BP 1125	-13.1 ± 2.8	1199 ± 22	AD 575 / BP 1375	-18.4 ± 3.2	1485 ± 26
AD 815 / BP 1135	-9.4 ± 2.8	1179 ± 22	AD 565 / BP 1385	-17.5 ± 3.0	1488 ± 24
AD 805 / BP 1145	-9.3 ± 3.2	1188 ± 26	AD 555 / BP 1395	-18.5 ± 3.2	1506 ± 26
AD 795 / BP 1155	-13.9 ± 1.7	1235 ± 14	AD 545 / BP 1405	-17.4 ± 3.0	1506 ± 24
AD 785 / BP 1165	-3.6 ± 2.4	1161 ± 19	AD 535 / BP 1415	-21.2 ± 3.0	1547 ± 24

TABLE 1-D

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 525 / BP 1425	-25.6 ± 2.0	1593 ± 16	AD 275 / BP 1675	-9.6 ± 2.8	1705 ± 22
AD 515 / BP 1435	-21.0 ± 2.6	1565 ± 21	AD 265 / BP 1685	-7.3 ± 2.2	1696 ± 18
AD 505 / BP 1445	-20.4 ± 3.2	1570 ± 26	AD 255 / BP 1695	-14.4 ± 1.6	1763 ± 13
AD 495 / BP 1455	-17.2 ± 2.6	1553 ± 21	AD 245 / BP 1705	-13.9 ± 1.6	1770 ± 13
AD 485 / BP 1465	-15.5 ± 3.2	1549 ± 26	AD 235 / BP 1715	-13.8 ± 2.2	1778 ± 18
AD 475 / BP 1475	-14.6 ± 2.8	1552 ± 22	AD 225 / BP 1725	-16.6 ± 3.2	1811 ± 26
AD 465 / BP 1485	-15.3 ± 3.2	1567 ± 26	AD 215 / BP 1735	-16.7 ± 3.2	1821 ± 26
AD 455 / BP 1495	-14.3 ± 3.2	1569 ± 26	AD 205 / BP 1745	-18.5 ± 2.2	1846 ± 18
AD 445 / BP 1505	-11.0 ± 3.2	1551 ± 26	AD 195 / BP 1755	-13.1 ± 3.2	1811 ± 26
AD 435 / BP 1515	-10.5 ± 3.2	1557 ± 26	AD 185 / BP 1765	-10.4 ± 2.8	1799 ± 22
AD 425 / BP 1525	-16.8 ± 2.4	1618 ± 19	AD 175 / BP 1775	-11.7 ± 3.2	1820 ± 26
AD 415 / BP 1535	-16.7 ± 3.0	1627 ± 24	AD 165 / BP 1785	-12.8 ± 3.4	1838 ± 27
AD 405 / BP 1545	-19.3 ± 2.8	1658 ± 22	AD 155 / BP 1795	-10.9 ± 2.8	1832 ± 22
AD 395 / BP 1555	-18.1 ± 2.4	1658 ± 19	AD 145 / BP 1805	-8.8 ± 3.2	1825 ± 26
AD 385 / BP 1565	-19.1 ± 2.0	1676 ± 16	AD 135 / BP 1815	-7.6 ± 2.0	1825 ± 16
AD 375 / BP 1575	-21.2 ± 1.8	1703 ± 14	AD 125 / BP 1825	-15.2 ± 1.7	1897 ± 13
AD 365 / BP 1585	-15.6 ± 2.8	1667 ± 22	AD 115 / BP 1835	-13.3 ± 3.4	1891 ± 27
AD 355 / BP 1595	-17.0 ± 3.2	1688 ± 26	AD 105 / BP 1845	-11.3 ± 3.2	1884 ± 26
AD 345 / BP 1605	-16.0 ± 2.8	1689 ± 22	AD 95 / BP 1855	-10.4 ± 2.4	1887 ± 19
AD 335 / BP 1615	-19.3 ± 3.0	1726 ± 24	AD 85 / BP 1865	-7.9 ± 3.2	1876 ± 26
AD 325 / BP 1625	-18.2 ± 3.2	1727 ± 26	AD 75 / BP 1875	-10.2 ± 2.2	1905 ± 18
AD 315 / BP 1635	-21.5 ± 3.0	1764 ± 24	AD 65 / BP 1885	-12.2 ± 2.2	1930 ± 18
AD 305 / BP 1645	-20.0 ± 3.0	1761 ± 24	AD 55 / BP 1895	-12.4 ± 1.9	1942 ± 15
AD 295 / BP 1655	-13.6 ± 2.8	1718 ± 22	AD 44.8 / BP 1905.3	-16.0 ± 1.6	1981 ± 13
AD 285 / BP 1665	-16.3 ± 3.0	1750 ± 24	AD 34.8 / BP 1915.3	-9.1 ± 2.4	1935 ± 19

Table 1-E

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 24.8 BP 1925.3	-13.1 ± 2.2	1977 ± 17	BC 225.5 BP 2174.5	-6.8 ± 2.4	2168 ± 19
AD 14.8 BP 1935.3	-14.0 ± 1.8	1994 ± 15	BC 235.5 BP 2184.5	-13.8 ± 1.8	2235 ± 14
AD 4.8 BP 1945.3	-10.5 ± 1.5	1976 ± 12	BC 245.5 BP 2194.5	-11.4 ± 2.3	2225 ± 19
BC 5.3 BP 1954.3	-16.8 ± 1.8	2035 ± 14	BC 255.5 BP 2204.5	-7.8 ± 3.1	2205 ± 25
BC 15.3 BP 1964.3	-10.2 ± 1.6	1991 ± 13	BC 265.5 BP 2214.5	-12.2 ± 3.0	2251 ± 24
BC 25.3 BP 1974.3	-12.2 ± 2.1	2017 ± 17	BC 275.5 BP 2224.5	-6.4 ± 2.2	2214 ± 18
BC 35.3 BP 1984.3	-8.6 ± 1.2	1998 ± 10	BC 285.5 BP 2234.5	-7.6 ± 2.9	2233 ± 23
BC 45.3 BP 1994.3	-12.1 ± 1.9	2036 ± 15	BC 295.5 BP 2244.5	-2.1 ± 2.1	2198 ± 17
BC 55.3 BP 2004.3	-11.3 ± 1.5	2039 ± 12	BC 305.5 BP 2254.5	1.4 ± 3.0	2179 ± 24
BC 65.3 BP 2014.3	-5.3 ± 1.7	2000 ± 14	BC 315.5 BP 2264.5	.7 ± 3.0	2195 ± 24
BC 75.3 BP 2024.3	-12.8 ± 2.3	2071 ± 18	BC 325.5 BP 2274.5	6.5 ± 2.1	2159 ± 17
BC 85.3 BP 2034.3	-1.5 ± 1.8	1989 ± 14	BC 335.5 BP 2284.5	8.8 ± 3.0	2150 ± 24
BC 95.3 BP 2044.3	-11.9 ± 2.2	2082 ± 17	BC 345.5 BP 2294.5	7.8 ± 2.2	2168 ± 17
BC 105.3 BP 2054.3	-10.7 ± 2.0	2083 ± 16	BC 355.5 BP 2304.5	2.6 ± 2.2	2218 ± 17
BC 115.3 BP 2064.3	-10.5 ± 1.9	2091 ± 15	BC 365.5 BP 2314.5	-.3 ± 2.2	2252 ± 18
BC 125.3 BP 2074.3	-11.7 ± 1.9	2111 ± 15	BC 375.5 BP 2324.5	1.5 ± 2.2	2247 ± 18
BC 135.3 BP 2084.3	-12.9 ± 2.2	2130 ± 18	BC 385.5 BP 2334.5	.4 ± 3.1	2265 ± 25
BC 145.3 BP 2094.3	-6.7 ± 1.9	2089 ± 15	BC 395.5 BP 2344.5	-4.3 ± 2.3	2313 ± 18
BC 155.5 BP 2104.5	-5.0 ± 3.3	2085 ± 27	BC 405.5 BP 2354.5	-10.0 ± 1.7	2368 ± 14
BC 165.5 BP 2114.5	-5.0 ± 2.1	2095 ± 17	BC 415.5 BP 2364.5	-15.7 ± 3.2	2425 ± 25
BC 175.5 BP 2124.5	-10.3 ± 3.3	2148 ± 26	BC 425.5 BP 2374.5	-12.0 ± 3.2	2405 ± 26
BC 185.5 BP 2134.5	-9.0 ± 3.2	2147 ± 26	BC 435.5 BP 2384.5	-14.9 ± 3.1	2438 ± 25
BC 195.5 BP 2144.5	-5.6 ± 2.2	2129 ± 17	BC 445.5 BP 2394.5	-14.5 ± 5.0	2444 ± 40
BC 205.5 BP 2154.5	-8.7 ± 3.0	2164 ± 24	BC 455.5 BP 2404.5	-18.1 ± 3.4	2483 ± 28
BC 215.5 BP 2164.5	-14.3 ± 1.7	2219 ± 14	BC 465.5 BP 2414.5	-11.2 ± 3.8	2437 ± 30

Table 1-F

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 475.5 BP 2424.5	-5.5 ± 2.3	2401 ± 18	*BC 771.5 BP 2720.5	13.0 ± 3.2	2540 ± 26
BC 485.5 BP 2434.5	-6.9 ± 3.2	2422 ± 26	BC 786.5 BP 2735.5	15.1 ± 2.4	2538 ± 19
BC 495.5 BP 2444.5	-6.3 ± 2.4	2426 ± 19	BC 796.5 BP 2745.5	8.6 ± 2.4	2599 ± 19
BC 505.5 BP 2454.5	-4.3 ± 3.2	2420 ± 26	BC 806.5 BP 2755.5	4.1 ± 2.4	2645 ± 19
BC 515.5 BP 2464.5	-4.3 ± 2.4	2430 ± 19	BC 816.5 BP 2765.5	3.9 ± 3.2	2656 ± 26
BC 525.5 BP 2474.5	-7.8 ± 2.6	2468 ± 21	BC 826.5 BP 2775.5	4.3 ± 2.4	2663 ± 19
BC 535.5 BP 2484.5	-3.6 ± 1.7	2444 ± 14	BC 836.5 BP 2785.5	-2.4 ± 2.4	2727 ± 19
BC 545.5 BP 2494.5	-6.0 ± 1.6	2472 ± 13	BC 846.5 BP 2795.5	-2.8 ± 2.4	2739 ± 20
BC 555.5 BP 2504.5	-5.5 ± 2.8	2478 ± 22	BC 856.5 BP 2805.5	-2.0 ± 3.2	2742 ± 26
BC 565.5 BP 2514.5	-5.5 ± 3.6	2488 ± 29	BC 866.5 BP 2815.5	.8 ± 3.1	2730 ± 25
BC 575.5 BP 2524.5	-2.7 ± 3.4	2475 ± 27	BC 876.5 BP 2825.5	2.8 ± 3.2	2723 ± 26
BC 585.5 BP 2534.5	1.9 ± 3.4	2448 ± 27	BC 886.5 BP 2835.5	7.6 ± 3.2	2695 ± 26
BC 595.5 BP 2544.5	-3.4 ± 2.8	2500 ± 22	BC 896.5 BP 2845.5	3.8 ± 3.2	2735 ± 26
BC 605.5 BP 2554.5	-3.5 ± 2.8	2511 ± 22	BC 906.5 BP 2855.5	.9 ± 3.2	2768 ± 26
BC 615.5 BP 2564.5	1.8 ± 2.6	2478 ± 21	BC 916.5 BP 2865.5	2.3 ± 3.2	2766 ± 26
BC 625.5 BP 2574.5	-.6 ± 2.6	2507 ± 21	BC 926.5 BP 2875.5	2.1 ± 3.2	2778 ± 26
BC 635.5 BP 2584.5	3.4 ± 3.2	2484 ± 26	BC 936.5 BP 2885.5	.3 ± 2.4	2802 ± 19
BC 646 BP 2595	6.7 ± 2.3	2468 ± 18	BC 946.5 BP 2895.5	-.8 ± 2.4	2820 ± 19
BC 655.5 BP 2604.5	8.3 ± 2.0	2464 ± 16	BC 956.5 BP 2905.5	1.3 ± 2.6	2813 ± 21
BC 665.5 BP 2614.5	-.9 ± 2.8	2548 ± 22	BC 966.5 BP 2915.5	9.8 ± 3.2	2755 ± 26
BC 696.5 BP 2645.5	15.7 ± 4.8	2446 ± 38	BC 976.5 BP 2925.5	.9 ± 2.4	2836 ± 19
BC 706.5 BP 2655.5	16.5 ± 5.0	2449 ± 40	BC 986.5 BP 2935.5	3.6 ± 3.0	2824 ± 24
BC 716.5 BP 2665.5	17.0 ± 5.0	2455 ± 40	BC 996.5 BP 2945.5	6.8 ± 3.0	2808 ± 24
*BC 731.5 BP 2680.5	21.6 ± 2.3	2434 ± 18	BC 1006.5 BP 2955.5	5.3 ± 3.2	2830 ± 26
*BC 751.5 BP 2700.5	22.5 ± 3.2	2446 ± 26	BC 1016.5 BP 2965.5	2.6 ± 3.2	2861 ± 26

TABLE 1-G

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 1026.5 BP 2975.5	2.2 ± 3.4	2874 ± 27	BC 1276.5 BP 3225.5	14.4 ± 3.3	3020 ± 26
BC 1036.5 BP 2985.5	4.4 ± 3.2	2866 ± 26	BC 1286.5 BP 3235.5	20.9 ± 3.4	2978 ± 27
BC 1046.5 BP 2995.5	8.4 ± 3.4	2844 ± 27	BC 1296.5 BP 3245.5	16.7 ± 3.4	3021 ± 27
BC 1056.5 BP 3005.5	.6 ± 3.2	2916 ± 26	BC 1306.5 BP 3255.5	19.2 ± 3.6	3011 ± 29
BC 1066.5 BP 3015.5	8.7 ± 3.4	2861 ± 27	BC 1316.5 BP 3265.5	18.5 ± 3.4	3026 ± 27
BC 1076.5 BP 3025.5	8.0 ± 3.4	2876 ± 27	BC 1326.5 BP 3275.5	11.4 ± 2.8	3092 ± 22
BC 1086.5 BP 3035.5	4.4 ± 3.3	2915 ± 27	BC 1336.5 BP 3285.5	17.7 ± 3.4	3052 ± 27
BC 1096.5 BP 3045.5	7.0 ± 2.3	2904 ± 18	BC 1346.5 BP 3295.5	22.0 ± 3.4	3028 ± 27
BC 1106.5 BP 3055.5	8.8 ± 2.3	2899 ± 18	BC 1356.5 BP 3305.5	19.5 ± 3.4	3057 ± 27
BC 1116.5 BP 3065.5	2.6 ± 3.4	2958 ± 27	BC 1366.5 BP 3315.5	25.0 ± 3.2	3024 ± 26
BC 1126.5 BP 3075.5	11.9 ± 3.2	2894 ± 26	BC 1376.5 BP 3325.5	20.0 ± 3.0	3073 ± 24
BC 1136.5 BP 3085.5	1.0 ± 2.3	2991 ± 18	BC 1386.5 BP 3335.5	20.7 ± 3.2	3077 ± 26
BC 1146.5 BP 3095.5	12.6 ± 3.2	2908 ± 26	BC 1396.5 BP 3345.5	19.6 ± 1.9	3095 ± 15
BC 1156.5 BP 3105.5	9.6 ± 3.4	2941 ± 27	BC 1406.5 BP 3355.5	21.5 ± 3.2	3090 ± 26
BC 1166.5 BP 3115.5	11.6 ± 3.2	2935 ± 26	BC 1416.5 BP 3365.5	16.3 ± 2.4	3140 ± 20
BC 1176.5 BP 3125.5	13.2 ± 4.0	2932 ± 32	BC 1426.5 BP 3375.5	21.2 ± 3.2	3112 ± 26
BC 1186.5 BP 3135.5	20.1 ± 3.4	2887 ± 27	BC 1436.5 BP 3385.5	15.8 ± 2.3	3164 ± 19
BC 1196.5 BP 3145.5	7.4 ± 3.0	2997 ± 24	BC 1446.5 BP 3395.5	16.4 ± 2.4	3169 ± 19
BC 1206.5 BP 3155.5	20.6 ± 3.4	2903 ± 27	BC 1456.5 BP 3405.5	15.2 ± 2.2	3188 ± 18
BC 1216.5 BP 3165.5	11.8 ± 1.9	2982 ± 15	BC 1466.5 BP 3415.5	14.1 ± 2.3	3207 ± 18
BC 1226.5 BP 3175.5	11.8 ± 3.2	2992 ± 26	BC 1476.5 BP 3425.5	15.6 ± 2.4	3205 ± 19
BC 1236.5 BP 3185.5	17.4 ± 3.4	2957 ± 27	BC 1486.5 BP 3435.5	20.7 ± 2.5	3174 ± 20
BC 1246.5 BP 3195.5	16.4 ± 3.4	2975 ± 27	BC 1496.5 BP 3445.5	16.0 ± 3.3	3221 ± 27
BC 1256.5 BP 3205.5	18.2 ± 2.6	2970 ± 21	BC 1506.5 BP 3455.5	15.2 ± 3.2	3237 ± 26
BC 1266.5 BP 3215.5	12.5 ± 3.4	3025 ± 27	BC 1516.5 BP 3465.5	16.5 ± 3.4	3236 ± 27

TABLE 1-H

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 1526.5 BP 3475.5	14.5 ± 3.0	3262 ± 24	BC 1776.5 BP 3725.5	16.9 ± 2.6	3486 ± 21
BC 1536.5 BP 3485.5	11.9 ± 3.2	3292 ± 26	BC 1786.5 BP 3735.5	16.0 ± 2.3	3503 ± 18
BC 1546.5 BP 3495.5	12.5 ± 3.4	3297 ± 27	BC 1796.5 BP 3745.5	18.8 ± 2.3	3491 ± 19
BC 1556.5 BP 3505.5	14.3 ± 3.2	3293 ± 26	BC 1806.5 BP 3755.5	23.5 ± 2.3	3463 ± 19
BC 1566.5 BP 3515.5	16.2 ± 4.9	3287 ± 39	BC 1816.5 BP 3765.5	20.1 ± 2.3	3499 ± 19
BC 1576.5 BP 3525.5	20.6 ± 4.9	3262 ± 39	BC 1826.5 BP 3775.5	24.5 ± 3.4	3475 ± 27
BC 1586.5 BP 3535.5	20.2 ± 3.4	3275 ± 27	BC 1836.5 BP 3785.5	17.3 ± 3.2	3541 ± 26
BC 1596.5 BP 3545.5	21.8 ± 2.6	3272 ± 21	BC 1846.5 BP 3795.5	27.4 ± 3.4	3471 ± 27
BC 1606.5 BP 3555.5	17.4 ± 2.4	3317 ± 19	BC 1856.5 BP 3805.5	28.4 ± 3.4	3473 ± 27
BC 1616.5 BP 3565.5	19.0 ± 2.6	3314 ± 21	BC 1866.5 BP 3815.5	28.1 ± 3.4	3485 ± 27
BC 1626.5 BP 3575.5	17.0 ± 2.6	3339 ± 21	BC 1876.5 BP 3825.5	28.8 ± 2.3	3489 ± 19
BC 1636.5 BP 3585.5	18.3 ± 3.4	3339 ± 27	BC 1886.5 BP 3835.5	22.8 ± 3.2	3546 ± 26
BC 1646.5 BP 3595.5	14.8 ± 2.0	3376 ± 16	BC 1896.5 BP 3845.5	20.8 ± 3.4	3572 ± 27
BC 1656.5 BP 3605.5	20.5 ± 2.4	3341 ± 19	BC 1906.5 BP 3855.5	25.1 ± 3.4	3548 ± 27
BC 1666.5 BP 3615.5	14.7 ± 3.4	3396 ± 27	BC 1916.5 BP 3865.5	26.2 ± 3.4	3549 ± 27
BC 1676.5 BP 3625.5	26.7 ± 3.2	3312 ± 26	BC 1926.5 BP 3875.5	21.6 ± 2.6	3595 ± 21
BC 1686.5 BP 3635.5	22.8 ± 3.4	3352 ± 27	BC 1936.5 BP 3885.5	23.9 ± 2.9	3586 ± 23
BC 1696.5 BP 3645.5	15.3 ± 2.3	3421 ± 19	BC 1946.5 BP 3895.5	23.7 ± 3.3	3597 ± 27
BC 1706.5 BP 3655.5	17.9 ± 3.4	3410 ± 27	BC 1956.5 BP 3905.5	25.3 ± 3.4	3595 ± 27
BC 1716.5 BP 3665.5	21.7 ± 3.4	3390 ± 27	BC 1966.5 BP 3915.5	24.5 ± 3.4	3611 ± 27
BC 1726.5 BP 3675.5	21.6 ± 3.4	3400 ± 27	BC 1976.5 BP 3925.5	23.3 ± 3.2	3630 ± 26
BC 1736.5 BP 3685.5	19.9 ± 3.4	3423 ± 27	BC 1986.5 BP 3935.5	21.6 ± 3.4	3653 ± 27
BC 1746.5 BP 3695.5	17.4 ± 3.4	3453 ± 27	BC 1996.5 BP 3945.5	30.9 ± 3.2	3590 ± 26
BC 1756.5 BP 3705.5	15.6 ± 2.4	3477 ± 19	BC 2006.5 BP 3955.5	34.2 ± 3.4	3574 ± 27
BC 1766.5 BP 3715.5	19.5 ± 2.6	3456 ± 21	BC 2016.5 BP 3965.5	28.4 ± 3.2	3629 ± 26

TABLE 1-I

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 2026.5 BP 3975.5	30.9 ± 3.4	3619 ± 27
BC 2036.5 BP 3985.5	25.5 ± 2.1	3671 ± 17
BC 2046.5 BP 3995.5	20.1 ± 3.2	3723 ± 26
BC 2056.5 BP 4005.5	23.4 ± 2.4	3707 ± 19
BC 2066.5 BP 4015.5	30.5 ± 3.3	3661 ± 26
BC 2076.5 BP 4025.5	23.2 ± 2.4	3728 ± 19
BC 2086.5 BP 4035.5	34.5 ± 3.4	3649 ± 27
BC 2096.5 BP 4045.5	31.7 ± 3.2	3681 ± 26
BC 2106.5 BP 4055.5	37.0 ± 2.3	3650 ± 18
BC 2116.5 BP 4065.5	33.7 ± 3.2	3685 ± 26
BC 2126.5 BP 4075.5	37.2 ± 3.4	3667 ± 27
BC 2136.5 BP 4085.5	33.7 ± 3.2	3704 ± 26
BC 2146.5 BP 4095.5	26.4 ± 2.6	3771 ± 21
BC 2156.5 BP 4105.5	30.8 ± 2.2	3746 ± 17
BC 2166.5 BP 4115.5	34.6 ± 3.4	3726 ± 27
BC 2176.5 BP 4125.5	35.5 ± 2.2	3729 ± 18
BC 2186.5 BP 4135.5	37.6 ± 1.9	3723 ± 15
BC 2196.5 BP 4145.5	37.3 ± 1.9	3735 ± 15
BC 2206.5 BP 4155.5	31.5 ± 2.8	3789 ± 22
BC 2216.5 BP 4165.5	32.2 ± 2.4	3794 ± 19
BC 2226.5 BP 4175.5	35.7 ± 2.0	3776 ± 16
BC 2236.5 BP 4185.5	30.4 ± 3.8	3827 ± 30
BC 2246.5 BP 4195.5	32.6 ± 2.5	3820 ± 20
BC 2256.5 BP 4205.5	38.8 ± 2.3	3781 ± 19
BC 2266.5 BP 4215.5	42.2 ± 3.4	3765 ± 27
BC 2276.5 BP 4225.5	37.5 ± 4.0	3811 ± 32
BC 2286.5 BP 4235.5	39.8 ± 2.8	3802 ± 22
BC 2296.5 BP 4245.5	36.7 ± 2.5	3836 ± 20
BC 2306.5 BP 4255.5	39.4 ± 3.8	3825 ± 30
BC 2316.5 BP 4265.5	36.7 ± 3.4	3856 ± 27
BC 2326.5 BP 4275.5	40.9 ± 2.4	3833 ± 19
BC 2336.5 BP 4285.5	41.0 ± 3.4	3842 ± 27
BC 2346.5 BP 4295.5	40.2 ± 2.4	3858 ± 19
BC 2356.5 BP 4305.5	37.6 ± 3.4	3888 ± 27
BC 2366.5 BP 4315.5	39.7 ± 2.4	3882 ± 19
BC 2376.5 BP 4325.5	40.2 ± 3.4	3887 ± 27
BC 2386.5 BP 4335.5	46.7 ± 2.4	3847 ± 19
BC 2406.5 BP 4355.5	43.5 ± 2.6	3891 ± 21
BC 2416.5 BP 4365.5	43.1 ± 2.8	3903 ± 22
BC 2426.5 BP 4375.5	49.4 ± 3.4	3865 ± 27
BC 2436.5 BP 4385.5	46.5 ± 1.8	3897 ± 14
BC 2446.5 BP 4395.5	50.5 ± 3.4	3876 ± 27
BC 2466.5 BP 4415.5	50.0 ± 3.4	3899 ± 27
BC 2476.5 BP 4425.5	39.1 ± 2.4	3993 ± 20
BC 2486.5 BP 4435.5	43.4 ± 2.5	3969 ± 20
BC 2496.5 BP 4445.5	38.0 ± 3.6	4021 ± 29

TABLE 2

Lab code	Species	Dendro-ages used	Wood treatment*	Location	Dendro-chronology
C	Douglas fir	AD 1915–1954 (single year)	CL	Olympic Peninsula, WA (47° 46′ N, 124° 06′ W)	Ring counted only
A	Douglas fir	AD 1820–1913 (single year)	DV**	Olympic Peninsula, WA (47° 46′ N, 124° 06′ W)	Ring counted only
B	Douglas fir	AD 1690–1719 AD 1790–1819 (single year)	DV	Mt Rainier Natl Park, WA (46° 45′ N, 121° 45′ W)	Ring counted only
F	Douglas fir	AD 1510–1699 (single year)	DV	Coos Bay, OR (43° 07′ N, 123° 40′ W)	Ring counted only
		AD 1505–1935 (decadal)	DV†		
R	Douglas fir	AD 1305–1505 (decadal)	DV	Pierce County, WA (47°N 122°W)	Ring counted only
S	Douglas fir	AD 945–1315 (decadal)	DV	Shawnigan Lake, Vancouver Island, BC Canada (48° 40′ N, 123° 40′ W)	Cross-dated by M Parker *et al*, Western Products Forestry Vancouver, BC
RC	Sequoia	AD 265–935 (decadal)	DV	Sequoia Nat'l Park, CA (36.5° N, 118.5° W)	Cross-dated by H Garfinkel, University of Washington, Seattle
ECK	Oak	AD 705–765 (decadal)	DV	Northern Germany	Cross-dated by D Eckstein, University of Hamburg
SR	Sequoia	145 BC–AD 265 (decadal)	DV	Sequoia Natl Park, CA (36.5° N, 118.5° W)	Cross-dated by H Garfinkel
BK	Oak	2495 BC–AD 45 (decadal)	CL	Southern Germany	Cross-dated by B Becker, University of Hohenheim, Stuttgart, W Germany
PQ	Oak	625–515 BC (decadal)	CL	Ireland	Cross-dated by JR Pilcher, MGL Baillie and GW Pearson, University of Belfast, Northern Ireland

*CL = cellulose method, DV = De Vries method
**Cellulose duplicates run for AD 1836, 1837 and 1853
†Cellulose treatment AD 1505 and 1515

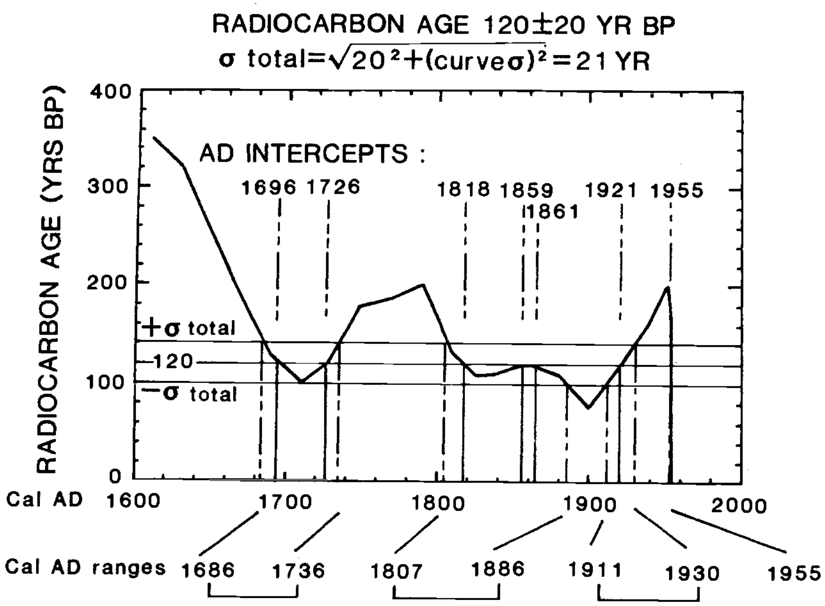
TABLE 3

The conversion of the radiocarbon ages to a series of ranges of cal AD/BC (*and* BP) dates is determined by the AD/BC intercepts of the sample radiocarbon age ± $\sqrt{(\text{sample } \sigma)^2 + (\text{curve } \sigma)^2}$ and the calibration curve. Intercepts of the radiocarbon age with the calibration curve are listed to the right. Sample σ is the standard error in the radiocarbon age.

The youngest decade of the calibration curve is AD 1940–1949 with a conventional radiocarbon age of 181 years BP. The curve has been extended to 1954 using data from Stuiver and Quay (1981). Nuclear bomb testing increased atmospheric ^{14}C substantially in 1955, resulting in the "vertical" portion of the Fig 1A calibration curve. Intercepts with this vertical portion yield the 1955*s of the table. In those instances where cal AD/BC ages indicate "negative" BP ages the BP age is given as 0* BP.

For sample sigmas and ranges larger or equal to 100 years the data were rounded to the nearest decade. When the gap between two successive ranges was less than 10 years, the two ranges were combined to a single one.

Illustrations from Stuiver and Pearson (1986) and Pearson and Stuiver (1986) are given below.



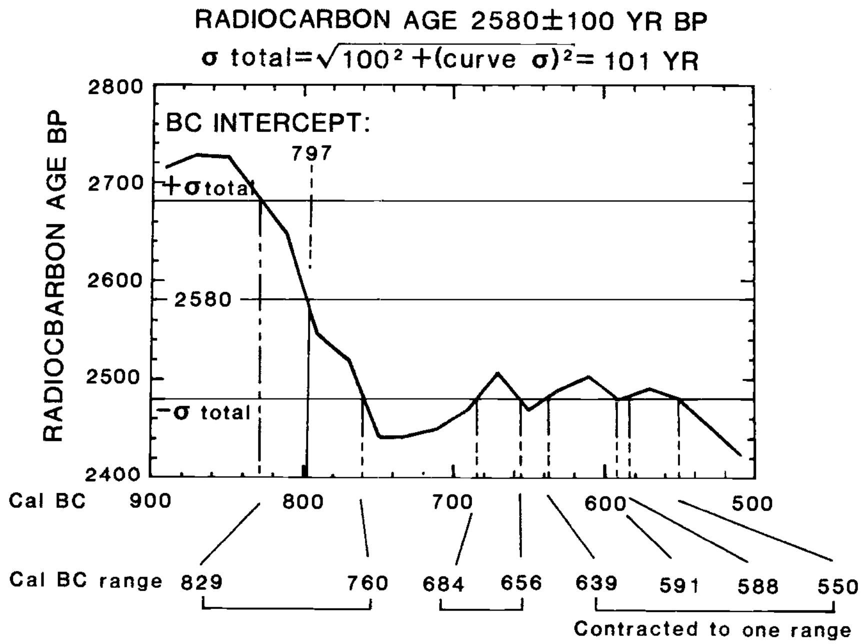


TABLE 3-A

```
RADIOCARBON AGE BP   80   CALIBRATED AGES:  cal AD 1897, 1908, 1955*
                                            cal BP   53,   42,    0*
Sample σ and cal AD(cal BP) ranges:
σ =  20     1710-1717(240-233)     1883-1914(67-36)
σ =  40     1693-1722(257-228)     1812-1922(138-28)
σ =  60     1685-1730(265-220)     1808-1932(142-18)
σ =  80     1677-1739(273-211)     1804-1939(146-11)
σ = 100     1671-1747(279-203)     1761-1770(189-180)     1800-1955*(150-0*)
σ = 120     1670-1955*(280-0*)
σ = 160     1650-1955*(300-0*)
σ = 200     1640-1955*(310-0*)
```

```
RADIOCARBON AGE BP  100   CALIBRATED AGES:  cal AD 1711, 1716, 1885, 1913, 1955*
                                            cal BP  239,  234,   65,   37,    0*
Sample σ and cal AD(cal BP) ranges:
σ =  20     1692-1722(258-228)     1811-1922(139-28)
σ =  40     1684-1731(266-219)     1808-1932(142-18)
σ =  60     1677-1739(273-211)     1804-1939(146-11)
σ =  80     1671-1747(279-203)     1761-1770(189-180)     1799-1955*(151-0*)
σ = 100     1670-1955*(280-0*)
σ = 120     1660-1955*(290-0*)
σ = 160     1650-1955*(300-0*)
σ = 200     1532-1541(418-409)     1640-1955*(310-0*)
```

```
RADIOCARBON AGE BP  120   CALIBRATED AGES:  cal AD 1693, 1722, 1812, 1859, 1869,
                                                 1921, 1955*
                                            cal BP  257,  228,  138,   91,   81,
                                                   29,    0*
Sample σ and cal AD(cal BP) ranges:
σ =  20     1684-1731(266-219)     1808-1886(142-64)      1913-1932(37-18)
σ =  40     1677-1739(273-211)     1804-1939(146-11)
σ =  60     1671-1747(279-203)     1761-1770(189-180)     1799-1955*(151-0*)
σ =  80     1665-1955*(285-0*)
σ = 100     1660-1955*(290-0*)
σ = 120     1650-1955*(300-0*)
σ = 160     1640-1955*(310-0*)
σ = 200     1525-1563(425-387)     1630-1955*(320-0*)
```

```
RADIOCARBON AGE BP  140   CALIBRATED AGES:  cal AD 1685, 1730, 1808, 1931, 1955*
                                            cal BP  265,  220,  142,   19,    0*
Sample σ and cal AD(cal BP) ranges:
σ =  20     1676-1696(274-254)     1721-1740(229-210)     1803-1813(147-137)
            1853-1874(97-76)       1920-1939(30-11)
σ =  40     1671-1748(279-202)     1761-1771(189-179)     1799-1886(151-64)
            1913-1955*(37-0*)
σ =  60     1665-1955*(285-0*)
σ =  80     1659-1955*(291-0*)
σ = 100     1650-1955*(300-0*)
σ = 120     1650-1955*(300-0*)
σ = 160     1532-1541(418-409)     1640-1955*(310-0*)
σ = 200     1516-1599(434-351)     1620-1955*(330-0*)
```

TABLE 3-B

```
RADIOCARBON AGE BP  160   CALIBRATED AGES:  cal AD 1677, 1739, 1804, 1938, 1955*
                                            cal BP  273,  211,  146,   12,    0*
Sample σ and cal AD(cal BP) ranges:
σ =  20     1670-1686(280-264)     1728-1748(222-202)     1760-1772(190-178)
            1798-1809(152-141)     1929-1955*(21-0*)
σ =  40     1665-1694(285-256)     1721-1812(229-138)     1856-1872(94-78)
            1920-1955*(30-0*)
σ =  60     1659-1886(291-64)      1913-1955*(37-0*)
σ =  80     1653-1898(297-52)      1908-1955*(42-0*)
σ = 100     1650-1955*(300-0*)
σ = 120     1640-1955*(310-0*)
σ = 160     1525-1564(425-386)     1630-1955*(320-0*)
σ = 200     1490-1955*(460-0*)
```

```
RADIOCARBON AGE BP  180   CALIBRATED AGES:  cal AD 1671, 1747, 1761, 1770, 1799,
                                                 1944, 1954
                                            cal BP  279,  203,  189,  180,  151,
                                                    6,    0*
Sample σ and cal AD(cal BP) ranges:
σ =  20     1664-1679(286-271)     1737-1805(213-145)     1937-1955*(13-0*)
σ =  40     1658-1686(292-264)     1728-1808(222-142)     1929-1955*(21-0*)
σ =  60     1652-1694(298-256)     1721-1812(229-138)     1855-1872(95-78)
            1920-1955*(30-0*)
σ =  80     1647-1886(303-64)      1913-1955*(37-0*)
σ = 100     1640-1955*(310-0*)
σ = 120     1532-1542(418-408)     1640-1955*(310-0*)
σ = 160     1516-1599(434-351)     1620-1955*(330-0*)
σ = 200     1480-1955*(470-0*)
```

```
RADIOCARBON AGE BP  200   CALIBRATED AGES:  cal AD 1665, 1784, 1787, 1951, 1952
                                            cal BP  285,  166,  163,   0*,   0*
Sample σ and cal AD(cal BP) ranges:
σ =  20     1657-1673(293-277)     1745-1800(205-150)     1943-1955*(7-0*)
σ =  40     1652-1679(298-271)     1738-1804(212-146)     1938-1955*(12-0*)
σ =  60     1647-1686(303-264)     1729-1808(221-142)     1930-1955*(20-0*)
σ =  80     1642-1694(308-256)     1721-1812(229-138)     1856-1871(94-79)
            1920-1955*(30-0*)
σ = 100     1532-1542(418-408)     1640-1890(310-60)      1913-1955*(37-0*)
σ = 120     1524-1564(426-386)     1630-1955*(320-0*)
σ = 160     1490-1955*(460-0*)
σ = 200     1450-1955*(500-0*)
```

Table 3-C

RADIOCARBON AGE BP 220 CALIBRATED AGE: cal AD 1659
cal BP 291

Sample σ and cal AD(cal BP) ranges:

σ = 20	1653-1666(297-284)	1783-1792(167-158)	1951-1952(0*)
σ = 40	1647-1671(303-279)	1747-1799(203-151)	1944-1954(6-0*)
σ = 60	1642-1678(308-272)	1739-1804(211-146)	1938-1955*(12-0*)
σ = 80	1532-1541(418-409)	1637-1685(313-265)	1730-1808(220-142)
	1931-1955*(19-0*)		
σ = 100	1525-1563(425-387)	1628-1694(322-256)	1722-1812(228-138)
	1858-1870(92-80)	1921-1955*(29-0*)	
σ = 120	1516-1599(434-351)	1620-1890(330-60)	1913-1955*(37-0*)
σ = 160	1480-1955*(470-0*)		
σ = 200	1440-1955*(510-0*)		

RADIOCARBON AGE BP 240 CALIBRATED AGE: cal AD 1653
cal BP 297

Sample σ and cal AD(cal BP) ranges:

σ = 20	1647-1659(303-291)		
σ = 40	1642-1666(308-284)	1784-1790(166-160)	1951-1952(0*)
σ = 60	1532-1541(418-409)	1637-1671(313-279)	1747-1799(203-151)
	1944-1954(6-0*)		
σ = 80	1525-1563(425-387)	1628-1678(322-272)	1739-1804(211-146)
	1938-1955*(12-0*)		
σ = 100	1516-1599(434-351)	1618-1685(332-265)	1730-1808(220-142)
	1931-1955*(19-0*)		
σ = 120	1490-1690(460-260)	1722-1812(228-138)	1858-1870(92-80)
	1921-1955*(29-0*)		
σ = 160	1450-1900(500-50)	1908-1955*(42-0*)	
σ = 200	1440-1955*(510-0*)		

RADIOCARBON AGE BP 260 CALIBRATED AGE: cal AD 1647
cal BP 303

Sample σ and cal AD(cal BP) ranges:

σ = 20	1642-1653(308-297)		
σ = 40	1532-1541(418-409)	1637-1659(313-291)	
σ = 60	1525-1563(425-387)	1628-1665(322-285)	1784-1789(166-161)
	1951-1952(0*)		
σ = 80	1516-1599(434-351)	1618-1671(332-279)	1747-1799(203-151)
	1944-1954(6-0*)		
σ = 100	1490-1680(460-270)	1739-1804(211-146)	1938-1955*(12-0*)
σ = 120	1480-1690(470-260)	1730-1808(220-142)	1931-1955*(19-0*)
σ = 160	1440-1890(510-60)	1913-1955*(37-0*)	
σ = 200	1430-1955*(520-0*)		

Table 3-D

RADIOCARBON AGE BP 280 CALIBRATED AGE: cal AD 1642
cal BP 308

Sample σ and cal AD(cal BP) ranges:

σ = 20	1532-1542(418-408)	1637-1648(313-302)	
σ = 40	1525-1564(425-386)	1628-1653(322-297)	
σ = 60	1516-1599(434-351)	1617-1659(333-291)	
σ = 80	1490-1665(460-285)	1784-1789(166-161)	1951-1952(0*)
σ = 100	1480-1670(470-280)	1747-1799(203-151)	1944-1954(6-0*)
σ = 120	1450-1680(500-270)	1739-1804(211-146)	1938-1955*(12-0*)
σ = 160	1440-1690(510-260)	1722-1812(228-138)	1858-1869(92-81)
	1921-1955*(29-0*)		
σ = 200	1430-1900(520-50)	1908-1955*(42-0*)	

RADIOCARBON AGE BP 300 CALIBRATED AGES: cal AD 1532, 1541, 1637
cal BP 418, 409, 313

Sample σ and cal AD(cal BP) ranges:

σ = 20	1524-1564(426-386)	1628-1642(322-308)	
σ = 40	1516-1599(434-351)	1617-1648(333-302)	
σ = 60	1490-1653(460-297)		
σ = 80	1476-1659(474-291)		
σ = 100	1450-1670(500-280)	1784-1788(166-162)	1951-1952(0*)
σ = 120	1440-1670(510-280)	1747-1799(203-151)	1944-1954(6-0*)
σ = 160	1430-1680(520-270)	1730-1808(220-142)	1931-1955*(19-0*)
σ = 200	1420-1890(530-60)	1913-1955*(37-0*)	

RADIOCARBON AGE BP 320 CALIBRATED AGES: cal AD 1525, 1563, 1628
cal BP 425, 387, 322

Sample σ and cal AD(cal BP) ranges:

σ = 20	1516-1599(434-351)	1617-1637(333-313)	
σ = 40	1490-1642(460-308)		
σ = 60	1476-1648(474-302)		
σ = 80	1450-1653(500-297)		
σ = 100	1440-1660(510-290)		
σ = 120	1440-1670(510-280)	1784-1788(166-162)	1951-1952(0*)
σ = 160	1430-1680(520-270)	1739-1804(211-146)	1938-1955*(12-0*)
σ = 200	1410-1690(540-260)	1722-1812(228-138)	1859-1869(91-81)
	1921-1955*(29-0*)		

RADIOCARBON AGE BP 340 CALIBRATED AGES: cal AD 1516, 1599, 1618
cal BP 434, 351, 332

Sample σ and cal AD(cal BP) ranges:

σ = 20	1490-1525(460-425)	1563-1629(387-321)	
σ = 40	1476-1637(474-313)		
σ = 60	1450-1642(500-308)		
σ = 80	1443-1647(507-303)		
σ = 100	1440-1650(510-300)		
σ = 120	1430-1660(520-290)		
σ = 160	1420-1670(530-280)	1747-1799(203-151)	1944-1954(6-0*)
σ = 200	1410-1680(540-270)	1730-1808(220-142)	1931-1955*(19-0*)

Table 3-E

```
RADIOCARBON AGE BP  360   CALIBRATED AGE:   cal AD 1490
                                            cal BP  460
Sample o and cal AD(cal BP) ranges:
o =  20     1467-1519(483-431)    1595-1621(355-329)
o =  40     1449-1526(501-424)    1561-1630(389-320)
o =  60     1443-1637(507-313)
o =  80     1439-1643(511-307)
o = 100     1430-1650(520-300)
o = 120     1430-1650(520-300)
o = 160     1410-1670(540-280)    1783-1792(167-158)    1951-1952(0*)
o = 200     1333-1339(617-611)    1400-1680(550-270)    1739-1804(211-146)
            1938-1955*(12-0*)
```

```
RADIOCARBON AGE BP  380   CALIBRATED AGE:   cal AD 1476
                                            cal BP  474
Sample o and cal AD(cal BP) ranges:
o =  20     1447-1494(503-456)
o =  40     1442-1518(508-432)    1596-1620(354-330)
o =  60     1438-1526(512-424)    1561-1630(389-320)
o =  80     1434-1637(516-313)
o = 100     1430-1640(520-310)
o = 120     1420-1650(530-300)
o = 160     1410-1660(540-290)
o = 200     1329-1347(621-603)    1390-1670(560-280)    1746-1799(204-151)
            1944-1954(6-0*)
```

```
RADIOCARBON AGE BP  400   CALIBRATED AGE:   cal AD 1451
                                            cal BP  499
Sample o and cal AD(cal BP) ranges:
o =  20     1442-1485(508-465)
o =  40     1438-1492(512-458)
o =  60     1434-1517(516-433)    1598-1619(352-331)
o =  80     1428-1525(522-425)    1562-1629(388-321)
o = 100     1420-1640(530-310)
o = 120     1410-1640(540-310)
o = 160     1333-1339(617-611)    1400-1650(550-300)
o = 200     1326-1365(624-585)    1390-1670(560-280)    1784-1790(166-160)
            1951-1952(0*)
```

```
RADIOCARBON AGE BP  420   CALIBRATED AGE:   cal AD 1443
                                            cal BP  507
Sample o and cal AD(cal BP) ranges:
o =  20     1437-1454(513-496)
o =  40     1433-1484(517-466)
o =  60     1428-1492(522-458)
o =  80     1421-1517(529-433)    1597-1619(353-331)
o = 100     1410-1530(540-420)    1562-1629(388-321)
o = 120     1410-1640(540-310)
o = 160     1329-1347(621-603)    1390-1650(560-300)
o = 200     1314-1369(636-581)    1390-1660(560-290)
```

Table 3-F

```
RADIOCARBON AGE BP  440   CALIBRATED AGE:   cal AD 1439
                                            cal BP  511
Sample o and cal AD(cal BP) ranges:
o =  20     1432-1445(518-505)
o =  40     1427-1453(523-497)
o =  60     1421-1481(529-469)
o =  80     1414-1491(536-459)
o = 100     1410-1520(540-430)    1598-1619(352-331)
o = 120     1333-1339(617-611)    1400-1530(550-420)    1562-1629(388-321)
o = 160     1325-1366(625-584)    1390-1640(560-310)
o = 200     1300-1650(650-300)
```

```
RADIOCARBON AGE BP  460   CALIBRATED AGE:   cal AD 1435
                                            cal BP  515
Sample o and cal AD(cal BP) ranges:
o =  20     1426-1441(524-509)
o =  40     1420-1444(530-506)
o =  60     1414-1452(536-498)
o =  80     1409-1480(541-470)
o = 100     1333-1339(617-611)    1400-1491(550-459)
o = 120     1329-1347(621-603)    1390-1520(560-430)    1598-1619(352-331)
o = 160     1314-1369(636-581)    1390-1640(560-310)
o = 200     1280-1650(670-300)
```

```
RADIOCARBON AGE BP  480   CALIBRATED AGE:   cal AD 1429
                                            cal BP  521
Sample o and cal AD(cal BP) ranges:
o =  20     1419-1437(531-513)
o =  40     1414-1440(536-510)
o =  60     1409-1444(541-506)
o =  80     1333-1340(617-610)    1399-1452(551-498)
o = 100     1329-1347(621-603)    1392-1480(558-470)
o = 120     1325-1366(625-584)    1390-1490(560-460)
o = 160     1300-1530(650-420)    1562-1629(388-321)
o = 200     1280-1640(670-310)
```

```
RADIOCARBON AGE BP  500   CALIBRATED AGE:   cal AD 1422
                                            cal BP  528
Sample o and cal AD(cal BP) ranges:
o =  20     1413-1431(537-519)
o =  40     1409-1436(541-514)
o =  60     1333-1340(617-610)    1398-1440(552-510)
o =  80     1329-1348(621-602)    1392-1444(558-506)
o = 100     1325-1366(625-584)    1389-1451(561-499)
o = 120     1313-1369(637-581)    1386-1479(564-471)
o = 160     1280-1520(670-430)    1598-1618(352-332)
o = 200     1280-1640(670-310)
```

TABLE 3-G

RADIOCARBON AGE BP 520 CALIBRATED AGE: cal AD 1415
cal BP 535

Sample o and cal AD(cal BP) ranges:

o = 20	1408-1425(542-525)	
o = 40	1333-1341(617-609)	1396-1430(554-520)
o = 60	1329-1348(621-602)	1392-1435(558-515)
o = 80	1325-1366(625-584)	1389-1440(561-510)
o = 100	1313-1370(637-580)	1386-1444(564-506)
o = 120	1300-1450(650-500)	
o = 160	1280-1490(670-460)	
o = 200	1280-1530(670-420)	1563-1629(387-321)

RADIOCARBON AGE BP 540 CALIBRATED AGE: cal AD 1410
cal BP 540

Sample o and cal AD(cal BP) ranges:

o = 20	1332-1342(618-608)	1394-1418(556-532)
o = 40	1329-1348(621-602)	1392-1424(558-526)
o = 60	1325-1366(625-584)	1389-1430(561-520)
o = 80	1312-1370(638-580)	1386-1435(564-515)
o = 100	1300-1440(650-510)	
o = 120	1280-1440(670-510)	
o = 160	1280-1480(670-470)	
o = 200	1280-1520(670-430)	1598-1618(352-332)

RADIOCARBON AGE BP 560 CALIBRATED AGES: cal AD 1334, 1338, 1403
cal BP 616, 612, 547

Sample o and cal AD(cal BP) ranges:

o = 20	1328-1349(622-601)	1392-1411(558-539)
o = 40	1325-1366(625-584)	1389-1416(561-534)
o = 60	1312-1370(638-580)	1386-1423(564-527)
o = 80	1299-1429(651-521)	
o = 100	1280-1440(670-510)	
o = 120	1280-1440(670-510)	
o = 160	1280-1450(670-500)	
o = 200	1260-1490(690-460)	

RADIOCARBON AGE BP 580 CALIBRATED AGES: cal AD 1330, 1347, 1393
cal BP 620, 603, 557

Sample o and cal AD(cal BP) ranges:

o = 20	1323-1367(627-583)	1388-1406(562-544)
o = 40	1310-1370(640-580)	1386-1411(564-539)
o = 60	1299-1416(651-534)	
o = 80	1284-1423(666-527)	
o = 100	1280-1430(670-520)	
o = 120	1280-1440(670-510)	
o = 160	1280-1440(670-510)	
o = 200	1260-1480(690-470)	

TABLE 3-H

RADIOCARBON AGE BP 600 CALIBRATED AGES: cal AD 1326, 1353, 1363, 1365, 1389
cal BP 624, 597, 587, 585, 561

Sample o and cal AD(cal BP) ranges:

o = 20	1306-1331(644-619)	1345-1370(605-580)	1385-1394(565-556)
o = 40	1298-1406(652-544)		
o = 60	1284-1410(666-540)		
o = 80	1282-1415(668-535)		
o = 100	1280-1420(670-530)		
o = 120	1280-1430(670-520)		
o = 160	1260-1440(690-510)		
o = 200	1229-1244(721-706)	1260-1450(690-500)	

RADIOCARBON AGE BP 620 CALIBRATED AGES: cal AD 1315, 1369, 1386
cal BP 635, 581, 564

Sample o and cal AD(cal BP) ranges:

o = 20	1297-1327(653-623)	1351-1390(599-560)
o = 40	1284-1330(666-620)	1346-1393(604-557)
o = 60	1282-1405(668-545)	
o = 80	1280-1410(670-540)	
o = 100	1280-1420(670-530)	
o = 120	1280-1420(670-530)	
o = 160	1260-1430(690-520)	
o = 200	1220-1440(730-510)	

RADIOCARBON AGE BP 640 CALIBRATED AGES: cal AD 1300, 1373, 1380
cal BP 650, 577, 570

Sample o and cal AD(cal BP) ranges:

o = 20	1284-1319(666-631)	1368-1387(582-563)
o = 40	1282-1326(668-624)	1352-1390(598-560)
o = 60	1280-1330(670-620)	1346-1393(604-557)
o = 80	1278-1405(672-545)	
o = 100	1280-1410(670-540)	
o = 120	1260-1420(690-530)	
o = 160	1229-1244(721-706)	1260-1430(690-520)
o = 200	1210-1440(740-510)	

RADIOCARBON AGE BP 660 CALIBRATED AGE: cal AD 1284
cal BP 666

Sample o and cal AD(cal BP) ranges:

o = 20	1281-1304(669-646)	1371-1384(579-566)
o = 40	1280-1319(670-631)	1368-1387(582-563)
o = 60	1278-1326(672-624)	1352-1390(598-560)
o = 80	1276-1330(674-620)	1346-1393(604-557)
o = 100	1260-1410(690-540)	
o = 120	1260-1410(690-540)	
o = 160	1220-1420(730-530)	
o = 200	1165-1165(785-785)	1190-1430(760-520)

Table 3-I

RADIOCARBON AGE BP 680 CALIBRATED AGE: cal AD 1282
cal BP 668

Sample o and cal AD(cal BP) ranges:

o = 20	1280-1296(670-654)		
o = 40	1278-1302(672-648)	1372-1382(578-568)	
o = 60	1276-1318(674-632)	1368-1387(582-563)	
o = 80	1262-1326(688-624)	1352-1390(598-560)	
o = 100	1259-1330(691-620)	1346-1393(604-557)	
o = 120	1230-1410(720-540)		
o = 160	1210-1420(740-530)		
o = 200	1160-1430(790-520)		

RADIOCARBON AGE BP 700 CALIBRATED AGE: cal AD 1280
cal BP 670

Sample o and cal AD(cal BP) ranges:

o = 20	1278-1283(672-667)		
o = 40	1276-1285(674-665)		
o = 60	1262-1301(688-649)	1372-1381(578-569)	
o = 80	1259-1317(691-633)	1369-1387(581-563)	
o = 100	1228-1326(722-624)	1352-1390(598-560)	
o = 120	1220-1330(730-620)	1346-1393(604-557)	
o = 160	1165-1166(785-784)	1190-1410(760-540)	
o = 200	1132-1136(818-814)	1160-1420(790-530)	

RADIOCARBON AGE BP 720 CALIBRATED AGE: cal AD 1279
cal BP 671

Sample o and cal AD(cal BP) ranges:

o = 20	1264-1281(686-669)		
o = 40	1262-1283(688-667)		
o = 60	1259-1285(691-665)		
o = 80	1227-1301(723-649)	1372-1381(578-569)	
o = 100	1218-1317(732-633)	1369-1387(581-563)	
o = 120	1210-1330(740-620)	1352-1390(598-560)	
o = 160	1160-1410(790-540)		
o = 200	1043-1091(907-859)	1122-1139(828-811)	1150-1420(800-530)

RADIOCARBON AGE BP 740 CALIBRATED AGE: cal AD 1277
cal BP 673

Sample o and cal AD(cal BP) ranges:

o = 20	1261-1279(689-671)		
o = 40	1258-1281(692-669)		
o = 60	1227-1283(723-667)		
o = 80	1218-1285(732-665)		
o = 100	1211-1301(739-649)	1372-1381(578-569)	
o = 120	1165-1166(785-784)	1190-1320(760-630)	1369-1387(581-563)
o = 160	1132-1136(818-814)	1160-1330(790-620)	1346-1393(604-557)
o = 200	1040-1410(910-540)		

Table 3-J

RADIOCARBON AGE BP 760 CALIBRATED AGE: cal AD 1263
cal BP 687

Sample o and cal AD(cal BP) ranges:

o = 20	1258-1278(692-672)		
o = 40	1225-1279(725-671)		
o = 60	1218-1281(732-669)		
o = 80	1211-1283(739-667)		
o = 100	1165-1167(785-783)	1191-1284(759-666)	
o = 120	1160-1300(790-650)	1373-1381(577-569)	
o = 160	1043-1091(907-859)	1122-1139(828-811)	1150-1330(800-620)
	1352-1390(598-560)		
o = 200	1030-1400(920-550)		

RADIOCARBON AGE BP 780 CALIBRATED AGE: cal AD 1259
cal BP 691

Sample o and cal AD(cal BP) ranges:

o = 20	1223-1276(727-674)		
o = 40	1217-1277(733-673)		
o = 60	1210-1279(740-671)		
o = 80	1165-1167(785-783)	1191-1281(759-669)	
o = 100	1160-1280(790-670)		
o = 120	1132-1136(818-814)	1160-1280(790-670)	
o = 160	1040-1320(910-630)	1369-1386(581-564)	
o = 200	1020-1330(930-620)	1346-1393(604-557)	

RADIOCARBON AGE BP 800 CALIBRATED AGES: cal AD 1230, 1243, 1256
cal BP 720, 707, 694

Sample o and cal AD(cal BP) ranges:

o = 20	1216-1261(734-689)		
o = 40	1210-1275(740-675)		
o = 60	1164-1168(786-782)	1190-1277(760-673)	
o = 80	1160-1279(790-671)		
o = 100	1131-1136(819-814)	1160-1280(790-670)	
o = 120	1043-1091(907-859)	1122-1139(828-811)	1150-1280(800-670)
o = 160	1030-1300(920-650)	1373-1380(577-570)	
o = 200	1003-1008(947-942)	1020-1330(930-620)	1353-1390(597-560)

RADIOCARBON AGE BP 820 CALIBRATED AGE: cal AD 1219
cal BP 731

Sample o and cal AD(cal BP) ranges:

o = 20	1208-1257(742-693)		
o = 40	1164-1169(786-781)	1190-1260(760-690)	
o = 60	1160-1263(790-687)	1274-1275(676-675)	
o = 80	1075-1076(875-874)	1131-1136(819-814)	1155-1277(795-673)
o = 100	1043-1091(907-859)	1121-1139(829-811)	1150-1280(800-670)
o = 120	1040-1280(910-670)		
o = 160	1020-1280(930-670)		
o = 200	1000-1320(950-630)	1369-1386(581-564)	

TABLE 3-K

RADIOCARBON AGE BP 840 CALIBRATED AGE: cal AD 1212
cal BP 738

Sample σ and cal AD(cal BP) ranges:

σ = 20	1163-1173(787-777)	1189-1223(761-727)	
σ = 40	1159-1257(791-693)		
σ = 60	1074-1077(876-873)	1131-1136(819-814)	1155-1260(795-690)
σ = 80	1043-1091(907-859)	1121-1139(829-811)	1152-1263(798-687)
σ = 100	1040-1280(910-670)		
σ = 120	1030-1280(920-670)		
σ = 160	1003-1008(947-942)	1020-1280(930-670)	
σ = 200	990-1300(960-650)	1373-1380(577-570)	

RADIOCARBON AGE BP 860 CALIBRATED AGE: cal AD 1191
cal BP 759

Sample σ and cal AD(cal BP) ranges:

σ = 20	1159-1215(791-735)		
σ = 40	1073-1079(877-871)	1130-1137(820-813)	1155-1221(795-729)
σ = 60	1042-1092(908-858)	1121-1139(829-811)	1152-1256(798-694)
σ = 80	1036-1260(914-690)		
σ = 100	1030-1260(920-690)		
σ = 120	1020-1280(930-670)		
σ = 160	1000-1280(950-670)		
σ = 200	980-1280(970-670)		

RADIOCARBON AGE BP 880 CALIBRATED AGES: cal AD 1161, 1185
cal BP 789, 765

Sample σ and cal AD(cal BP) ranges:

σ = 20	1071-1084(879-866)	1127-1137(823-813)	1154-1207(796-743)
σ = 40	1042-1093(908-857)	1120-1139(830-811)	1152-1213(798-737)
σ = 60	1035-1221(915-729)		
σ = 80	1027-1256(923-694)		
σ = 100	1020-1260(930-690)		
σ = 120	1000-1260(950-690)		
σ = 160	990-1280(960-670)		
σ = 200	980-1280(970-670)		

RADIOCARBON AGE BP 900 CALIBRATED AGES: cal AD 1133, 1136, 1156
cal BP 817, 814, 794

Sample σ and cal AD(cal BP) ranges:

σ = 20	1041-1094(909-856)	1119-1140(831-810)	1151-1162(799-788)
	1176-1188(774-762)		
σ = 40	1035-1193(915-757)	1203-1206(747-744)	
σ = 60	1027-1213(923-737)		
σ = 80	1022-1220(928-730)		
σ = 100	1000-1260(950-690)		
σ = 120	1000-1260(950-690)		
σ = 160	980-1280(970-670)		
σ = 200	906-916(1044-1034)	980-1280(970-670)	

TABLE 3-L

RADIOCARBON AGE BP 920 CALIBRATED AGES: cal AD 1043, 1090, 1122, 1139, 1152
cal BP 907, 860, 828, 811, 798

Sample σ and cal AD(cal BP) ranges:

σ = 20	1034-1157(916-793)		
σ = 40	1027-1161(923-789)	1181-1186(769-764)	
σ = 60	1022-1192(928-758)		
σ = 80	1003-1008(947-942)	1018-1212(932-738)	
σ = 100	1000-1220(950-730)		
σ = 120	990-1230(960-720)	1241-1256(709-694)	
σ = 160	980-1260(970-690)		
σ = 200	898-920(1052-1030)	940-1280(1010-670)	

RADIOCARBON AGE BP 940 CALIBRATED AGES: cal AD 1037, 1142, 1149
cal BP 913, 808, 801

Sample σ and cal AD(cal BP) ranges:

σ = 20	1026-1067(924-883)	1087-1124(863-826)	1138-1153(812-797)
σ = 40	1022-1157(928-793)		
σ = 60	1003-1161(947-789)	1182-1186(768-764)	
σ = 80	999-1192(951-758)		
σ = 100	990-1210(960-740)		
σ = 120	980-1220(970-730)		
σ = 160	906-915(1044-1035)	980-1260(970-690)	
σ = 200	892-925(1058-1025)	940-1280(1010-670)	

RADIOCARBON AGE BP 960 CALIBRATED AGES: cal AD 1028, 1144, 1146
cal BP 922, 806, 804

Sample σ and cal AD(cal BP) ranges:

σ = 20	1021-1039(929-911)	1099-1117(851-833)	1141-1150(809-800)
σ = 40	1003-1066(947-884)	1088-1124(862-826)	1138-1153(812-797)
σ = 60	999-1157(951-793)		
σ = 80	994-1161(956-789)	1183-1186(767-764)	
σ = 100	980-1190(970-760)		
σ = 120	980-1210(970-740)		
σ = 160	898-920(1052-1030)	940-1230(1010-720)	1242-1256(708-694)
σ = 200	890-1260(1060-690)		

RADIOCARBON AGE BP 980 CALIBRATED AGE: cal AD 1023
cal BP 927

Sample σ and cal AD(cal BP) ranges:

σ = 20	1002-1032(948-918)	1143-1147(807-803)	
σ = 40	998-1038(952-912)	1100-1117(850-833)	1141-1150(809-800)
σ = 60	993-1066(957-884)	1088-1124(862-826)	1138-1153(812-797)
σ = 80	984-1157(966-793)		
σ = 100	980-1160(970-790)	1182-1186(768-764)	
σ = 120	905-916(1045-1034)	980-1190(970-760)	
σ = 160	890-1220(1060-730)		
σ = 200	782-788(1168-1162)	812-816(1138-1134)	833-836(1117-1114)
	870-1260(1080-690)		

Table 3-M

RADIOCARBON AGE BP 1000 CALIBRATED AGES: cal AD 1004, 1008, 1019
cal BP 946, 942, 931

Sample σ and cal AD(cal BP) ranges:

σ = 20	997-1024(953-926)		
σ = 40	992-1031(958-919)	1144-1147(806-803)	
σ = 60	984-1038(966-912)	1102-1116(848-834)	1141-1150(809-800)
σ = 80	981-1044(969-906)	1089-1123(861-827)	1138-1153(812-797)
σ = 100	905-916(1045-1034)	980-1160(970-790)	
σ = 120	898-920(1052-1030)	940-1160(1010-790)	1182-1186(768-764)
σ = 160	890-1210(1060-740)		
σ = 200	780-790(1170-1160)	800-1230(1150-720)	1241-1256(709-694)

RADIOCARBON AGE BP 1020 CALIBRATED AGE: cal AD 999
cal BP 951

Sample σ and cal AD(cal BP) ranges:

σ = 20	990-1020(960-930)		
σ = 40	984-1024(966-926)		
σ = 60	980-1030(970-920)	1144-1146(806-804)	
σ = 80	904-916(1046-1034)	977-1038(973-912)	1103-1116(847-834)
	1141-1149(809-801)		
σ = 100	898-921(1052-1029)	940-1040(1010-910)	1089-1123(861-827)
	1138-1153(812-797)		
σ = 120	890-1160(1060-790)		
σ = 160	782-788(1168-1162)	812-816(1138-1134)	833-837(1117-1113)
	870-1190(1080-760)		
σ = 200	780-1220(1170-730)		

RADIOCARBON AGE BP 1040 CALIBRATED AGE: cal AD 995
cal BP 955

Sample σ and cal AD(cal BP) ranges:

σ = 20	983-1001(967-949)	1012-1016(938-934)	
σ = 40	980-1020(970-930)		
σ = 60	904-916(1046-1034)	977-1023(973-927)	
σ = 80	898-921(1052-1029)	941-1029(1009-921)	1144-1146(806-804)
σ = 100	890-1040(1060-910)	1103-1116(847-834)	1141-1149(809-801)
σ = 120	890-1040(1060-910)	1089-1123(861-827)	1138-1153(812-797)
σ = 160	780-790(1170-1160)	800-1160(1150-790)	1183-1186(767-764)
σ = 200	770-1210(1180-740)		

Table 3-N

RADIOCARBON AGE BP 1060 CALIBRATED AGE: cal AD 985
cal BP 965

Sample σ and cal AD(cal BP) ranges:

σ = 20	979-997(971-953)		
σ = 40	904-917(1046-1033)	976-1000(974-950)	1013-1016(937-934)
σ = 60	897-921(1053-1029)	941-1019(1009-931)	
σ = 80	891-1023(1059-927)		
σ = 100	890-1030(1060-920)	1144-1146(806-804)	
σ = 120	782-788(1168-1162)	812-816(1138-1134)	833-837(1117-1113)
	870-1040(1080-910)	1104-1116(846-834)	1141-1149(809-801)
σ = 160	780-1160(1170-790)		
σ = 200	727-745(1223-1205)	770-1190(1180-760)	

RADIOCARBON AGE BP 1080 CALIBRATED AGE: cal AD 981
cal BP 969

Sample σ and cal AD(cal BP) ranges:

σ = 20	902-918(1048-1032)	957-989(993-961)	
σ = 40	897-921(1053-1029)	940-996(1010-954)	
σ = 60	891-1000(1059-950)	1014-1015(936-935)	
σ = 80	885-1019(1065-931)		
σ = 100	782-788(1168-1162)	811-817(1139-1133)	832-837(1118-1113)
	870-1020(1080-930)		
σ = 120	780-791(1170-1159)	800-1030(1150-920)	1144-1146(806-804)
σ = 160	770-1040(1180-910)	1089-1123(861-827)	1138-1153(812-797)
σ = 200	689-751(1261-1199)	760-1160(1190-790)	1183-1185(767-765)

RADIOCARBON AGE BP 1100 CALIBRATED AGES: cal AD 910, 915, 977
cal BP 1040, 1035, 973

Sample σ and cal AD(cal BP) ranges:

σ = 20	895-922(1055-1028)	939-983(1011-967)	
σ = 40	890-988(1060-962)		
σ = 60	885-996(1065-954)		
σ = 80	782-788(1168-1162)	810-817(1140-1133)	832-837(1118-1113)
	866-1000(1084-950)	1014-1015(936-935)	
σ = 100	780-791(1170-1159)	800-1020(1150-930)	
σ = 120	780-1020(1170-930)		
σ = 160	695-696(1255-1254)	727-745(1223-1205)	770-1040(1180-910)
	1104-1115(846-835)	1141-1149(809-801)	
σ = 200	680-1160(1270-790)		

RADIOCARBON AGE BP 1120 CALIBRATED AGES: cal AD 899, 920, 942
cal BP 1051, 1030, 1008

Sample σ and cal AD(cal BP) ranges:

σ = 20	889-979(1061-971)		
σ = 40	784-786(1166-1164)	878-982(1072-968)	
σ = 60	782-788(1168-1162)	809-818(1141-1132)	831-838(1119-1112)
	866-987(1084-963)		
σ = 80	779-791(1171-1159)	802-996(1148-954)	
σ = 100	780-1000(1170-950)	1014-1015(936-935)	
σ = 120	770-1020(1180-930)		
σ = 160	689-751(1261-1199)	760-1030(1190-920)	1144-1146(806-804)
σ = 200	670-1040(1280-910)	1089-1123(861-827)	1138-1153(812-797)

TABLE 3-O

RADIOCARBON AGE BP 1140 CALIBRATED AGES: cal AD 892, 925, 936
cal BP 1058, 1025, 1014

Sample σ and cal AD(cal BP) ranges:

σ = 20	784-786(1166-1164)	873-902(1077-1048)	917-976(1033-974)
σ = 40	782-788(1168-1162)	806-819(1144-1131)	830-838(1120-1112)
	864-979(1086-971)		
σ = 60	779-791(1171-1159)	801-982(1149-968)	
σ = 80	777-986(1173-964)		
σ = 100	770-1000(1180-950)		
σ = 120	694-696(1256-1254)	726-745(1224-1205)	770-1000(1180-950)
σ = 160	680-1020(1270-930)		
σ = 200	660-1040(1290-910)	1104-1115(846-835)	1141-1149(809-801)

RADIOCARBON AGE BP 1160 CALIBRATED AGE: cal AD 886
cal BP 1064

Sample σ and cal AD(cal BP) ranges:

σ = 20	781-789(1169-1161)	804-840(1146-1110)	860-896(1090-1054)
	922-940(1028-1010)		
σ = 40	779-901(1171-1049)	918-944(1032-1006)	
σ = 60	776-978(1174-972)		
σ = 80	773-982(1177-968)		
σ = 100	694-696(1256-1254)	726-745(1224-1205)	770-990(1180-960)
σ = 120	688-751(1262-1199)	760-1000(1190-950)	
σ = 160	670-1020(1280-930)		
σ = 200	660-1030(1290-920)	1144-1146(806-804)	

RADIOCARBON AGE BP 1180 CALIBRATED AGES: cal AD 782, 788, 814, 816, 833, 836, 868
cal BP 1168, 1162, 1136, 1134, 1117, 1114, 1082

Sample σ and cal AD(cal BP) ranges:

σ = 20	779-889(1171-1061)		
σ = 40	776-894(1174-1056)	923-937(1027-1013)	
σ = 60	773-900(1177-1050)	919-943(1031-1007)	
σ = 80	694-696(1256-1254)	726-745(1224-1205)	768-978(1182-972)
σ = 100	689-751(1261-1199)	760-980(1190-970)	
σ = 120	680-990(1270-960)		
σ = 160	660-1000(1290-950)		
σ = 200	650-1020(1300-930)		

TABLE 3-P

RADIOCARBON AGE BP 1200 CALIBRATED AGES: cal AD 780, 790, 802, 842, 853
cal BP 1170, 1160, 1148, 1108, 1097

Sample σ and cal AD(cal BP) ranges:

σ = 20	776-873(1174-1077)		
σ = 40	773-888(1177-1062)		
σ = 60	694-696(1256-1254)	726-745(1224-1205)	768-893(1182-1057)
	924-937(1026-1013)		
σ = 80	689-751(1261-1199)	762-899(1188-1051)	919-943(1031-1007)
σ = 100	680-980(1270-970)		
σ = 120	670-980(1280-970)		
σ = 160	660-1000(1290-950)		
σ = 200	640-1020(1310-930)		

RADIOCARBON AGE BP 1220 CALIBRATED AGES: cal AD 777, 793, 798
cal BP 1173, 1157, 1152

Sample σ and cal AD(cal BP) ranges:

σ = 20	772-804(1178-1146)	822-828(1128-1122)	840-859(1110-1091)
σ = 40	694-696(1256-1254)	715-746(1235-1204)	768-870(1182-1080)
σ = 60	688-751(1262-1199)	762-887(1188-1063)	
σ = 80	681-893(1269-1057)	924-936(1026-1014)	
σ = 100	670-900(1280-1050)	920-942(1030-1008)	
σ = 120	660-980(1290-970)		
σ = 160	650-990(1300-960)		
σ = 200	640-1000(1310-950)		

RADIOCARBON AGE BP 1240 CALIBRATED AGE: cal AD 774
cal BP 1176

Sample σ and cal AD(cal BP) ranges:

σ = 20	694-697(1256-1253)	714-746(1236-1204)	768-778(1182-1172)
	792-799(1158-1151)		
σ = 40	688-751(1262-1199)	762-803(1188-1147)	824-826(1126-1124)
	842-856(1108-1094)		
σ = 60	681-869(1269-1081)		
σ = 80	672-887(1278-1063)		
σ = 100	660-890(1290-1060)	924-936(1026-1014)	
σ = 120	660-900(1290-1050)	920-942(1030-1008)	
σ = 160	640-980(1310-970)		
σ = 200	608-627(1342-1323)	640-1000(1310-950)	

RADIOCARBON AGE BP 1260 CALIBRATED AGES: cal AD 695, 728, 744, 769
cal BP 1255, 1222, 1206, 1181

Sample σ and cal AD(cal BP) ranges:

σ = 20	688-775(1262-1175)		
σ = 40	681-778(1269-1172)	793-799(1157-1151)	
σ = 60	672-803(1278-1147)	824-826(1126-1124)	842-855(1108-1095)
σ = 80	664-869(1286-1081)		
σ = 100	660-890(1290-1060)		
σ = 120	650-890(1300-1060)	924-936(1026-1014)	
σ = 160	640-980(1310-970)		
σ = 200	600-980(1350-970)		

Table 3-Q

RADIOCARBON AGE BP 1280 CALIBRATED AGES: cal AD 689, 702, 708, 751, 763
cal BP 1261, 1248, 1242, 1199, 1187

Sample o and cal AD(cal BP) ranges:

o = 20	679-771(1271-1179)		
o = 40	671-775(1279-1175)		
o = 60	664-777(1286-1173)	793-799(1157-1151)	
o = 80	656-803(1294-1147)	824-825(1126-1125)	842-855(1108-1095)
o = 100	650-870(1300-1080)		
o = 120	640-890(1310-1060)		
o = 160	608-627(1342-1323)	640-900(1310-1050)	920-942(1030-1008)
o = 200	580-980(1370-970)		

RADIOCARBON AGE BP 1300 CALIBRATED AGE: cal AD 682
cal BP 1268

Sample o and cal AD(cal BP) ranges:

o = 20	668-713(1282-1237)	747-767(1203-1183)	
o = 40	662-771(1288-1179)		
o = 60	655-775(1295-1175)		
o = 80	646-778(1304-1172)	792-799(1158-1151)	
o = 100	640-800(1310-1150)	824-826(1126-1124)	841-856(1109-1094)
o = 120	640-870(1310-1080)		
o = 160	600-890(1350-1060)	924-936(1026-1014)	
o = 200	560-980(1390-970)		

RADIOCARBON AGE BP 1320 CALIBRATED AGE: cal AD 672
cal BP 1278

Sample o and cal AD(cal BP) ranges:

o = 20	660-687(1290-1263)	753-759(1197-1191)	
o = 40	653-711(1297-1239)	748-766(1202-1184)	
o = 60	645-770(1305-1180)		
o = 80	643-775(1307-1175)		
o = 100	640-780(1310-1170)	793-799(1157-1151)	
o = 120	610-800(1340-1150)	824-826(1126-1124)	842-856(1108-1094)
o = 160	580-890(1370-1060)		
o = 200	540-900(1410-1050)	920-942(1030-1008)	

RADIOCARBON AGE BP 1340 CALIBRATED AGE: cal AD 665
cal BP 1285

Sample o and cal AD(cal BP) ranges:

o = 20	651-678(1299-1272)	
o = 40	645-686(1305-1264)	
o = 60	642-710(1308-1240)	749-765(1201-1185)
o = 80	640-770(1310-1180)	
o = 100	610-770(1340-1180)	
o = 120	600-780(1350-1170)	793-799(1157-1151)
o = 160	560-870(1390-1080)	
o = 200	540-890(1410-1060)	924-936(1026-1014)

Table 3-R

RADIOCARBON AGE BP 1360 CALIBRATED AGE: cal AD 656
cal BP 1294

Sample o and cal AD(cal BP) ranges:

o = 20	644-669(1306-1281)		
o = 40	642-675(1308-1275)		
o = 60	640-685(1310-1265)		
o = 80	605-690(1345-1260)	701-710(1249-1240)	749-765(1201-1185)
o = 100	600-730(1350-1220)	741-770(1209-1180)	
o = 120	580-770(1370-1180)		
o = 160	540-800(1410-1150)	824-825(1126-1125)	842-855(1108-1095)
o = 200	434-451(1516-1499)	469-500(1481-1450)	530-890(1420-1060)

RADIOCARBON AGE BP 1380 CALIBRATED AGE: cal AD 648
cal BP 1302

Sample o and cal AD(cal BP) ranges:

o = 20	641-662(1309-1288)		
o = 40	639-668(1311-1282)		
o = 60	605-674(1345-1276)		
o = 80	599-684(1351-1266)		
o = 100	580-690(1370-1260)	701-709(1249-1241)	750-765(1200-1185)
o = 120	560-730(1390-1220)	741-770(1209-1180)	
o = 160	540-780(1410-1170)	793-799(1157-1151)	
o = 200	430-870(1520-1080)		

RADIOCARBON AGE BP 1400 CALIBRATED AGE: cal AD 643
cal BP 1307

Sample o and cal AD(cal BP) ranges:

o = 20	639-652(1311-1298)		
o = 40	604-659(1346-1291)		
o = 60	599-666(1351-1284)		
o = 80	576-674(1374-1276)		
o = 100	560-680(1390-1270)		
o = 120	540-690(1410-1260)	701-709(1249-1241)	750-764(1200-1186)
o = 160	434-451(1516-1499)	469-500(1481-1450)	530-770(1420-1180)
o = 200	430-780(1520-1170)	790-803(1160-1147)	842-854(1108-1096)

RADIOCARBON AGE BP 1420 CALIBRATED AGE: cal AD 640
cal BP 1310

Sample o and cal AD(cal BP) ranges:

o = 20	603-645(1347-1305)	
o = 40	599-650(1351-1300)	
o = 60	576-658(1374-1292)	
o = 80	556-666(1394-1284)	
o = 100	540-670(1410-1280)	
o = 120	540-680(1410-1270)	
o = 160	430-730(1520-1220)	742-770(1208-1180)
o = 200	420-780(1530-1170)	793-798(1157-1152)

TABLE 3-S

RADIOCARBON AGE BP 1440 CALIBRATED AGES: cal AD 608, 627, 638
cal BP 1342, 1323, 1312

Sample σ and cal AD(cal BP) ranges:

σ = 20	583-642(1367-1308)		
σ = 40	572-644(1378-1306)		
σ = 60	556-650(1394-1300)		
σ = 80	541-658(1409-1292)		
σ = 100	540-670(1410-1280)		
σ = 120	434-451(1516-1499)	468-500(1482-1450)	530-670(1420-1280)
σ = 160	430-690(1520-1260)	701-709(1249-1241)	750-764(1200-1186)
σ = 200	410-770(1540-1180)		

RADIOCARBON AGE BP 1460 CALIBRATED AGE: cal AD 600
cal BP 1350

Sample σ and cal AD(cal BP) ranges:

σ = 20	563-639(1387-1311)		
σ = 40	545-641(1405-1309)		
σ = 60	541-644(1409-1306)		
σ = 80	536-649(1414-1301)		
σ = 100	434-452(1516-1498)	468-501(1482-1449)	530-660(1420-1290)
σ = 120	430-670(1520-1280)		
σ = 160	420-680(1530-1270)		
σ = 200	390-730(1560-1220)	743-769(1207-1181)	

RADIOCARBON AGE BP 1480 CALIBRATED AGE: cal AD 578
cal BP 1372

Sample σ and cal AD(cal BP) ranges:

σ = 20	544-604(1406-1346)	631-636(1319-1314)	
σ = 40	540-638(1410-1312)		
σ = 60	536-641(1414-1309)		
σ = 80	434-452(1516-1498)	467-501(1483-1449)	531-644(1419-1306)
σ = 100	430-650(1520-1300)		
σ = 120	430-660(1520-1290)		
σ = 160	410-670(1540-1280)		
σ = 200	358-369(1592-1581)	380-690(1570-1260)	701-709(1249-1241)
	750-764(1200-1186)		

RADIOCARBON AGE BP 1500 CALIBRATED AGE: cal AD 558
cal BP 1392

Sample σ and cal AD(cal BP) ranges:

σ = 20	539-598(1411-1352)		
σ = 40	535-602(1415-1348)	633-636(1317-1314)	
σ = 60	434-453(1516-1497)	466-502(1484-1448)	531-612(1419-1338)
	623-638(1327-1312)		
σ = 80	431-641(1519-1309)		
σ = 100	430-640(1520-1310)		
σ = 120	420-650(1530-1300)		
σ = 160	390-670(1560-1280)		
σ = 200	264-271(1686-1679)	340-680(1610-1270)	

TABLE 3-T

RADIOCARBON AGE BP 1520 CALIBRATED AGE: cal AD 542
cal BP 1408

Sample σ and cal AD(cal BP) ranges:

σ = 20	476-490(1474-1460)	534-564(1416-1386)	
σ = 40	433-454(1517-1496)	465-516(1485-1434)	531-596(1419-1354)
σ = 60	430-602(1520-1348)	634-635(1316-1315)	
σ = 80	427-611(1523-1339)	625-638(1325-1312)	
σ = 100	420-640(1530-1310)		
σ = 120	410-640(1540-1310)		
σ = 160	358-369(1592-1581)	380-660(1570-1290)	
σ = 200	261-279(1689-1671)	294-296(1656-1654)	340-670(1610-1280)

RADIOCARBON AGE BP 1540 CALIBRATED AGE: cal AD 537
cal BP 1413

Sample σ and cal AD(cal BP) ranges:

σ = 20	433-517(1517-1433)	530-544(1420-1406)
σ = 40	430-562(1520-1388)	
σ = 60	427-581(1523-1369)	592-596(1358-1354)
σ = 80	419-601(1531-1349)	634-635(1316-1315)
σ = 100	410-610(1540-1340)	626-638(1324-1312)
σ = 120	390-640(1560-1310)	
σ = 160	264-271(1686-1679)	340-650(1610-1300)
σ = 200	258-300(1692-1650)	320-670(1630-1280)

RADIOCARBON AGE BP 1560 CALIBRATED AGES: cal AD 435, 450, 470, 499, 532
cal BP 1515, 1500, 1480, 1451, 1418

Sample σ and cal AD(cal BP) ranges:

σ = 20	430-539(1520-1411)		
σ = 40	427-543(1523-1407)		
σ = 60	418-561(1532-1389)		
σ = 80	410-580(1540-1370)	594-595(1356-1355)	
σ = 100	390-600(1560-1350)		
σ = 120	358-369(1592-1581)	380-610(1570-1340)	626-638(1324-1312)
σ = 160	261-279(1689-1671)	294-296(1656-1654)	340-640(1610-1310)
σ = 200	260-660(1690-1290)		

RADIOCARBON AGE BP 1580 CALIBRATED AGES: cal AD 431, 520, 528
cal BP 1519, 1430, 1422

Sample σ and cal AD(cal BP) ranges:

σ = 20	427-475(1523-1475)	491-534(1459-1416)
σ = 40	418-538(1532-1412)	
σ = 60	410-542(1540-1408)	
σ = 80	392-560(1558-1390)	
σ = 100	358-369(1592-1581)	380-580(1570-1370)
σ = 120	264-271(1686-1679)	340-600(1610-1350)
σ = 160	258-300(1692-1650)	320-640(1630-1310)
σ = 200	230-650(1720-1300)	

Table 3-U

RADIOCARBON AGE BP 1600 CALIBRATED AGE: cal AD 428
cal BP 1522

Sample σ and cal AD(cal BP) ranges:

σ = 20	414-433(1536-1517)	517-530(1433-1420)	
σ = 40	409-473(1541-1477)	495-534(1455-1416)	
σ = 60	392-538(1558-1412)		
σ = 80	357-370(1593-1580)	382-542(1568-1408)	
σ = 100	264-272(1686-1678)	340-560(1610-1390)	
σ = 120	261-279(1689-1671)	294-296(1656-1654)	340-580(1610-1370)
σ = 160	260-610(1690-1340)	626-638(1324-1312)	
σ = 200	184-187(1766-1763)	230-640(1720-1310)	

RADIOCARBON AGE BP 1620 CALIBRATED AGE: cal AD 423
cal BP 1527

Sample σ and cal AD(cal BP) ranges:

σ = 20	408-430(1542-1520)	524-526(1426-1424)	
σ = 40	391-432(1559-1518)	518-529(1432-1421)	
σ = 60	357-370(1593-1580)	382-437(1568-1513)	448-472(1502-1478)
	497-533(1453-1417)		
σ = 80	264-272(1686-1678)	341-537(1609-1413)	
σ = 100	261-279(1689-1671)	294-296(1656-1654)	340-540(1610-1410)
σ = 120	258-301(1692-1649)	320-560(1630-1390)	
σ = 160	230-600(1720-1350)		
σ = 200	174-198(1776-1752)	220-640(1730-1310)	

RADIOCARBON AGE BP 1640 CALIBRATED AGE: cal AD 411
cal BP 1539

Sample σ and cal AD(cal BP) ranges:

σ = 20	363-366(1587-1584)	388-426(1562-1524)	
σ = 40	356-370(1594-1580)	381-429(1569-1521)	
σ = 60	264-274(1686-1676)	341-432(1609-1518)	519-529(1431-1421)
σ = 80	261-279(1689-1671)	293-296(1657-1654)	336-436(1614-1514)
	448-472(1502-1478)	497-533(1453-1417)	
σ = 100	258-301(1692-1649)	320-540(1630-1410)	
σ = 120	260-540(1690-1410)		
σ = 160	184-187(1766-1763)	230-580(1720-1370)	
σ = 200	130-610(1820-1340)	626-638(1324-1312)	

RADIOCARBON AGE BP 1660 CALIBRATED AGE: cal AD 394
cal BP 1556

Sample σ and cal AD(cal BP) ranges:

σ = 20	356-371(1594-1579)	381-413(1569-1537)	
σ = 40	264-273(1686-1677)	341-425(1609-1525)	
σ = 60	261-279(1689-1671)	294-296(1656-1654)	336-428(1614-1522)
σ = 80	258-301(1692-1649)	321-432(1629-1518)	520-528(1430-1422)
σ = 100	260-430(1690-1520)	449-471(1501-1479)	498-533(1452-1417)
σ = 120	230-540(1720-1410)		
σ = 160	174-198(1776-1752)	220-560(1730-1390)	
σ = 200	130-600(1820-1350)		

Table 3-V

RADIOCARBON AGE BP 1680 CALIBRATED AGES: cal AD 359, 369, 383
cal BP 1591, 1581, 1567

Sample σ and cal AD(cal BP) ranges:

σ = 20	263-276(1687-1674)	340-407(1610-1543)	
σ = 40	261-279(1689-1671)	293-296(1657-1654)	335-412(1615-1538)
σ = 60	258-301(1692-1649)	321-425(1629-1525)	
σ = 80	255-428(1695-1522)		
σ = 100	230-430(1720-1520)	520-528(1430-1422)	
σ = 120	184-187(1766-1763)	230-430(1720-1520)	449-471(1501-1479)
	498-533(1452-1417)		
σ = 160	130-540(1820-1410)		
σ = 200	83-90(1867-1860)	130-580(1820-1370)	

RADIOCARBON AGE BP 1700 CALIBRATED AGES: cal AD 264, 269, 342, 374, 376
cal BP 1686, 1681, 1608, 1576, 1574

Sample σ and cal AD(cal BP) ranges:

σ = 20	260-280(1690-1670)	292-297(1658-1653)	325-387(1625-1563)
σ = 40	258-301(1692-1649)	320-406(1630-1544)	
σ = 60	255-412(1695-1538)		
σ = 80	234-425(1716-1525)		
σ = 100	184-187(1766-1763)	230-430(1720-1520)	
σ = 120	174-198(1776-1752)	210-430(1740-1520)	520-528(1430-1422)
σ = 160	130-540(1820-1410)		
σ = 200	80-560(1870-1390)		

RADIOCARBON AGE BP 1720 CALIBRATED AGES: cal AD 261, 278, 294, 295, 337
cal BP 1689, 1672, 1656, 1655, 1613

Sample σ and cal AD(cal BP) ranges:

σ = 20	257-302(1693-1648)	319-345(1631-1605)	372-380(1578-1570)
σ = 40	252-386(1698-1564)		
σ = 60	233-406(1717-1544)		
σ = 80	183-188(1767-1762)	227-412(1723-1538)	
σ = 100	174-198(1776-1752)	210-430(1740-1520)	
σ = 120	130-430(1820-1520)		
σ = 160	83-90(1867-1860)	130-430(1820-1520)	449-470(1501-1480)
	498-533(1452-1417)		
σ = 200	70-540(1880-1410)		

RADIOCARBON AGE BP 1740 CALIBRATED AGES: cal AD 258, 283, 288, 300, 321
cal BP 1692, 1667, 1662, 1650, 1629

Sample σ and cal AD(cal BP) ranges:

σ = 20	245-263(1705-1687)	276-339(1674-1611)	
σ = 40	233-344(1717-1606)	373-378(1577-1572)	
σ = 60	183-189(1767-1761)	227-385(1723-1565)	
σ = 80	173-198(1777-1752)	214-405(1736-1545)	
σ = 100	130-410(1820-1540)		
σ = 120	130-430(1820-1520)		
σ = 160	80-430(1870-1520)	520-528(1430-1422)	
σ = 200	33-36(1917-1914)	60-540(1890-1410)	

TABLE 3-W

RADIOCARBON AGE BP 1760 CALIBRATED AGES: cal AD 256, 305, 316
cal BP 1694, 1645, 1634

Sample σ and cal AD(cal BP) ranges:

σ = 20	232-260(1718-1690)	281-324(1669-1626)	
σ = 40	182-190(1768-1760)	227-262(1723-1688)	277-338(1673-1612)
σ = 60	173-199(1777-1751)	214-343(1736-1607)	373-377(1577-1573)
σ = 80	132-384(1818-1566)		
σ = 100	130-410(1820-1540)		
σ = 120	83-90(1867-1860)	130-410(1820-1540)	
σ = 160	70-430(1880-1520)		
σ = 200	30-430(1920-1520)	449-470(1501-1480)	498-532(1452-1418)

RADIOCARBON AGE BP 1780 CALIBRATED AGE: cal AD 234
cal BP 1716

Sample σ and cal AD(cal BP) ranges:

σ = 20	180-193(1770-1757)	225-257(1725-1693)	303-319(1647-1631)
σ = 40	135-145(1815-1805)	172-199(1778-1751)	213-259(1737-1691)
	282-323(1668-1627)		
σ = 60	132-262(1818-1688)	277-338(1673-1612)	
σ = 80	130-343(1820-1607)	373-377(1577-1573)	
σ = 100	83-91(1867-1859)	130-380(1820-1570)	
σ = 120	80-390(1870-1560)		
σ = 160	33-36(1917-1914)	60-420(1890-1530)	
σ = 200	4-8(1946-1942)	20-430(1930-1520)	520-528(1430-1422)

RADIOCARBON AGE BP 1800 CALIBRATED AGES: cal AD 185, 186, 228
cal BP 1765, 1764, 1722

Sample σ and cal AD(cal BP) ranges:

σ = 20	134-152(1816-1798)	169-201(1781-1749)	211-245(1739-1705)
σ = 40	132-256(1818-1694)	303-318(1647-1632)	
σ = 60	129-259(1821-1691)	282-323(1668-1627)	
σ = 80	82-92(1868-1858)	127-262(1823-1688)	278-338(1672-1612)
σ = 100	80-340(1870-1610)	373-377(1577-1573)	
σ = 120	70-380(1880-1570)		
σ = 160	30-410(1920-1540)		
σ = 200	cal BC 87-84(2036-2033)	cal BC 36-33(1985-1982)	
	cal BC 19-13(1968-1962)	1-430(1949-1520)	

RADIOCARBON AGE BP 1820 CALIBRATED AGES: cal AD 175, 198, 216
cal BP 1775, 1752, 1734

Sample σ and cal AD(cal BP) ranges:

σ = 20	131-232(1819-1718)		
σ = 40	129-241(1821-1709)		
σ = 60	82-106(1868-1844)	127-256(1823-1694)	304-317(1646-1633)
σ = 80	75-259(1875-1691)	282-322(1668-1628)	
σ = 100	70-260(1880-1690)	278-337(1672-1613)	
σ = 120	33-36(1917-1914)	50-340(1900-1610)	374-377(1576-1573)
σ = 160	4-8(1946-1942)	20-390(1930-1560)	
σ = 200	cal BC 89-81(2038-2030)	cal BC 68-60(2017-2009)	
	cal BC 40-cal AD 420(1990-1530)		

TABLE 3-X

RADIOCARBON AGE BP 1840 CALIBRATED AGES: cal AD 133, 203, 207
cal BP 1817, 1747, 1743

Sample σ and cal AD(cal BP) ranges:

σ = 20	129-179(1821-1771)	195-224(1755-1726)	
σ = 40	82-93(1868-1857)	127-230(1823-1720)	
σ = 60	76-236(1874-1714)		
σ = 80	68-256(1882-1694)	304-317(1646-1633)	
σ = 100	33-36(1917-1914)	50-260(1900-1690)	282-289(1668-1661)
	300-322(1650-1628)		
σ = 120	30-260(1920-1690)	278-337(1672-1613)	
σ = 160	cal BC 87-84(2036-2033)	cal BC 36-34(1985-1983)	
	cal BC 19-13(1968-1962)	1-380(1949-1570)	
σ = 200	cal BC 90-cal AD 410(2040-1540)		

RADIOCARBON AGE BP 1860 CALIBRATED AGE: cal AD 130
cal BP 1820

Sample σ and cal AD(cal BP) ranges:

σ = 20	82-106(1868-1844)	127-134(1823-1816)	160-167(1790-1783)
	202-209(1748-1741)		
σ = 40	76-176(1874-1774)	197-219(1753-1731)	
σ = 60	68-229(1882-1721)		
σ = 80	33-36(1917-1914)	55-235(1895-1715)	
σ = 100	30-260(1920-1690)	305-316(1645-1634)	
σ = 120	4-8(1946-1942)	20-260(1930-1690)	283-288(1667-1662)
	300-322(1650-1628)		
σ = 160	cal BC 89-81(2038-2030)	cal BC 68-60(2017-2009)	
	cal BC 40-cal AD 340(1990-1610)	374-376(1576-1574)	
σ = 200	cal BC 90-cal AD 390(2040-1560)		

RADIOCARBON AGE BP 1880 CALIBRATED AGES: cal AD 84, 89, 127
cal BP 1866, 1861, 1823

Sample σ and cal AD(cal BP) ranges:

σ = 20	74-131(1876-1819)		
σ = 40	67-134(1883-1816)	160-166(1790-1784)	202-209(1748-1741)
σ = 60	33-37(1917-1913)	55-176(1895-1774)	197-219(1753-1731)
σ = 80	28-229(1922-1721)		
σ = 100	4-8(1946-1942)	20-230(1930-1720)	
σ = 120	cal BC 87-84(2036-2033)	cal BC 36-33(1985-1982)	
	cal BC 19-13(1968-1962)	1-260(1949-1690)	304-316(1646-1634)
σ = 160	cal BC 90-cal AD 260(2040-1690)	278-337(1672-1613)	
σ = 200	cal BC 100-cal AD 380(2050-1570)		

TABLE 3-Y

RADIOCARBON AGE BP 1900 CALIBRATED AGE: cal AD 77
cal BP 1873

Sample σ and cal AD(cal BP) ranges:

σ = 20	65-129(1885-1821)		
σ = 40	32-37(1918-1913)	54-131(1896-1819)	
σ = 60	28-133(1922-1817)	162-166(1788-1784)	202-209(1748-1741)
σ = 80	4-9(1946-1941)	21-176(1929-1774)	197-219(1753-1731)
σ = 100	cal BC 87-84(2036-2033)	cal BC 66-65(2015-2014)	
	cal BC 36-33(1985-1982)	cal BC 20-13(1969-1962)	
	1-230(1949-1720)		
σ = 120	cal BC 89-81(2038-2030)	cal BC 68-60(2017-2009)	
	cal BC 40-cal AD 230(1990-1720)		
σ = 160	cal BC 90-cal AD 260(2040-1690)	282-289(1668-1661)	
	300-322(1650-1628)		
σ = 200	cal BC 167-142(2116-2091)	cal BC 120-cal AD 340(2070-1610)	
	374-376(1576-1574)		

RADIOCARBON AGE BP 1920 CALIBRATED AGE: cal AD 69
cal BP 1881

Sample σ and cal AD(cal BP) ranges:

σ = 20	32-37(1918-1913)	54-79(1896-1871)	119-125(1831-1825)
σ = 40	28-128(1922-1822)		
σ = 60	4-8(1946-1942)	21-130(1929-1820)	
σ = 80	cal BC 87-84(2036-2033)	cal BC 36-33(1985-1982)	
	cal BC 19-13(1968-1962)	1-133(1949-1817)	203-208(1747-1742)
σ = 100	cal BC 89-81(2038-2030)	cal BC 68-60(2017-2009)	
	cal BC 40-cal AD 180(1990-1770)	197-218(1753-1732)	
σ = 120	cal BC 90-cal AD 230(2040-1720)		
σ = 160	cal BC 100-cal AD 260(2050-1690)	305-316(1645-1634)	
σ = 200	cal BC 170-cal AD 260(2120-1690)	278-337(1672-1613)	

RADIOCARBON AGE BP 1940 CALIBRATED AGES: cal AD 34, 36, 57
cal BP 1916, 1914, 1893

Sample σ and cal AD(cal BP) ranges:

σ = 20	27-71(1923-1879)		
σ = 40	3-9(1947-1941)	21-78(1929-1872)	
σ = 60	cal BC 87-84(2036-2033)	cal BC 66-65(2015-2014)	
	cal BC 36-33(1985-1982)	cal BC 20-13(1969-1962)	
	1-128(1949-1822)		
σ = 80	cal BC 89-81(2038-2030)	cal BC 68-60(2017-2009)	
	cal BC 42-cal AD 130(1991-1820)		
σ = 100	cal BC 90-cal AD 130(2040-1820)	203-208(1747-1742)	
σ = 120	cal BC 90-cal AD 180(2040-1770)	197-217(1753-1733)	
σ = 160	cal BC 167-142(2116-2091)	cal BC 120-cal AD 230(2070-1720)	
σ = 200	cal BC 199-189(2148-2138)	cal BC 170-cal AD 260(2120-1690)	
	283-288(1667-1662)	300-322(1650-1628)	

TABLE 3-Z

RADIOCARBON AGE BP 1960 CALIBRATED AGES: cal AD 29, 40, 50
cal BP 1921, 1910, 1900

Sample σ and cal AD(cal BP) ranges:

σ = 20	3-62(1947-1888)	
σ = 40	cal BC 87-84(2036-2033)	cal BC 66-65(2015-2014)
	cal BC 37-33(1986-1982)	cal BC 20-13(1969-1962)
	1-70(1949-1880)	
σ = 60	cal BC 89-81(2038-2030)	cal BC 68-60(2017-2009)
	cal BC 42-cal AD 77(1991-1873)	
σ = 80	cal BC 91-cal AD 128(2040-1822)	
σ = 100	cal BC 90-cal AD 130(2040-1820)	
σ = 120	cal BC 100-cal AD 130(2050-1820)	203-208(1747-1742)
σ = 160	cal BC 170-cal AD 230(2120-1720)	
σ = 200	cal BC 342-325(2291-2274)	cal BC 200-cal AD 260(2150-1690)
	305-316(1645-1634)	

RADIOCARBON AGE BP 1980 CALIBRATED AGES: cal AD 4, 7, 23, 45
cal BP 1946, 1943, 1927, 1905

Sample σ and cal AD(cal BP) ranges:

σ = 20	cal BC 87-83(2036-2032)	cal BC 66-64(2015-2013)
	cal BC 37-32(1986-1981)	cal BC 20-12(1969-1961)
	cal BC 1-cal AD 51(1950-1899)	
σ = 40	cal BC 89-81(2038-2030)	cal BC 68-59(2017-2008)
	cal BC 42-cal AD 59(1991-1891)	
σ = 60	cal BC 91-cal AD 70(2040-1880)	
σ = 80	cal BC 93-cal AD 77(2042-1873)	
σ = 100	cal BC 100-cal AD 130(2050-1820)	
σ = 120	cal BC 167-142(2116-2091)	cal BC 120-cal AD 130(2070-1820)
σ = 160	cal BC 199-189(2148-2138)	cal BC 170-cal AD 180(2120-1770)
	197-217(1753-1733)	
σ = 200	cal BC 348-320(2297-2269)	cal BC 306-305(2255-2254)
	cal BC 227-223(2176-2172)	cal BC 210-cal AD 230(2160-1720)

RADIOCARBON AGE BP 2000 CALIBRATED AGES: cal AD 86, 84, 36, 34, 19, 13, 1
cal BP 2035, 2033, 1985, 1983, 1968, 1962, 1949

Sample σ and cal AD(cal BP) ranges:

σ = 20	cal BC 89-81(2038-2030)	cal BC 69-59(2018-2008)
	cal BC 42-cal AD 25(1991-1925)	44-46(1906-1904)
σ = 40	cal BC 91-cal AD 29(2040-1921)	40-51(1910-1899)
σ = 60	cal BC 93-cal AD 58(2042-1892)	
σ = 80	cal BC 95-cal AD 70(2044-1880)	
σ = 100	cal BC 167-142(2116-2091)	cal BC 120-cal AD 80(2070-1870)
σ = 120	cal BC 170-cal AD 130(2120-1820)	
σ = 160	cal BC 342-325(2291-2274)	cal BC 200-cal AD 130(2150-1820)
	203-208(1747-1742)	
σ = 200	cal BC 352-295(2301-2244)	cal BC 230-cal AD 230(2180-1720)

TABLE 3-AA

RADIOCARBON AGE BP 2020 CALIBRATED AGES: cal BC 89, 81, 68, 60, 41, 9, 3
cal BP 2038, 2030, 2017, 2009, 1990, 1958, 1952

Sample σ and cal BC(cal BP) ranges:
σ = 20 cal BC 91-cal AD 1(2040-1949)
σ = 40 cal BC 93-cal AD 24(2042-1926) cal AD 44-46(1906-1904)
σ = 60 cal BC 95-cal AD 29(2044-1921) cal AD 40-51(1910-1899)
σ = 80 167-142(2116-2091) cal BC 121-cal AD 58(2070-1892)
σ = 100 cal BC 170-cal AD 70(2120-1880)
σ = 120 199-189(2148-2138) cal BC 170-cal AD 80(2120-1870)
σ = 160 348-320(2297-2269) 306-305(2255-2254) 227-223(2176-2172)
cal BC 210-cal AD 130(2160-1820)
σ = 200 356-274(2305-2223) 259-248(2208-2197)
cal BC 230-cal AD 180(2180-1770) cal AD 197-217(1753-1733)

RADIOCARBON AGE BP 2040 CALIBRATED AGES: cal BC 91, 79, 71
cal BP 2040, 2028, 2020

Sample σ and cal BC(cal BP) ranges:
σ = 20 93-40(2042-1989) 27-24(1976-1973) 10-2(1959-1951)
σ = 40 cal BC 106-cal AD 1(2055-1949)
σ = 60 167-142(2116-2091) cal BC 121-cal AD 24(2070-1926)
cal AD 44-46(1906-1904)
σ = 80 cal BC 171-cal AD 29(2120-1921) cal AD 40-51(1910-1899)
σ = 100 199-189(2148-2138) cal BC 170-cal AD 60(2120-1890)
σ = 120 342-325(2291-2274) cal BC 200-cal AD 70(2150-1880)
σ = 160 352-295(2301-2244) cal BC 230-cal AD 130(2180-1820)
σ = 200 cal BC 360-cal AD 130(2310-1820) cal AD 203-208(1747-1742)

RADIOCARBON AGE BP 2060 CALIBRATED AGES: cal BC 93, 77, 74
cal BP 2042, 2026, 2023

Sample σ and cal BC(cal BP) ranges:
σ = 20 156-155(2105-2104) 109-90(2058-2039) 80-70(2029-2019)
56-45(2005-1994)
σ = 40 167-142(2116-2091) 121-40(2070-1989) 9-2(1958-1951)
σ = 60 cal BC 171-cal AD 1(2120-1949)
σ = 80 199-189(2148-2138) cal BC 174-cal AD 24(2123-1926)
cal AD 44-45(1906-1905)
σ = 100 342-325(2291-2274) cal BC 200-cal AD 30(2150-1920)
cal AD 40-51(1910-1899)
σ = 120 348-319(2297-2268) 307-305(2256-2254) 227-223(2176-2172)
cal BC 210-cal AD 60(2160-1890)
σ = 160 356-274(2305-2223) 259-247(2208-2196)
cal BC 230-cal AD 80(2180-1870)
σ = 200 cal BC 380-cal AD 130(2330-1820)

TABLE 3-BB

RADIOCARBON AGE BP 2080 CALIBRATED AGE: cal BC 95
cal BP 2044

Sample σ and cal BC(cal BP) ranges:
σ = 20 167-141(2116-2090) 123-92(2072-2041) 77-73(2026-2022)
σ = 40 171-90(2120-2039) 79-70(2028-2019) 56-50(2005-1999)
σ = 60 199-188(2148-2137) 174-41(2123-1990) 9-2(1958-1951)
σ = 80 342-325(2291-2274) cal BC 205-cal AD 1(2154-1949)
σ = 100 348-319(2297-2268) 307-304(2256-2253) 228-223(2177-2172)
cal BC 210-cal AD 20(2160-1930) cal AD 44-45(1906-1905)
σ = 120 352-295(2301-2244) cal BC 230-cal AD 30(2180-1920)
cal AD 40-50(1910-1900)
σ = 160 cal BC 360-cal AD 70(2310-1880)
σ = 200 cal BC 390-cal AD 130(2340-1820)

RADIOCARBON AGE BP 2100 CALIBRATED AGES: cal BC 166, 143, 120
cal BP 2115, 2092, 2069

Sample σ and cal BC(cal BP) ranges:
σ = 20 171-94(2120-2043)
σ = 40 200-187(2149-2136) 175-92(2124-2041) 77-73(2026-2022)
σ = 60 343-324(2292-2273) 205-90(2154-2039) 79-71(2028-2020)
56-51(2005-2000)
σ = 80 348-319(2297-2268) 307-304(2256-2253) 228-223(2177-2172)
209-41(2158-1990) 9-2(1958-1951)
σ = 100 352-294(2301-2243) cal BC 230-cal AD 1(2180-1949)
σ = 120 356-273(2305-2222) 259-247(2208-2196)
cal BC 230-cal AD 20(2180-1930) cal AD 44-45(1906-1905)
σ = 160 cal BC 380-cal AD 60(2330-1890)
σ = 200 cal BC 390-cal AD 80(2340-1870)

RADIOCARBON AGE BP 2120 CALIBRATED AGES: cal BC 170, 138, 130
cal BP 2119, 2087, 2079

Sample σ and cal BC(cal BP) ranges:
σ = 20 201-186(2150-2135) 175-163(2124-2112) 144-116(2093-2065)
σ = 40 344-324(2293-2273) 205-95(2154-2044)
σ = 60 348-319(2297-2268) 308-304(2257-2253) 228-223(2177-2172)
209-93(2158-2042) 77-73(2026-2022)
σ = 80 352-294(2301-2243) 231-90(2180-2039) 79-71(2028-2020)
55-53(2004-2002)
σ = 100 356-273(2305-2222) 259-247(2208-2196) 230-40(2180-1990)
9-2(1958-1951)
σ = 120 cal BC 360-cal AD 1(2310-1949)
σ = 160 cal BC 390-cal AD 30(2340-1920) cal AD 40-50(1910-1900)
σ = 200 cal BC 400-cal AD 70(2350-1880)

Table 3-CC

RADIOCARBON AGE BP 2140 CALIBRATED AGES: cal BC 199, 189, 174
cal BP 2148, 2138, 2123

Sample σ and cal BC(cal BP) ranges:

σ = 20	346-323(2295-2272)	226-225(2175-2174)	206-168(2155-2117)
	140-125(2089-2074)		
σ = 40	349-302(2298-2251)	228-222(2177-2171)	209-165(2158-2114)
	144-117(2093-2066)		
σ = 60	353-294(2302-2243)	231-95(2180-2044)	
σ = 80	357-273(2306-2222)	259-246(2208-2195)	234-93(2183-2042)
	77-73(2026-2022)		
σ = 100	360-90(2310-2040)	79-71(2028-2020)	55-52(2004-2001)
σ = 120	380-40(2330-1990)	9-2(1958-1951)	
σ = 160	cal BC 390-cal AD 20(2340-1930)	cal AD 44-45(1906-1905)	
σ = 200	cal BC 400-cal AD 60(2350-1890)		

RADIOCARBON AGE BP 2160 CALIBRATED AGES: cal BC 341, 325, 204
cal BP 2290, 2274, 2153

Sample σ and cal BC(cal BP) ranges:

σ = 20	350-300(2299-2249)	229-221(2178-2170)	210-172(2159-2121)
σ = 40	353-293(2302-2242)	256-255(2205-2204)	231-169(2180-2118)
	139-128(2088-2077)		
σ = 60	357-273(2306-2222)	260-246(2209-2195)	234-166(2183-2115)
	143-118(2092-2067)		
σ = 80	363-95(2312-2044)		
σ = 100	380-90(2330-2040)	77-73(2026-2022)	
σ = 120	390-90(2340-2040)	79-71(2028-2020)	55-54(2004-2003)
σ = 160	cal BC 400-cal AD 1(2350-1949)		
σ = 200	cal BC 400-cal AD 30(2350-1920)	cal AD 40-50(1910-1900)	

RADIOCARBON AGE BP 2180 CALIBRATED AGES: cal BC 348, 320, 306, 305, 227, 223, 208
cal BP 2297, 2269, 2255, 2254, 2176, 2172, 2157

Sample σ and cal BC(cal BP) ranges:

σ = 20	353-293(2302-2242)	256-254(2205-2203)	231-202(2180-2151)
σ = 40	357-273(2306-2222)	260-246(2209-2195)	234-173(2183-2122)
σ = 60	363-170(2312-2119)	138-129(2087-2078)	
σ = 80	384-166(2333-2115)	143-119(2092-2068)	
σ = 100	390-90(2340-2040)		
σ = 120	390-90(2340-2040)	77-74(2026-2023)	
σ = 160	400-40(2350-1990)	9-2(1958-1951)	
σ = 200	cal BC 410-cal AD 20(2360-1930)	cal AD 44-45(1906-1905)	

Table 3-DD

RADIOCARBON AGE BP 2200 CALIBRATED AGES: cal BC 352, 295, 230, 219, 212
cal BP 2301, 2244, 2179, 2168, 2161

Sample σ and cal BC(cal BP) ranges:

σ = 20	358-347(2307-2296)	322-272(2271-2221)	260-207(2209-2156)
σ = 40	363-339(2312-2288)	328-203(2277-2152)	
σ = 60	384-174(2333-2123)		
σ = 80	389-170(2338-2119)	138-129(2087-2078)	
σ = 100	390-170(2340-2120)	143-119(2092-2068)	
σ = 120	400-90(2350-2040)		
σ = 160	400-90(2350-2040)	79-71(2028-2020)	
σ = 200	476-475(2425-2424)	cal BC 410-cal AD 1(2360-1949)	

RADIOCARBON AGE BP 2220 CALIBRATED AGES: cal BC 356, 289, 279, 274, 259, 248, 233
cal BP 2305, 2238, 2228, 2223, 2208, 2197, 2182

Sample σ and cal BC(cal BP) ranges:

σ = 20	376-350(2325-2299)	317-313(2266-2262)	299-210(2248-2159)
σ = 40	385-347(2334-2296)	321-207(2270-2156)	
σ = 60	389-339(2338-2288)	328-203(2277-2152)	
σ = 80	393-174(2342-2123)		
σ = 100	400-170(2350-2120)	138-129(2087-2078)	
σ = 120	400-170(2350-2120)	143-119(2092-2068)	
σ = 160	410-90(2360-2040)	77-74(2026-2023)	
σ = 200	507-504(2456-2453)	485-470(2434-2419)	430-40(2380-1990)
	9-3(1958-1952)		

RADIOCARBON AGE BP 2240 CALIBRATED AGES: cal BC 362, 268, 263
cal BP 2311, 2217, 2212

Sample σ and cal BC(cal BP) ranges:

σ = 20	386-354(2335-2303)	292-232(2241-2181)	217-214(2166-2163)
σ = 40	390-351(2339-2300)	316-315(2265-2264)	297-211(2246-2160)
σ = 60	393-347(2342-2296)	321-208(2270-2157)	
σ = 80	397-340(2346-2289)	327-204(2276-2153)	
σ = 100	400-170(2350-2120)		
σ = 120	400-170(2350-2120)	138-129(2087-2078)	
σ = 160	476-475(2425-2424)	410-90(2360-2040)	
σ = 200	744-726(2693-2675)	519-465(2468-2414)	440-90(2390-2040)
	79-71(2028-2020)		

TABLE 3-EE

RADIOCARBON AGE BP 2260 CALIBRATED AGE: cal BC 382
cal BP 2331

Sample σ and cal BC(cal BP) ranges:

σ = 20	390-359(2339-2308)	286-285(2235-2234)	271-261(2220-2210)
	239-235(2188-2184)		
σ = 40	394-355(2343-2304)	291-233(2240-2182)	216-215(2165-2164)
σ = 60	397-351(2346-2300)	296-211(2245-2160)	
σ = 80	401-347(2350-2296)	320-208(2269-2157)	
σ = 100	404-340(2353-2289)	330-200(2280-2150)	
σ = 120	410-170(2360-2120)		
σ = 160	507-503(2456-2452)	485-470(2434-2419)	430-170(2380-2120)
	143-119(2092-2068)		
σ = 200	755-692(2704-2641)	588-581(2537-2530)	542-460(2491-2409)
	450-90(2400-2040)	77-74(2026-2023)	

RADIOCARBON AGE BP 2280 CALIBRATED AGE: cal BC 389
cal BP 2338

Sample σ and cal BC(cal BP) ranges:

σ = 20	395-365(2344-2314)		
σ = 40	398-360(2347-2309)	270-262(2219-2211)	236-235(2185-2184)
σ = 60	401-355(2350-2304)	290-233(2239-2182)	216-215(2165-2164)
σ = 80	404-351(2353-2300)	296-230(2245-2179)	220-212(2169-2161)
σ = 100	408-348(2357-2297)	320-210(2270-2160)	
σ = 120	476-475(2425-2424)	411-340(2360-2289)	330-200(2280-2150)
σ = 160	744-726(2693-2675)	519-464(2468-2413)	440-170(2390-2120)
	138-129(2087-2078)		
σ = 200	759-686(2708-2635)	658-637(2607-2586)	617-615(2566-2564)
	592-571(2541-2520)	560-90(2510-2040)	

RADIOCARBON AGE BP 2300 CALIBRATED AGE: cal BC 393
cal BP 2342

Sample σ and cal BC(cal BP) ranges:

σ = 20	398-387(2347-2336)		
σ = 40	401-380(2350-2329)		
σ = 60	405-361(2354-2310)	269-262(2218-2211)	
σ = 80	408-355(2357-2304)	290-233(2239-2182)	216-215(2165-2164)
σ = 100	476-475(2425-2424)	411-351(2360-2300)	296-230(2245-2179)
	220-212(2169-2161)		
σ = 120	508-502(2457-2451)	486-470(2435-2419)	431-348(2380-2297)
	320-210(2270-2160)		
σ = 160	755-692(2704-2641)	588-581(2537-2530)	542-460(2491-2409)
	450-170(2400-2120)		
σ = 200	763-680(2712-2629)	660-608(2609-2557)	600-170(2550-2120)
	143-119(2092-2068)		

TABLE 3-FF

RADIOCARBON AGE BP 2320 CALIBRATED AGE: cal BC 397
cal BP 2346

Sample σ and cal BC(cal BP) ranges:

σ = 20	401-392(2350-2341)		
σ = 40	405-388(2354-2337)		
σ = 60	408-381(2357-2330)		
σ = 80	476-475(2425-2424)	411-361(2360-2310)	269-263(2218-2212)
σ = 100	507-503(2456-2452)	485-470(2434-2419)	430-356(2379-2305)
	289-259(2238-2208)	249-233(2198-2182)	216-215(2165-2164)
σ = 120	744-726(2693-2675)	518-465(2467-2414)	440-352(2389-2301)
	295-230(2244-2179)	219-212(2168-2161)	
σ = 160	759-686(2708-2635)	657-638(2606-2587)	616-615(2565-2564)
	592-571(2541-2520)	560-340(2510-2290)	330-200(2280-2150)
σ = 200	767-674(2716-2623)	660-170(2610-2120)	138-130(2087-2079)

RADIOCARBON AGE BP 2340 CALIBRATED AGE: cal BC 400
cal BP 2349

Sample σ and cal BC(cal BP) ranges:

σ = 20	405-396(2354-2345)		
σ = 40	408-392(2357-2341)		
σ = 60	476-475(2425-2424)	411-388(2360-2337)	
σ = 80	507-503(2456-2452)	485-470(2434-2419)	430-382(2379-2331)
σ = 100	744-726(2693-2675)	519-465(2468-2414)	441-362(2390-2311)
	269-263(2218-2212)		
σ = 120	750-220(2700-2170)		
σ = 160	763-680(2712-2629)	660-609(2609-2558)	600-350(2550-2300)
	320-210(2270-2160)		
σ = 200	790-170(2740-2120)		

RADIOCARBON AGE BP 2360 CALIBRATED AGE: cal BC 404
cal BP 2353

Sample σ and cal BC(cal BP) ranges:

σ = 20	409-399(2358-2348)		
σ = 40	477-475(2426-2424)	412-396(2361-2345)	
σ = 60	508-502(2457-2451)	486-470(2435-2419)	431-392(2380-2341)
σ = 80	744-726(2693-2675)	519-464(2468-2413)	441-388(2390-2337)
σ = 100	755-692(2704-2641)	588-581(2537-2530)	542-460(2491-2409)
	450-382(2399-2331)		
σ = 120	759-686(2708-2635)	657-637(2606-2586)	617-615(2566-2564)
	592-571(2541-2520)	560-360(2510-2310)	269-263(2218-2212)
σ = 160	767-674(2716-2623)	660-350(2610-2300)	295-230(2244-2179)
	219-212(2168-2161)		
σ = 200	790-340(2740-2290)	330-200(2280-2150)	

Table 3-GG

RADIOCARBON AGE BP 2380 CALIBRATED AGE: cal BC 408
cal BP 2357

Sample σ and cal BC(cal BP) ranges:

σ = 20	479-473(2428-2422)	426-424(2375-2373)	412-403(2361-2352)
σ = 40	510-469(2459-2418)	431-400(2380-2349)	
σ = 60	747-725(2696-2674)	519-464(2468-2413)	444-396(2393-2345)
σ = 80	755-692(2704-2641)	588-580(2537-2529)	542-392(2491-2341)
σ = 100	759-686(2708-2635)	658-637(2607-2586)	617-614(2566-2563)
	592-570(2541-2519)	560-390(2510-2340)	
σ = 120	763-680(2712-2629)	660-608(2609-2557)	600-380(2550-2330)
σ = 160	790-360(2740-2310)	289-259(2238-2208)	248-233(2197-2182)
	216-215(2165-2164)		
σ = 200	790-350(2740-2300)	320-210(2270-2160)	

RADIOCARBON AGE BP 2400 CALIBRATED AGE: cal BC 411
cal BP 2360

Sample σ and cal BC(cal BP) ranges:

σ = 20	514-468(2463-2417)	432-406(2381-2355)	
σ = 40	749-724(2698-2673)	536-535(2485-2484)	519-464(2468-2413)
	446-403(2395-2352)		
σ = 60	755-691(2704-2640)	588-580(2537-2529)	542-400(2491-2349)
σ = 80	759-685(2708-2634)	658-637(2607-2586)	617-614(2566-2563)
	592-396(2541-2345)		
σ = 100	763-680(2712-2629)	660-608(2609-2557)	600-390(2550-2340)
σ = 120	768-674(2717-2623)	660-390(2610-2340)	
σ = 160	790-360(2740-2310)	269-263(2218-2212)	
σ = 200	800-350(2750-2300)	295-230(2244-2179)	219-212(2168-2161)

RADIOCARBON AGE BP 2420 CALIBRATED AGES: cal BC 506, 505, 485, 470, 430, 418, 415
cal BP 2455, 2454, 2434, 2419, 2379, 2367, 2364

Sample σ and cal BC(cal BP) ranges:

σ = 20	752-720(2701-2669)	709-695(2658-2644)	586-585(2535-2534)
	538-533(2487-2482)	521-463(2470-2412)	447-409(2396-2358)
σ = 40	756-690(2705-2639)	656-651(2605-2600)	589-579(2538-2528)
	543-406(2492-2355)		
σ = 60	760-685(2709-2634)	658-635(2607-2584)	618-614(2567-2563)
	592-403(2541-2352)		
σ = 80	764-679(2713-2628)	660-400(2609-2349)	
σ = 100	768-673(2717-2622)	660-400(2610-2350)	
σ = 120	790-390(2740-2340)		
σ = 160	790-380(2740-2330)		
σ = 200	800-360(2750-2310)	290-233(2239-2182)	216-215(2165-2164)

Table 3-HH

RADIOCARBON AGE BP 2440 CALIBRATED AGES: cal BC 742, 727, 518, 465, 439
cal BP 2691, 2676, 2467, 2414, 2388

Sample σ and cal BC(cal BP) ranges:

σ = 20	757-688(2706-2637)	657-643(2606-2592)	590-576(2539-2525)
	547-412(2496-2361)		
σ = 40	760-684(2709-2633)	658-634(2607-2583)	619-612(2568-2561)
	593-410(2542-2359)		
σ = 60	764-678(2713-2627)	660-407(2609-2356)	
σ = 80	768-673(2717-2622)	663-403(2612-2352)	
σ = 100	790-400(2740-2350)		
σ = 120	790-400(2740-2350)		
σ = 160	800-390(2750-2340)		
σ = 200	810-360(2760-2310)	269-263(2218-2212)	

RADIOCARBON AGE BP 2460 CALIBRATED AGES: cal BC 754, 692, 588, 581, 541, 529, 524, 460, 450
cal BP 2703, 2641, 2537, 2530, 2490, 2478, 2473, 2409, 2399

Sample σ and cal BC(cal BP) ranges:

σ = 20	761-683(2710-2632)	659-632(2608-2581)	620-611(2569-2560)
	594-514(2543-2463)	468-433(2417-2382)	
σ = 40	764-678(2713-2627)	661-413(2610-2362)	
σ = 60	768-410(2717-2359)		
σ = 80	787-407(2736-2356)		
σ = 100	790-400(2740-2350)		
σ = 120	790-400(2740-2350)		
σ = 160	800-390(2750-2340)		
σ = 200	820-380(2770-2330)		

RADIOCARBON AGE BP 2480 CALIBRATED AGES: cal BC 759, 686, 657, 638, 616, 615, 592, 572, 558, 456, 455
cal BP 2708, 2635, 2606, 2587, 2565, 2564, 2541, 2521, 2507, 2405, 2404

Sample σ and cal BC(cal BP) ranges:

σ = 20	766-752(2715-2701)	722-676(2671-2625)	661-520(2610-2469)
	463-446(2412-2395)		
σ = 40	769-516(2718-2465)	467-434(2416-2383)	
σ = 60	788-482(2737-2431)	472-414(2421-2363)	
σ = 80	791-410(2740-2359)		
σ = 100	790-410(2740-2360)		
σ = 120	800-400(2750-2350)		
σ = 160	810-400(2760-2350)		
σ = 200	830-390(2780-2340)		

TABLE 3-II

RADIOCARBON AGE BP 2500 CALIBRATED AGES: cal BC 763, 680, 660, 629, 623, 609, 595
cal BP 2712, 2629, 2609, 2578, 2572, 2558, 2545

Sample o and cal BC(cal BP) ranges:

o = 20	770-756(2719-2705)	689-656(2638-2605)	645-590(2594-2539)
	578-544(2527-2493)	458-452(2407-2401)	
o = 40	788-753(2737-2702)	717-714(2666-2663)	694-522(2643-2471)
	462-448(2411-2397)		
o = 60	791-517(2740-2466)	466-435(2415-2384)	
o = 80	794-483(2743-2432)	471-414(2420-2363)	
o = 100	800-410(2750-2360)		
o = 120	800-410(2750-2360)		
o = 160	820-400(2770-2350)		
o = 200	888-884(2837-2833)	830-390(2780-2340)	

RADIOCARBON AGE BP 2520 CALIBRATED AGES: cal BC 767, 674, 662
cal BP 2716, 2623, 2611

Sample o and cal BC(cal BP) ranges:

o = 20	789-760(2738-2709)	684-658(2633-2607)	634-593(2583-2542)
	566-565(2515-2514)		
o = 40	791-757(2740-2706)	688-657(2637-2606)	643-590(2592-2539)
	576-546(2525-2495)	458-453(2407-2402)	
o = 60	794-753(2743-2702)	717-716(2666-2665)	694-522(2643-2471)
	462-448(2411-2397)		
o = 80	798-517(2747-2466)	466-435(2415-2384)	
o = 100	800-480(2750-2430)	471-414(2420-2363)	
o = 120	810-410(2760-2360)		
o = 160	830-400(2780-2350)		
o = 200	893-877(2842-2826)	840-400(2790-2350)	

RADIOCARBON AGE BP 2540 CALIBRATED AGES: cal BC 787, 772, 668, 665
cal BP 2736, 2721, 2617, 2614

Sample o and cal BC(cal BP) ranges:

o = 20	792-765(2741-2714)	677-661(2626-2610)	606-604(2555-2553)
o = 40	794-762(2743-2711)	682-659(2631-2608)	631-621(2580-2570)
	611-594(2560-2543)		
o = 60	798-758(2747-2707)	687-657(2636-2606)	641-591(2590-2540)
	575-552(2524-2501)	457-454(2406-2403)	
o = 80	802-754(2751-2703)	693-540(2642-2489)	530-523(2479-2472)
	461-449(2410-2398)		
o = 100	810-520(2760-2470)	465-435(2414-2384)	
o = 120	830-480(2780-2430)	471-429(2420-2378)	419-414(2368-2363)
o = 160	888-884(2837-2833)	830-410(2780-2360)	
o = 200	900-400(2850-2350)		

TABLE 3-JJ

RADIOCARBON AGE BP 2560 CALIBRATED AGE: cal BC 790
cal BP 2739

Sample o and cal BC(cal BP) ranges:

o = 20	795-770(2744-2719)	670-664(2619-2613)	
o = 40	798-766(2747-2715)	675-662(2624-2611)	
o = 60	802-762(2751-2711)	681-659(2630-2608)	630-622(2579-2571)
	610-595(2559-2544)		
o = 80	806-758(2755-2707)	687-657(2636-2606)	640-591(2589-2540)
	573-555(2522-2504)	457-454(2406-2403)	
o = 100	825-754(2774-2703)	690-540(2640-2490)	529-523(2478-2472)
	461-449(2410-2398)		
o = 120	829-739(2778-2688)	730-520(2680-2470)	465-436(2414-2385)
o = 160	893-877(2842-2826)	840-410(2790-2360)	
o = 200	967-965(2916-2914)	900-400(2850-2350)	

RADIOCARBON AGE BP 2580 CALIBRATED AGE: cal BC 793
cal BP 2742

Sample o and cal BC(cal BP) ranges:

o = 20	798-789(2747-2738)		
o = 40	802-771(2751-2720)	669-664(2618-2613)	
o = 60	806-767(2755-2716)	675-662(2624-2611)	
o = 80	825-763(2774-2712)	681-659(2630-2608)	630-622(2579-2571)
	610-595(2559-2544)		
o = 100	829-758(2778-2707)	687-657(2636-2606)	639-591(2588-2540)
	573-556(2522-2505)	457-454(2406-2403)	
o = 120	888-884(2837-2833)	833-754(2782-2703)	690-540(2640-2490)
	529-523(2478-2472)	461-449(2410-2398)	
o = 160	900-480(2850-2430)	470-430(2419-2379)	419-414(2368-2363)
o = 200	970-962(2919-2911)	930-410(2880-2360)	

RADIOCARBON AGE BP 2600 CALIBRATED AGE: cal BC 797
cal BP 2746

Sample o and cal BC(cal BP) ranges:

o = 20	803-792(2752-2741)		
o = 40	806-789(2755-2738)		
o = 60	827-771(2776-2720)	669-664(2618-2613)	
o = 80	830-767(2779-2716)	675-662(2624-2611)	
o = 100	888-884(2837-2833)	833-763(2782-2712)	681-660(2630-2609)
	629-622(2578-2571)	609-595(2558-2544)	
o = 120	893-877(2842-2826)	836-758(2785-2707)	687-657(2636-2606)
	639-591(2588-2540)	573-556(2522-2505)	457-454(2406-2403)
o = 160	967-965(2916-2914)	900-740(2850-2690)	730-520(2680-2470)
	465-437(2414-2386)		
o = 200	972-959(2921-2908)	940-410(2890-2360)	

Table 3-KK

RADIOCARBON AGE BP 2620 CALIBRATED AGE: cal BC 801
cal BP 2750

Sample σ and cal BC(cal BP) ranges:

σ = 20	809-795(2758-2744)		
σ = 40	827-793(2776-2742)		
σ = 60	830-790(2779-2739)		
σ = 80	888-884(2837-2833)	833-771(2782-2720)	669-664(2618-2613)
σ = 100	893-877(2842-2826)	836-767(2785-2716)	675-662(2624-2611)
σ = 120	900-760(2850-2710)	681-660(2630-2609)	629-623(2578-2572)
	609-595(2558-2544)		
σ = 160	970-962(2919-2911)	930-750(2880-2700)	690-540(2640-2490)
	529-523(2478-2472)	461-449(2410-2398)	
σ = 200	1002-988(2951-2937)	970-480(2920-2430)	470-430(2419-2379)
	418-414(2367-2363)		

RADIOCARBON AGE BP 2640 CALIBRATED AGE: cal BC 805
cal BP 2754

Sample σ and cal BC(cal BP) ranges:

σ = 20	827-799(2776-2748)		
σ = 40	830-796(2779-2745)		
σ = 60	889-884(2838-2833)	833-793(2782-2742)	
σ = 80	893-877(2842-2826)	836-790(2785-2739)	
σ = 100	900-770(2850-2720)	668-664(2617-2613)	
σ = 120	967-965(2916-2914)	900-770(2850-2720)	674-662(2623-2611)
σ = 160	972-959(2921-2908)	940-760(2890-2710)	687-657(2636-2606)
	639-591(2588-2540)	573-556(2522-2505)	456-454(2405-2403)
σ = 200	1010-740(2960-2690)	730-520(2680-2470)	465-437(2414-2386)

RADIOCARBON AGE BP 2660 CALIBRATED AGE: cal BC 822
cal BP 2771

Sample σ and cal BC(cal BP) ranges:

σ = 20	831-803(2780-2752)		
σ = 40	889-883(2838-2832)	833-800(2782-2749)	
σ = 60	894-875(2843-2824)	836-796(2785-2745)	
σ = 80	899-793(2848-2742)		
σ = 100	967-965(2916-2914)	900-790(2850-2740)	
σ = 120	970-962(2919-2911)	930-770(2880-2720)	669-664(2618-2613)
σ = 160	1003-988(2952-2937)	970-760(2920-2710)	681-660(2630-2609)
	629-623(2578-2572)	609-595(2558-2544)	
σ = 200	1067-1066(3016-3015)	1049-1039(2998-2988)	1020-750(2970-2700)
	690-540(2640-2490)	529-523(2478-2472)	461-449(2410-2398)

Table 3-LL

RADIOCARBON AGE BP 2680 CALIBRATED AGE: cal BC 829
cal BP 2778

Sample σ and cal BC(cal BP) ranges:

σ = 20	890-882(2839-2831)	834-813(2783-2762)	
σ = 40	894-875(2843-2824)	836-804(2785-2753)	
σ = 60	899-800(2848-2749)		
σ = 80	967-965(2916-2914)	905-796(2854-2745)	
σ = 100	970-962(2919-2911)	930-790(2880-2740)	
σ = 120	972-958(2921-2907)	940-790(2890-2740)	
σ = 160	1010-770(2960-2720)	674-662(2623-2611)	
σ = 200	1078-1063(3027-3012)	1050-760(3000-2710)	686-657(2635-2606)
	639-591(2588-2540)	572-557(2521-2506)	456-454(2405-2403)

RADIOCARBON AGE BP 2700 CALIBRATED AGES: cal BC 888, 885, 832
cal BP 2837, 2834, 2781

Sample σ and cal BC(cal BP) ranges:

σ = 20	895-865(2844-2814)	840-827(2789-2776)	
σ = 40	900-814(2849-2763)		
σ = 60	968-965(2917-2914)	905-804(2854-2753)	
σ = 80	970-962(2919-2911)	929-800(2878-2749)	
σ = 100	972-958(2921-2907)	940-800(2890-2750)	
σ = 120	1003-988(2952-2937)	970-790(2920-2740)	
σ = 160	1067-1066(3016-3015)	1049-1038(2998-2987)	1020-770(2970-2720)
	668-664(2617-2613)		
σ = 200	1188-1183(3137-3132)	1127-1125(3076-3074)	1107-1102(3056-3051)
	1080-760(3030-2710)	681-660(2630-2609)	629-623(2578-2572)
	609-595(2558-2544)		

RADIOCARBON AGE BP 2720 CALIBRATED AGES: cal BC 893, 878, 835
cal BP 2842, 2827, 2784

Sample σ and cal BC(cal BP) ranges:

σ = 20	901-831(2850-2780)		
σ = 40	968-965(2917-2914)	917-828(2866-2777)	
σ = 60	970-961(2919-2910)	929-816(2878-2765)	
σ = 80	972-958(2921-2907)	937-805(2886-2754)	
σ = 100	1003-987(2952-2936)	970-800(2920-2750)	
σ = 120	1010-800(2960-2750)		
σ = 160	1078-1063(3027-3012)	1050-790(3000-2740)	
σ = 200	1209-1205(3158-3154)	1190-1179(3139-3128)	1151-1145(3100-3094)
	1129-1122(3078-3071)	1110-770(3060-2720)	674-662(2623-2611)

Table 3-MM

RADIOCARBON AGE BP 2740 CALIBRATED AGES: cal BC 898, 858, 849
cal BP 2847, 2807, 2798

Sample σ and cal BC(cal BP) ranges:

σ = 20	969-964(2918-2913)	921-834(2870-2783)	
σ = 40	970-961(2919-2910)	930-831(2879-2780)	
σ = 60	973-958(2922-2907)	938-828(2887-2777)	
σ = 80	1004-987(2953-2936)	975-816(2924-2765)	
σ = 100	1010-800(2960-2750)		
σ = 120	1068-1066(3017-3015)	1049-1038(2998-2987)	1020-800(2970-2750)
σ = 160	1188-1183(3137-3132)	1127-1125(3076-3074)	1107-1101(3056-3050)
	1080-790(3030-2740)		
σ = 200	1211-1202(3160-3151)	1191-1142(3140-3091)	1130-770(3080-2720)
	668-664(2617-2613)		

RADIOCARBON AGE BP 2760 CALIBRATED AGES: cal BC 967, 966, 904
cal BP 2916, 2915, 2853

Sample σ and cal BC(cal BP) ranges:

σ = 20	971-960(2920-2909)	932-895(2881-2844)	868-838(2817-2787)
σ = 40	973-958(2922-2907)	939-891(2888-2840)	880-834(2829-2783)
σ = 60	1004-986(2953-2935)	975-832(2924-2781)	
σ = 80	1011-829(2960-2778)		
σ = 100	1068-1066(3017-3015)	1049-1038(2998-2987)	1020-820(2970-2770)
σ = 120	1078-1063(3027-3012)	1050-800(3000-2750)	
σ = 160	1209-1205(3158-3154)	1190-1179(3139-3128)	1151-1145(3100-3094)
	1129-1122(3078-3071)	1110-800(3060-2750)	
σ = 200	1239-1235(3188-3184)	1210-790(3160-2740)	

RADIOCARBON AGE BP 2780 CALIBRATED AGES: cal BC 970, 962, 927
cal BP 2919, 2911, 2876

Sample σ and cal BC(cal BP) ranges:

σ = 20	998-995(2947-2944)	973-957(2922-2906)	941-901(2890-2850)
σ = 40	1005-896(2954-2845)	863-842(2812-2791)	
σ = 60	1047-1046(2996-2995)	1011-892(2960-2841)	879-835(2828-2784)
σ = 80	1068-1066(3017-3015)	1049-1038(2998-2987)	1018-832(2967-2781)
σ = 100	1078-1063(3027-3012)	1050-830(3000-2780)	
σ = 120	1188-1183(3137-3132)	1127-1125(3076-3074)	1107-1100(3056-3049)
	1080-820(3030-2770)		
σ = 160	1211-1202(3160-3151)	1191-1142(3140-3091)	1130-800(3080-2750)
σ = 200	1287-1286(3236-3235)	1259-1230(3208-3179)	1220-790(3170-2740)

Table 3-NN

RADIOCARBON AGE BP 2800 CALIBRATED AGES: cal BC 972, 959, 936
cal BP 2921, 2908, 2885

Sample σ and cal BC(cal BP) ranges:

σ = 20	1007-920(2956-2869)		
σ = 40	1047-1046(2996-2995)	1012-902(2961-2851)	
σ = 60	1069-1066(3018-3015)	1049-1037(2998-2986)	1019-897(2968-2846)
	862-844(2811-2793)		
σ = 80	1078-1062(3027-3011)	1052-892(3001-2841)	879-835(2828-2784)
σ = 100	1188-1183(3137-3132)	1127-1125(3076-3074)	1107-1099(3056-3048)
	1080-830(3030-2780)		
σ = 120	1209-1204(3158-3153)	1190-1179(3139-3128)	1151-1145(3100-3094)
	1129-1122(3078-3071)	1110-830(3060-2780)	
σ = 160	1239-1235(3188-3184)	1210-810(3160-2760)	
σ = 200	1292-1281(3241-3230)	1260-800(3210-2750)	

RADIOCARBON AGE BP 2820 CALIBRATED AGES: cal BC 1002, 989, 975, 947
cal BP 2951, 2938, 2924, 2896

Sample σ and cal BC(cal BP) ranges:

σ = 20	1047-1044(2996-2993)	1013-971(2962-2920)	961-931(2910-2880)
σ = 40	1070-1066(3019-3015)	1050-1036(2999-2985)	1020-923(2969-2872)
σ = 60	1079-1062(3028-3011)	1052-903(3001-2852)	
σ = 80	1207-1206(3156-3155)	1188-1183(3137-3132)	1127-1125(3076-3074)
	1107-1098(3056-3047)	1083-897(3032-2846)	861-845(2810-2794)
σ = 100	1209-1204(3158-3153)	1190-1179(3139-3128)	1151-1145(3100-3094)
	1129-1122(3078-3071)	1110-890(3060-2840)	879-835(2828-2784)
σ = 120	1211-1202(3160-3151)	1192-1142(3141-3091)	1130-830(3080-2780)
σ = 160	1287-1286(3236-3235)	1259-1229(3208-3178)	1220-820(3170-2770)
σ = 200	1310-800(3260-2750)		

RADIOCARBON AGE BP 2840 CALIBRATED AGE: cal BC 1010
cal BP 2959

Sample σ and cal BC(cal BP) ranges:

σ = 20	1074-1064(3023-3013)	1050-973(2999-2922)	957-940(2906-2889)
σ = 40	1187-1186(3136-3135)	1079-971(3028-2920)	960-933(2909-2882)
σ = 60	1207-1206(3156-3155)	1188-1182(3137-3131)	1128-1125(3077-3074)
	1108-1095(3057-3044)	1084-924(3033-2873)	
σ = 80	1209-1204(3158-3153)	1190-1178(3139-3127)	1151-1145(3100-3094)
	1130-1122(3079-3071)	1111-903(3060-2852)	
σ = 100	1212-1202(3161-3151)	1192-1142(3141-3091)	1130-900(3080-2850)
	861-844(2810-2793)		
σ = 120	1240-1235(3189-3184)	1210-890(3160-2840)	879-835(2828-2784)
σ = 160	1292-1281(3241-3230)	1260-830(3210-2780)	
σ = 200	1370-1341(3319-3290)	1320-810(3270-2760)	

Table 3-OO

RADIOCARBON AGE BP 2860 CALIBRATED AGES: cal BC 1049, 1039, 1016
cal BP 2998, 2988, 2965

Sample σ and cal BC(cal BP) ranges:

σ = 20	1187-1185(3136-3134)	1081-1005(3030-2954)	984-975(2933-2924)
σ = 40	1207-1206(3156-3155)	1188-1182(3137-3131)	1128-1124(3077-3073)
	1108-974(3057-2923)	957-942(2906-2891)	
σ = 60	1209-1204(3158-3153)	1190-1178(3139-3127)	1152-1144(3101-3093)
	1130-1122(3079-3071)	1111-971(3060-2920)	960-933(2909-2882)
σ = 80	1212-1202(3161-3151)	1192-1142(3141-3091)	1132-925(3081-2874)
σ = 100	1240-1235(3189-3184)	1210-900(3160-2850)	
σ = 120	1288-1285(3237-3234)	1259-1229(3208-3178)	1220-900(3170-2850)
	861-845(2810-2794)		
σ = 160	1310-830(3260-2780)		
σ = 200	1374-1334(3323-3283)	1320-820(3270-2770)	

RADIOCARBON AGE BP 2880 CALIBRATED AGES: cal BC 1078, 1063, 1052
cal BP 3027, 3012, 3001

Sample σ and cal BC(cal BP) ranges:

σ = 20	1208-1205(3157-3154)	1189-1181(3138-3130)	1148-1146(3097-3095)
	1128-1123(3077-3072)	1109-1012(3058-2961)	
σ = 40	1210-1204(3159-3153)	1190-1177(3139-3126)	1153-1144(3102-3093)
	1130-1007(3079-2956)	980-976(2929-2925)	
σ = 60	1212-1202(3161-3151)	1192-1142(3141-3091)	1132-974(3081-2923)
	955-943(2904-2892)		
σ = 80	1241-1234(3190-3183)	1214-972(3163-2921)	959-934(2908-2883)
σ = 100	1288-1285(3237-3234)	1259-1229(3208-3178)	1220-930(3170-2880)
σ = 120	1292-1281(3241-3230)	1260-900(3210-2850)	
σ = 160	1370-1341(3319-3290)	1320-890(3270-2840)	878-835(2827-2784)
σ = 200	1390-830(3340-2780)		

RADIOCARBON AGE BP 2900 CALIBRATED AGES: cal BC 1188, 1184, 1127, 1126, 1107, 1104, 1083, 1059, 1054
cal BP 3137, 3133, 3076, 3075, 3056, 3053, 3032, 3008, 3003

Sample σ and cal BC(cal BP) ranges:

σ = 20	1210-1203(3159-3152)	1191-1177(3140-3126)	1154-1144(3103-3093)
	1130-1050(3079-2999)	1034-1022(2983-2971)	
σ = 40	1212-1014(3161-2963)		
σ = 60	1241-1234(3190-3183)	1214-1008(3163-2957)	977-976(2926-2925)
σ = 80	1288-1285(3237-3234)	1259-1229(3208-3178)	1218-974(3167-2923)
	952-944(2901-2893)		
σ = 100	1292-1281(3241-3230)	1260-970(3210-2920)	959-934(2908-2883)
σ = 120	1310-930(3260-2880)		
σ = 160	1374-1334(3323-3283)	1320-900(3270-2850)	860-846(2809-2795)
σ = 200	1410-830(3360-2780)		

Table 3-PP

RADIOCARBON AGE BP 2920 CALIBRATED AGES: cal BC 1209, 1205, 1189, 1179, 1150, 1145, 1129, 1122, 1110
cal BP 3158, 3154, 3138, 3128, 3099, 3094, 3078, 3071, 3059

Sample σ and cal BC(cal BP) ranges:

σ = 20	1213-1080(3162-3029)	1062-1053(3011-3002)	
σ = 40	1242-1234(3191-3183)	1215-1075(3164-3024)	1064-1051(3013-3000)
	1028-1026(2977-2975)		
σ = 60	1288-1285(3237-3234)	1259-1015(3208-2964)	
σ = 80	1292-1280(3241-3229)	1263-1009(3212-2958)	
σ = 100	1310-970(3260-2920)	951-945(2900-2894)	
σ = 120	1370-1340(3319-3289)	1320-970(3270-2920)	959-935(2908-2884)
σ = 160	1390-900(3340-2850)		
σ = 200	1428-1423(3377-3372)	1410-890(3360-2840)	878-835(2827-2784)

RADIOCARBON AGE BP 2940 CALIBRATED AGES: cal BC 1211, 1203, 1191, 1158, 1156, 1143, 1131, 1119, 1113
cal BP 3160, 3152, 3140, 3107, 3105, 3092, 3080, 3068, 3062

Sample σ and cal BC(cal BP) ranges:

σ = 20	1257-1128(3206-3077)	1092-1108(3041-3057)	1199-1055(3148-3004)
σ = 40	1289-1284(3238-3233)	1260-1081(3209-3030)	1061-1053(3010-3002)
σ = 60	1293-1280(3242-3229)	1263-1076(3212-3025)	1064-1051(3013-3000)
σ = 80	1315-1015(3264-2964)		
σ = 100	1370-1340(3319-3289)	1320-1010(3270-2960)	
σ = 120	1374-1334(3323-3283)	1320-1000(3270-2950)	991-974(2940-2923)
	950-945(2899-2894)		
σ = 160	1410-930(3360-2880)		
σ = 200	1430-900(3380-2850)	859-846(2808-2795)	

RADIOCARBON AGE BP 2960 CALIBRATED AGES: cal BC 1238, 1236, 1214, 1200, 1193, 1140, 1133
cal BP 3187, 3185, 3163, 3149, 3142, 3089, 3082

Sample σ and cal BC(cal BP) ranges:

σ = 20	1290-1283(3239-3232)	1260-1190(3209-3139)	1177-1112(3126-3061)
σ = 40	1293-1280(3242-3229)	1263-1109(3212-3058)	1088-1086(3037-3035)
	1057-1056(3006-3005)		
σ = 60	1367-1366(3316-3315)	1316-1081(3265-3030)	1060-1054(3009-3003)
σ = 80	1370-1340(3319-3289)	1319-1077(3268-3026)	1064-1051(3013-3000)
σ = 100	1374-1334(3323-3283)	1320-1020(3270-2970)	
σ = 120	1390-1010(3340-2960)		
σ = 160	1428-1423(3377-3372)	1410-970(3360-2920)	959-935(2908-2884)
σ = 200	1440-900(3390-2850)		

Table 3-QQ

RADIOCARBON AGE BP 2980 CALIBRATED AGES: cal BC 1287, 1286, 1258, 1230, 1216, 1198, 1195, 1138, 1135
cal BP 3236, 3235, 3207, 3179, 3165, 3147, 3144, 3087, 3084

Sample σ and cal BC(cal BP) ranges:

σ = 20	1307-1306(3256-3255)	1294-1279(3243-3228)	1264-1212(3213-3161)
	1202-1192(3151-3141)	1142-1132(3091-3081)	1118-1115(3067-3064)
σ = 40	1367-1366(3316-3315)	1317-1191(3266-3140)	1173-1154(3122-3103)
	1143-1131(3092-3080)	1120-1112(3069-3061)	
σ = 60	1371-1340(3320-3289)	1319-1109(3268-3058)	1057-1056(3006-3005)
σ = 80	1375-1334(3324-3283)	1322-1082(3271-3031)	1060-1054(3009-3003)
σ = 100	1390-1080(3340-3030)	1064-1051(3013-3000)	
σ = 120	1410-1020(3360-2970)		
σ = 160	1430-1000(3380-2950)	990-974(2939-2923)	949-945(2898-2894)
σ = 200	1488-1484(3437-3433)	1450-930(3400-2880)	

RADIOCARBON AGE BP 3000 CALIBRATED AGES: cal BC 1292, 1281, 1262
cal BP 3241, 3230, 3211

Sample σ and cal BC(cal BP) ranges:

σ = 20	1368-1364(3317-3313)	1348-1344(3297-3293)	1318-1215(3267-3164)
	1200-1194(3149-3143)	1139-1134(3088-3083)	
σ = 40	1371-1338(3320-3287)	1320-1213(3269-3162)	1201-1192(3150-3141)
	1141-1133(3090-3082)	1117-1116(3066-3065)	
σ = 60	1375-1333(3324-3282)	1322-1191(3271-3140)	1168-1155(3117-3104)
	1143-1131(3092-3080)	1120-1113(3069-3062)	
σ = 80	1390-1109(3339-3058)	1057-1056(3006-3005)	
σ = 100	1410-1080(3360-3030)	1060-1054(3009-3003)	
σ = 120	1430-1080(3380-3030)	1064-1051(3013-3000)	
σ = 160	1440-1010(3390-2960)		
σ = 200	1492-1478(3441-3427)	1460-970(3410-2920)	959-935(2908-2884)

RADIOCARBON AGE BP 3020 CALIBRATED AGES: cal BC 1313, 1298, 1296, 1277, 1266
cal BP 3262, 3247, 3245, 3226, 3215

Sample σ and cal BC(cal BP) ranges:

σ = 20	1373-1336(3322-3285)	1321-1260(3270-3209)	1228-1221(3177-3170)
	1198-1196(3147-3145)	1137-1136(3086-3085)	
σ = 40	1376-1245(3325-3194)	1232-1215(3181-3164)	1199-1194(3148-3143)
	1139-1135(3088-3084)		
σ = 60	1391-1213(3340-3162)	1201-1193(3150-3142)	1141-1133(3090-3082)
	1117-1116(3066-3065)		
σ = 80	1409-1191(3358-3140)	1165-1155(3114-3104)	1143-1131(3092-3080)
	1120-1113(3069-3062)		
σ = 100	1430-1110(3380-3060)		
σ = 120	1430-1080(3380-3030)	1060-1054(3009-3003)	
σ = 160	1488-1484(3437-3433)	1450-1020(3400-2970)	
σ = 200	1500-1000(3450-2950)	990-974(2939-2923)	949-946(2898-2895)

Table 3-RR

RADIOCARBON AGE BP 3040 CALIBRATED AGES: cal BC 1370, 1362, 1351, 1342, 1319
cal BP 3319, 3311, 3300, 3291, 3268

Sample σ and cal BC(cal BP) ranges:

σ = 20	1376-1293(3325-3242)	1280-1263(3229-3212)	
σ = 40	1392-1261(3341-3210)	1197-1196(3146-3145)	
σ = 60	1410-1257(3359-3206)	1247-1246(3196-3195)	1231-1216(3180-3165)
	1199-1194(3148-3143)	1138-1135(3087-3084)	
σ = 80	1429-1213(3378-3162)	1201-1193(3150-3142)	1141-1133(3090-3082)
	1117-1116(3066-3065)		
σ = 100	1430-1190(3380-3140)	1164-1155(3113-3104)	1143-1131(3092-3080)
	1120-1113(3069-3062)		
σ = 120	1440-1110(3390-3060)		
σ = 160	1493-1477(3442-3426)	1460-1080(3410-3030)	1063-1051(3012-3000)
σ = 200	1520-1010(3470-2960)		

RADIOCARBON AGE BP 3060 CALIBRATED AGES: cal BC 1374, 1335, 1322
cal BP 3323, 3284, 3271

Sample σ and cal BC(cal BP) ranges:

σ = 20	1407-1317(3356-3266)		
σ = 40	1410-1295(3359-3244)	1278-1264(3227-3213)	
σ = 60	1429-1261(3378-3210)	1197-1196(3146-3145)	
σ = 80	1433-1258(3382-3207)	1231-1216(3180-3165)	1199-1195(3148-3144)
	1138-1135(3087-3084)		
σ = 100	1440-1210(3390-3160)	1201-1193(3150-3142)	1141-1133(3090-3082)
	1117-1116(3066-3065)		
σ = 120	1488-1484(3437-3433)	1450-1190(3400-3140)	1162-1155(3111-3104)
	1143-1131(3092-3080)	1120-1113(3069-3062)	
σ = 160	1500-1080(3450-3030)	1060-1054(3009-3003)	
σ = 200	1530-1020(3480-2970)		

RADIOCARBON AGE BP 3080 CALIBRATED AGES: cal BC 1388, 1330, 1325
cal BP 3337, 3279, 3274

Sample σ and cal BC(cal BP) ranges:

σ = 20	1411-1372(3360-3321)	1359-1354(3308-3303)	1338-1320(3287-3269)
σ = 40	1429-1318(3378-3267)		
σ = 60	1433-1295(3382-3244)	1278-1265(3227-3214)	
σ = 80	1436-1261(3385-3210)	1197-1196(3146-3145)	
σ = 100	1488-1484(3437-3433)	1450-1260(3400-3210)	1231-1216(3180-3165)
	1199-1195(3148-3144)	1138-1135(3087-3084)	
σ = 120	1493-1477(3442-3426)	1460-1210(3410-3160)	1201-1193(3150-3142)
	1140-1133(3089-3082)	1117-1116(3066-3065)	
σ = 160	1520-1110(3470-3060)		
σ = 200	1599-1569(3548-3518)	1530-1080(3480-3030)	1063-1051(3012-3000)

Table 3-SS

RADIOCARBON AGE BP 3100 CALIBRATED AGE: cal BC 1408
cal BP 3357

Sample σ and cal BC(cal BP) ranges:

σ = 20	1430-1376(3379-3325)	1332-1323(3281-3272)	
σ = 40	1433-1373(3382-3322)	1357-1355(3306-3304)	1336-1321(3285-3270)
σ = 60	1436-1318(3385-3267)		
σ = 80	1488-1484(3437-3433)	1454-1296(3403-3245)	1277-1265(3226-3214)
σ = 100	1493-1477(3442-3426)	1460-1260(3410-3210)	
σ = 120	1500-1260(3450-3210)	1231-1216(3180-3165)	1199-1195(3148-3144)
	1138-1135(3087-3084)		
σ = 160	1530-1190(3480-3140)	1161-1156(3110-3105)	1143-1131(3092-3080)
	1120-1113(3069-3062)		
σ = 200	1600-1080(3550-3030)	1060-1054(3009-3003)	

RADIOCARBON AGE BP 3120 CALIBRATED AGES: cal BC 1428, 1424, 1412
cal BP 3377, 3373, 3361

Sample σ and cal BC(cal BP) ranges:

σ = 20	1434-1394(3383-3343)	1327-1326(3276-3275)	
σ = 40	1440-1379(3389-3328)	1331-1324(3280-3273)	
σ = 60	1489-1483(3438-3432)	1454-1373(3403-3322)	1357-1356(3306-3305)
	1336-1321(3285-3270)		
σ = 80	1493-1477(3442-3426)	1464-1318(3413-3267)	
σ = 100	1500-1310(3450-3260)	1300-1296(3249-3245)	1277-1265(3226-3214)
σ = 120	1520-1260(3470-3210)		
σ = 160	1599-1569(3548-3518)	1530-1210(3480-3160)	1201-1193(3150-3142)
	1140-1133(3089-3082)		
σ = 200	1679-1675(3628-3624)	1620-1110(3570-3060)	

RADIOCARBON AGE BP 3140 CALIBRATED AGES: cal BC 1432, 1417, 1416
cal BP 3381, 3366, 3365

Sample σ and cal BC(cal BP) ranges:

σ = 20	1447-1410(3396-3359)		
σ = 40	1489-1483(3438-3432)	1455-1396(3404-3345)	
σ = 60	1493-1477(3442-3426)	1465-1384(3414-3333)	1331-1324(3280-3273)
σ = 80	1498-1373(3447-3322)	1357-1356(3306-3305)	1335-1321(3284-3270)
σ = 100	1520-1320(3470-3270)		
σ = 120	1530-1310(3480-3260)	1300-1296(3249-3245)	1277-1265(3226-3214)
σ = 160	1600-1260(3550-3210)	1230-1216(3179-3165)	1198-1195(3147-3144)
	1138-1135(3087-3084)		
σ = 200	1684-1673(3633-3622)	1657-1656(3606-3605)	1640-1190(3590-3140)
	1160-1156(3109-3105)	1143-1131(3092-3080)	1120-1113(3069-3062)

Table 3-TT

RADIOCARBON AGE BP 3160 CALIBRATED AGE: cal BC 1436
cal BP 3385

Sample σ and cal BC(cal BP) ranges:

σ = 20	1490-1481(3439-3430)	1457-1414(3406-3363)	
σ = 40	1493-1411(3442-3360)		
σ = 60	1499-1408(3448-3357)		
σ = 80	1519-1386(3468-3335)	1330-1324(3279-3273)	
σ = 100	1577-1576(3526-3525)	1530-1370(3480-3320)	1335-1321(3284-3270)
σ = 120	1599-1569(3548-3518)	1530-1320(3480-3270)	
σ = 160	1679-1675(3628-3624)	1620-1260(3570-3210)	
σ = 200	1688-1671(3637-3620)	1660-1210(3610-3160)	1201-1193(3150-3142)
	1140-1133(3089-3082)		

RADIOCARBON AGE BP 3180 CALIBRATED AGES: cal BC 1488, 1485, 1452
cal BP 3437, 3434, 3401

Sample σ and cal BC(cal BP) ranges:

σ = 20	1494-1434(3443-3383)		
σ = 40	1499-1431(3448-3380)	1418-1415(3367-3364)	
σ = 60	1519-1412(3468-3361)		
σ = 80	1577-1576(3526-3525)	1527-1408(3476-3357)	
σ = 100	1599-1569(3548-3518)	1530-1390(3480-3340)	1330-1324(3279-3273)
σ = 120	1600-1370(3550-3320)	1335-1321(3284-3270)	
σ = 160	1684-1673(3633-3622)	1657-1656(3606-3605)	1640-1310(3590-3260)
	1299-1296(3248-3245)	1277-1265(3226-3214)	
σ = 200	1690-1260(3640-3210)	1230-1216(3179-3165)	1198-1195(3147-3144)
	1138-1135(3087-3084)		

RADIOCARBON AGE BP 3200 CALIBRATED AGES: cal BC 1492, 1478, 1463
cal BP 3441, 3427, 3412

Sample σ and cal BC(cal BP) ranges:

σ = 20	1501-1448(3450-3397)		
σ = 40	1520-1435(3469-3384)		
σ = 60	1577-1576(3526-3525)	1527-1431(3476-3380)	1418-1416(3367-3365)
σ = 80	1599-1568(3548-3517)	1533-1412(3482-3361)	
σ = 100	1600-1410(3550-3360)		
σ = 120	1679-1675(3628-3624)	1620-1390(3570-3340)	1330-1324(3279-3273)
σ = 160	1688-1671(3637-3620)	1660-1320(3610-3270)	
σ = 200	1727-1711(3676-3660)	1690-1260(3640-3210)	

RADIOCARBON AGE BP 3220 CALIBRATED AGE: cal BC 1496
cal BP 3445

Sample σ and cal BC(cal BP) ranges:

σ = 20	1522-1457(3471-3406)		
σ = 40	1580-1575(3529-3524)	1528-1449(3477-3398)	
σ = 60	1599-1568(3548-3517)	1534-1435(3483-3384)	
σ = 80	1603-1431(3552-3380)	1418-1416(3367-3365)	
σ = 100	1679-1675(3628-3624)	1620-1410(3570-3360)	
σ = 120	1684-1673(3633-3622)	1657-1656(3606-3605)	1640-1410(3590-3360)
σ = 160	1690-1370(3640-3320)	1335-1321(3284-3270)	
σ = 200	1740-1310(3690-3260)	1299-1296(3248-3245)	1277-1265(3226-3214)

TABLE 3-UU

RADIOCARBON AGE BP 3240 CALIBRATED AGE: cal BC 1518
cal BP 3467

Sample σ and cal BC(cal BP) ranges:

σ = 20	1597-1595(3546-3544)	1585-1572(3534-3521)	1530-1494(3479-3443)
σ = 40	1600-1566(3549-3515)	1535-1459(3484-3408)	
σ = 60	1604-1450(3553-3399)		
σ = 80	1679-1675(3628-3624)	1620-1435(3569-3384)	
σ = 100	1684-1673(3633-3622)	1657-1656(3606-3605)	1640-1430(3590-3380)
	1418-1416(3367-3365)		
σ = 120	1688-1670(3637-3619)	1660-1410(3610-3360)	
σ = 160	1727-1710(3676-3659)	1690-1390(3640-3340)	1330-1324(3279-3273)
σ = 200	1740-1320(3690-3270)		

RADIOCARBON AGE BP 3260 CALIBRATED AGE: cal BC 1526
cal BP 3475

Sample σ and cal BC(cal BP) ranges:

σ = 20	1601-1557(3550-3506)	1537-1501(3486-3450)	
σ = 40	1604-1495(3553-3444)		
σ = 60	1680-1675(3629-3624)	1621-1491(3570-3440)	1480-1460(3429-3409)
σ = 80	1684-1673(3633-3622)	1657-1656(3606-3605)	1638-1450(3587-3399)
σ = 100	1690-1440(3640-3390)		
σ = 120	1690-1430(3640-3380)	1418-1416(3367-3365)	
σ = 160	1740-1410(3690-3360)		
σ = 200	1768-1764(3717-3713)	1750-1370(3700-3320)	1335-1321(3284-3270)

RADIOCARBON AGE BP 3280 CALIBRATED AGES: cal BC 1598, 1569, 1533
cal BP 3547, 3518, 3482

Sample σ and cal BC(cal BP) ranges:

σ = 20	1677-1676(3626-3625)	1617-1520(3566-3469)	
σ = 40	1681-1675(3630-3624)	1622-1503(3571-3452)	
σ = 60	1685-1672(3634-3621)	1657-1655(3606-3604)	1638-1495(3587-3444)
σ = 80	1688-1491(3637-3440)	1480-1460(3429-3409)	
σ = 100	1690-1450(3640-3400)		
σ = 120	1728-1710(3677-3659)	1690-1440(3640-3390)	
σ = 160	1740-1410(3690-3360)		
σ = 200	1864-1845(3813-3794)	1828-1824(3777-3773)	1812-1800(3761-3749)
	1780-1390(3730-3340)	1330-1324(3279-3273)	

RADIOCARBON AGE BP 3300 CALIBRATED AGE: cal BC 1603
cal BP 3552

Sample σ and cal BC(cal BP) ranges:

σ = 20	1681-1675(3630-3624)	1622-1584(3571-3533)	1573-1530(3522-3479)
σ = 40	1685-1673(3634-3622)	1657-1655(3606-3604)	1638-1524(3587-3473)
σ = 60	1688-1506(3637-3455)		
σ = 80	1691-1496(3640-3445)		
σ = 100	1727-1711(3676-3660)	1690-1490(3640-3440)	1479-1462(3428-3411)
σ = 120	1740-1450(3690-3400)		
σ = 160	1768-1764(3717-3713)	1750-1430(3700-3380)	1417-1416(3366-3365)
σ = 200	1879-1842(3828-3791)	1830-1410(3780-3360)	

TABLE 3-VV

RADIOCARBON AGE BP 3320 CALIBRATED AGES: cal BC 1679, 1676, 1619
cal BP 3628, 3625, 3568

Sample σ and cal BC(cal BP) ranges:

σ = 20	1686-1672(3635-3621)	1658-1653(3607-3602)	1640-1600(3589-3549)
	1565-1535(3514-3484)		
σ = 40	1689-1585(3638-3534)	1572-1530(3521-3479)	
σ = 60	1691-1524(3640-3473)		
σ = 80	1728-1710(3677-3659)	1694-1506(3643-3455)	
σ = 100	1740-1500(3690-3450)		
σ = 120	1740-1490(3690-3440)	1479-1462(3428-3411)	
σ = 160	1864-1845(3813-3794)	1828-1824(3777-3773)	1812-1800(3761-3749)
	1780-1440(3730-3390)		
σ = 200	1880-1410(3830-3360)		

RADIOCARBON AGE BP 3340 CALIBRATED AGES: cal BC 1684, 1673, 1637
cal BP 3633, 3622, 3586

Sample σ and cal BC(cal BP) ranges:

σ = 20	1689-1605(3638-3554)		
σ = 40	1692-1601(3641-3550)	1557-1538(3506-3487)	
σ = 60	1729-1709(3678-3658)	1694-1597(3643-3546)	1571-1531(3520-3480)
σ = 80	1737-1524(3686-3473)		
σ = 100	1740-1520(3690-3470)	1507-1506(3456-3455)	
σ = 120	1769-1763(3718-3712)	1750-1500(3700-3450)	
σ = 160	1879-1842(3828-3791)	1830-1450(3780-3400)	
σ = 200	1890-1430(3840-3380)	1417-1416(3366-3365)	

RADIOCARBON AGE BP 3360 CALIBRATED AGES: cal BC 1688, 1671, 1660, 1651, 1642
cal BP 3637, 3620, 3609, 3600, 3591

Sample σ and cal BC(cal BP) ranges:

σ = 20	1692-1623(3641-3572)		
σ = 40	1729-1709(3678-3658)	1694-1606(3643-3555)	
σ = 60	1737-1602(3686-3551)	1549-1544(3498-3493)	
σ = 80	1743-1598(3692-3547)	1571-1531(3520-3480)	
σ = 100	1769-1763(3718-3712)	1750-1520(3700-3470)	
σ = 120	1864-1845(3813-3794)	1828-1824(3777-3773)	1812-1800(3761-3749)
	1780-1520(3730-3470)		
σ = 160	1880-1490(3830-3440)	1479-1462(3428-3411)	
σ = 200	1920-1440(3870-3390)		

RADIOCARBON AGE BP 3380 CALIBRATED AGES: cal BC 1691, 1668, 1664
cal BP 3640, 3617, 3613

Sample σ and cal BC(cal BP) ranges:

σ = 20	1731-1705(3680-3654)	1695-1686(3644-3635)	1672-1639(3621-3588)
σ = 40	1738-1624(3687-3573)		
σ = 60	1744-1606(3693-3555)		
σ = 80	1807-1806(3756-3755)	1769-1763(3718-3712)	1751-1602(3700-3551)
	1548-1545(3497-3494)		
σ = 100	1865-1845(3814-3794)	1828-1823(3777-3772)	1812-1799(3761-3748)
	1780-1600(3730-3550)	1571-1532(3520-3481)	
σ = 120	1879-1842(3828-3791)	1830-1520(3780-3470)	
σ = 160	1890-1500(3840-3450)		
σ = 200	2008-2002(3957-3951)	1920-1450(3870-3400)	

Table 3-WW

RADIOCARBON AGE BP 3400 CALIBRATED AGES: cal BC 1727, 1712, 1693
cal BP 3676, 3661, 3642

Sample σ and cal BC(cal BP) ranges:

σ = 20	1740-1689(3689-3638)	1670-1661(3619-3610)	1649-1644(3598-3593)
σ = 40	1745-1687(3694-3636)	1672-1640(3621-3589)	
σ = 60	1807-1806(3756-3755)	1770-1762(3719-3711)	1752-1625(3701-3574)
σ = 80	1866-1845(3815-3794)	1828-1823(3777-3772)	1812-1799(3761-3748)
	1776-1606(3725-3555)		
σ = 100	1879-1842(3828-3791)	1830-1600(3780-3550)	1547-1546(3496-3495)
σ = 120	1880-1600(3830-3550)	1570-1532(3519-3481)	
σ = 160	1920-1520(3870-3470)		
σ = 200	2012-1995(3961-3944)	1960-1490(3910-3440)	1479-1462(3428-3411)

RADIOCARBON AGE BP 3420 CALIBRATED AGES: cal BC 1735, 1697, 1696
cal BP 3684, 3646, 3645

Sample σ and cal BC(cal BP) ranges:

σ = 20	1746-1692(3695-3641)	1667-1665(3616-3614)	
σ = 40	1808-1805(3757-3754)	1770-1690(3719-3639)	1669-1662(3618-3611)
	1647-1646(3596-3595)		
σ = 60	1866-1845(3815-3794)	1828-1823(3777-3772)	1812-1799(3761-3748)
	1776-1687(3725-3636)	1671-1641(3620-3590)	
σ = 80	1879-1842(3828-3791)	1831-1625(3780-3574)	
σ = 100	1880-1620(3830-3570)		
σ = 120	1890-1600(3840-3550)		
σ = 160	2008-2002(3957-3951)	1920-1530(3870-3480)	
σ = 200	2027-1992(3976-3941)	1970-1500(3920-3450)	

RADIOCARBON AGE BP 3440 CALIBRATED AGE: cal BC 1742
cal BP 3691

Sample σ and cal BC(cal BP) ranges:

σ = 20	1857-1846(3806-3795)	1810-1803(3759-3752)	1772-1729(3721-3678)
	1708-1694(3657-3643)		
σ = 40	1874-1844(3823-3793)	1829-1797(3778-3746)	1778-1692(3727-3641)
	1667-1666(3616-3615)		
σ = 60	1879-1842(3828-3791)	1831-1690(3780-3639)	1669-1663(3618-3612)
	1647-1646(3596-3595)		
σ = 80	1883-1687(3832-3636)	1671-1641(3620-3590)	
σ = 100	1890-1630(3840-3580)		
σ = 120	1920-1620(3870-3570)	1607-1606(3556-3555)	
σ = 160	2012-1995(3961-3944)	1960-1600(3910-3550)	1570-1532(3519-3481)
σ = 200	2030-1520(3980-3470)		

Table 3-XX

RADIOCARBON AGE BP 3460 CALIBRATED AGES: cal BC 1768, 1765, 1749
cal BP 3717, 3714, 3698

Sample σ and cal BC(cal BP) ranges:

σ = 20	1876-1844(3825-3793)	1829-1797(3778-3746)	1778-1739(3727-3688)
σ = 40	1879-1842(3828-3791)	1831-1733(3780-3682)	1702-1696(3651-3645)
σ = 60	1883-1693(3832-3642)		
σ = 80	1886-1690(3835-3639)	1669-1663(3618-3612)	
σ = 100	1920-1690(3870-3640)	1671-1642(3620-3591)	
σ = 120	2008-2002(3957-3951)	1920-1630(3870-3580)	
σ = 160	2027-1992(3976-3941)	1970-1600(3920-3550)	
σ = 200	2110-2103(4059-4052)	2090-2085(4039-4034)	2067-2066(4016-4015)
	2030-1530(3980-3480)		

RADIOCARBON AGE BP 3480 CALIBRATED AGES: cal BC 1862, 1845, 1827, 1824, 1811, 1800, 1775
cal BP 3811, 3794, 3776, 3773, 3760, 3749, 3724

Sample σ and cal BC(cal BP) ranges:

σ = 20	1880-1745(3829-3694)		
σ = 40	1883-1740(3832-3689)		
σ = 60	1886-1733(3835-3682)	1701-1696(3650-3645)	
σ = 80	1920-1723(3869-3672)	1713-1693(3662-3642)	
σ = 100	2008-2001(3957-3950)	1920-1690(3870-3640)	1669-1663(3618-3612)
σ = 120	2012-1995(3961-3944)	1960-1690(3910-3640)	1671-1642(3620-3591)
σ = 160	2030-1620(3980-3570)		
σ = 200	2130-2082(4079-4031)	2070-2062(4019-4011)	2040-1600(3990-3550)
	1570-1532(3519-3481)		

RADIOCARBON AGE BP 3500 CALIBRATED AGES: cal BC 1878, 1842, 1830, 1789, 1785
cal BP 3827, 3791, 3779, 3738, 3734

Sample σ and cal BC(cal BP) ranges:

σ = 20	1884-1771(3833-3720)	1760-1754(3709-3703)	
σ = 40	1886-1747(3835-3696)		
σ = 60	1920-1741(3869-3690)		
σ = 80	2008-2001(3957-3950)	1924-1734(3873-3683)	1700-1696(3649-3645)
σ = 100	2012-1995(3961-3944)	1960-1720(3910-3670)	1713-1693(3662-3642)
σ = 120	2027-1991(3976-3940)	1970-1690(3920-3640)	1669-1663(3618-3612)
σ = 160	2110-2103(4059-4052)	2090-2085(4039-4034)	2067-2066(4016-4015)
	2030-1630(3980-3580)		
σ = 200	2136-2058(4085-4007)	2040-1600(3990-3550)	

TABLE 3-YY

RADIOCARBON AGE BP 3520 CALIBRATED AGES: cal BC 1882, 1840, 1833
cal BP 3831, 3789, 3782

Sample σ and cal BC(cal BP) ranges:

σ = 20	1917-1905(3866-3854)	1889-1873(3838-3822)	1844-1813(3793-3762)
	1797-1778(3746-3727)		
σ = 40	1920-1772(3869-3721)	1758-1755(3707-3704)	
σ = 60	2008-2000(3957-3949)	1924-1747(3873-3696)	
σ = 80	2012-1994(3961-3943)	1962-1741(3911-3690)	
σ = 100	2027-1991(3976-3940)	1970-1730(3920-3680)	1700-1696(3649-3645)
σ = 120	2030-1720(3980-3670)	1713-1693(3662-3642)	
σ = 160	2131-2082(4080-4031)	2070-2062(4019-4011)	2040-1690(3990-3640)
	1671-1642(3620-3591)		
σ = 200	2140-1620(4090-3570)		

RADIOCARBON AGE BP 3540 CALIBRATED AGES: cal BC 1885, 1837, 1836
cal BP 3834, 3786, 3785

Sample σ and cal BC(cal BP) ranges:

σ = 20	1921-1880(3870-3829)	1841-1832(3790-3781)	
σ = 40	2009-1998(3958-3947)	1937-1935(3886-3884)	1925-1877(3874-3826)
	1843-1829(3792-3778)	1819-1815(3768-3764)	1795-1781(3744-3730)
σ = 60	2012-1994(3961-3943)	1963-1858(3912-3807)	1846-1773(3795-3722)
	1757-1756(3706-3705)		
σ = 80	2027-1991(3976-3940)	1973-1748(3922-3697)	
σ = 100	2030-1740(3980-3690)		
σ = 120	2110-2102(4059-4051)	2091-2085(4040-4034)	2067-2066(4016-4015)
	2030-1730(3980-3680)	1700-1696(3649-3645)	
σ = 160	2136-2058(4085-4007)	2040-1690(3990-3640)	1669-1663(3618-3612)
σ = 200	2198-2159(4147-4108)	2140-1630(4090-3580)	

RADIOCARBON AGE BP 3560 CALIBRATED AGES: cal BC 1919, 1902, 1892
cal BP 3868, 3851, 3841

Sample σ and cal BC(cal BP) ranges:

σ = 20	2010-1996(3959-3945)	1942-1883(3891-3832)	1838-1834(3787-3783)
σ = 40	2013-1994(3962-3943)	1964-1881(3913-3830)	1841-1832(3790-3781)
σ = 60	2028-1991(3977-3940)	1974-1877(3923-3826)	1843-1829(3792-3778)
	1818-1815(3767-3764)	1793-1782(3742-3731)	
σ = 80	2031-1859(3980-3808)	1846-1773(3795-3722)	1757-1756(3706-3705)
σ = 100	2110-2102(4059-4051)	2091-2085(4040-4034)	2067-2066(4016-4015)
	2030-1750(3980-3700)		
σ = 120	2131-2082(4080-4031)	2070-2062(4019-4011)	2040-1740(3990-3690)
σ = 160	2140-1720(4090-3670)	1713-1693(3662-3642)	
σ = 200	2200-1690(4150-3640)	1671-1642(3620-3591)	

Table 3-ZZ

RADIOCARBON AGE BP 3580 CALIBRATED AGES: cal BC 2008, 2003, 1923
cal BP 3957, 3952, 3872

Sample σ and cal BC(cal BP) ranges:

σ = 20	2013-1993(3962-3942)	1967-1887(3916-3836)	
σ = 40	2028-1991(3977-3940)	1975-1884(3924-3833)	1838-1835(3787-3784)
σ = 60	2032-1881(3981-3830)	1840-1833(3789-3782)	
σ = 80	2111-2102(4060-4051)	2091-2085(4040-4034)	2067-2066(4016-4015)
	2035-1878(3984-3827)	1843-1830(3792-3779)	1818-1816(3767-3765)
	1792-1783(3741-3732)		
σ = 100	2131-2082(4080-4031)	2070-2062(4019-4011)	2040-1860(3990-3810)
	1846-1773(3795-3722)	1757-1756(3706-3705)	
σ = 120	2136-2057(4085-4006)	2040-1750(3990-3700)	
σ = 160	2198-2159(4147-4108)	2140-1730(4090-3680)	1699-1696(3648-3645)
σ = 200	2270-2256(4219-4205)	2228-2223(4177-4172)	2210-1690(4160-3640)
	1669-1663(3618-3612)		

RADIOCARBON AGE BP 3600 CALIBRATED AGES: cal BC 2011, 1995, 1960
cal BP 3960, 3944, 3909

Sample σ and cal BC(cal BP) ranges:

σ = 20	2029-1990(3978-3939)	1978-1920(3927-3869)	1899-1894(3848-3843)
σ = 40	2032-1917(3981-3866)	1905-1889(3854-3838)	
σ = 60	2111-2084(4060-4033)	2067-2065(4016-4014)	2035-1884(3984-3833)
	1837-1835(3786-3784)		
σ = 80	2131-2082(4080-4031)	2070-2061(4019-4010)	2039-1881(3988-3830)
	1840-1833(3789-3782)		
σ = 100	2136-2057(4085-4006)	2040-1880(3990-3830)	1843-1830(3792-3779)
	1818-1816(3767-3765)	1792-1783(3741-3732)	
σ = 120	2187-2186(4136-4135)	2140-1860(4090-3810)	1846-1774(3795-3723)
σ = 160	2200-1740(4150-3690)		
σ = 200	2274-2251(4223-4200)	2230-1720(4180-3670)	1712-1693(3661-3642)

RADIOCARBON AGE BP 3620 CALIBRATED AGES: cal BC 2027, 2026, 2015, 1992, 1971
cal BP 3976, 3975, 3964, 3941, 3920

Sample σ and cal BC(cal BP) ranges:

σ = 20	2107-2106(4056-4055)	2088-2086(4037-4035)	2033-2009(3982-3958)
	1998-1925(3947-3874)		
σ = 40	2127-2126(4076-4075)	2112-2084(4061-4033)	2067-2065(4016-4014)
	2036-1922(3985-3871)		
σ = 60	2131-2082(4080-4031)	2070-2061(4019-4010)	2039-1918(3988-3867)
	1904-1890(3853-3839)		
σ = 80	2136-2057(4085-4006)	2043-1885(3992-3834)	1837-1836(3786-3785)
σ = 100	2187-2186(4136-4135)	2140-1880(4090-3830)	1840-1833(3789-3782)
σ = 120	2198-2158(4147-4107)	2140-1880(4090-3830)	1843-1830(3792-3779)
	1817-1816(3766-3765)	1791-1783(3740-3732)	
σ = 160	2270-2256(4219-4205)	2228-2223(4177-4172)	2210-1750(4160-3700)
σ = 200	2290-1730(4240-3680)	1699-1696(3648-3645)	

Table 3-AAA

RADIOCARBON AGE BP 3640 CALIBRATED AGES: cal BC 2031, 1989, 1981
cal BP 3980, 3938, 3930

Sample σ and cal BC(cal BP) ranges:

σ = 20	2128-2124(4077-4073)	2113-2084(4062-4033)	2068-2064(4017-4013)
	2037-2013(3986-3962)	1994-1965(3943-3914)	
σ = 40	2132-2082(4081-4031)	2070-2061(4019-4010)	2040-2010(3989-3959)
	1996-1942(3945-3891)	1929-1926(3878-3875)	
σ = 60	2137-2057(4086-4006)	2043-1922(3992-3871)	
σ = 80	2187-2185(4137-4134)	2139-1918(4088-3867)	1903-1890(3852-3839)
σ = 100	2198-2158(4147-4107)	2140-1880(4090-3830)	1837-1836(3786-3785)
σ = 120	2200-1880(4150-3830)	1840-1833(3789-3782)	
σ = 160	2275-2251(4224-4200)	2230-1860(4180-3810)	1845-1774(3794-3723)
σ = 200	2336-2323(4285-4272)	2310-1740(4260-3690)	

RADIOCARBON AGE BP 3660 CALIBRATED AGES: cal BC 2109, 2103, 2090, 2085, 2034
cal BP 4058, 4052, 4039, 4034, 3983

Sample σ and cal BC(cal BP) ranges:

σ = 20	2133-2081(4082-4030)	2071-2060(4020-4009)	2040-2028(3989-3977)
	1990-1976(3939-3925)		
σ = 40	2137-2057(4086-4006)	2043-2014(3992-3963)	1993-1968(3942-3917)
σ = 60	2188-2184(4137-4133)	2140-2010(4089-3959)	1996-1945(3945-3894)
σ = 80	2198-2158(4147-4107)	2142-1923(4091-3872)	
σ = 100	2200-1920(4150-3870)	1903-1891(3852-3840)	
σ = 120	2270-2256(4219-4205)	2228-2223(4177-4172)	2210-1890(4160-3840)
	1837-1836(3786-3785)		
σ = 160	2290-1880(4240-3830)	1843-1830(3792-3779)	1817-1816(3766-3765)
	1790-1784(3739-3733)		
σ = 200	2393-2383(4342-4332)	2350-1750(4300-3700)	

RADIOCARBON AGE BP 3680 CALIBRATED AGES: cal BC 2130, 2119, 2115, 2097, 2096,
2083, 2069, 2062, 2038
cal BP 4079, 4068, 4064, 4046, 4045,
4032, 4018, 4011, 3987

Sample σ and cal BC(cal BP) ranges:

σ = 20	2138-2032(4087-3981)	1987-1985(3936-3934)	
σ = 40	2190-2180(4139-4129)	2168-2166(4117-4115)	2140-2029(4089-3978)
	1990-1978(3939-3927)		
σ = 60	2198-2157(4147-4106)	2143-2014(4092-3963)	1992-1969(3941-3918)
σ = 80	2202-2011(4151-3960)	1995-1946(3944-3895)	
σ = 100	2270-2256(4219-4205)	2228-2223(4177-4172)	2210-1920(4160-3870)
σ = 120	2287-2286(4236-4235)	2275-2251(4224-4200)	2230-1920(4180-3870)
	1902-1891(3851-3840)		
σ = 160	2336-2323(4285-4272)	2310-1880(4260-3830)	1840-1833(3789-3782)
σ = 200	2451-2444(4400-4393)	2432-2422(4381-4371)	2402-2378(4351-4327)
	2350-1860(4300-3810)	1845-1811(3794-3760)	1801-1774(3750-3723)

Table 3-BBB

RADIOCARBON AGE BP 3700 CALIBRATED AGES: cal BC 2135, 2080, 2072, 2058, 2042
cal BP 4084, 4029, 4021, 4007, 3991

Sample σ and cal BC(cal BP) ranges:

σ = 20	2193-2164(4142-4113)	2140-2112(4089-4061)	2100-2036(4049-3985)
σ = 40	2199-2156(4148-4105)	2143-2033(4092-3982)	
σ = 60	2202-2030(4151-3979)	1989-1979(3938-3928)	
σ = 80	2270-2256(4219-4205)	2228-2222(4177-4171)	2205-2014(4154-3963)
	1992-1969(3941-3918)		
σ = 100	2287-2286(4236-4235)	2275-2251(4224-4200)	2230-2010(4180-3960)
	1995-1958(3944-3907)	1947-1946(3896-3895)	
σ = 120	2290-1920(4240-3870)		
σ = 160	2393-2383(4342-4332)	2350-1890(4300-3840)	1837-1836(3786-3785)
σ = 200	2470-1880(4420-3830)	1843-1830(3792-3779)	1817-1816(3766-3765)
	1790-1784(3739-3733)		

RADIOCARBON AGE BP 3720 CALIBRATED AGES: cal BC 2139, 2077, 2075, 2048, 2046
cal BP 4088, 4026, 4024, 3997, 3995

Sample σ and cal BC(cal BP) ranges:

σ = 20	2199-2155(4148-4104)	2143-2133(4092-4082)	2081-2071(4030-4020)
	2060-2040(4009-3989)		
σ = 40	2267-2266(4216-4215)	2202-2113(4151-4062)	2099-2094(4048-4043)
	2083-2037(4032-3986)		
σ = 60	2271-2256(4220-4205)	2228-2222(4177-4171)	2206-2034(4155-3983)
σ = 80	2287-2286(4236-4235)	2275-2251(4224-4200)	2232-2030(4181-3979)
	1989-1979(3938-3928)		
σ = 100	2290-2010(4240-3960)	1992-1970(3941-3919)	
σ = 120	2337-2323(4286-4272)	2310-2010(4260-3960)	1995-1958(3944-3907)
σ = 160	2451-2444(4400-4393)	2432-2422(4381-4371)	2402-2378(4351-4327)
	2367-2366(4316-4315)	2350-1920(4300-3870)	1902-1891(3851-3840)
σ = 200	2470-1880(4420-3830)	1840-1833(3789-3782)	

RADIOCARBON AGE BP 3740 CALIBRATED AGES: cal BC 2197, 2160, 2142
cal BP 4146, 4109, 4091

Sample σ and cal BC(cal BP) ranges:

σ = 20	2267-2264(4216-4213)	2203-2137(4152-4086)	2079-2074(4028-4023)
	2054-2044(4003-3993)		
σ = 40	2271-2255(4220-4204)	2228-2221(4177-4170)	2206-2134(4155-4083)
	2081-2072(4030-4021)	2059-2041(4008-3990)	
σ = 60	2287-2251(4236-4200)	2232-2114(4181-4063)	2098-2095(4047-4044)
	2083-2037(4032-3986)		
σ = 80	2293-2034(4242-3983)		
σ = 100	2337-2322(4286-4271)	2310-2030(4260-3980)	1989-1980(3938-3929)
σ = 120	2393-2383(4342-4332)	2350-2010(4300-3960)	1992-1970(3941-3919)
σ = 160	2470-1920(4420-3870)		
σ = 200	2470-1890(4420-3840)	1837-1836(3786-3785)	

Table 3-CCC

RADIOCARBON AGE BP 3760 CALIBRATED AGES: cal BC 2201, 2151, 2145
cal BP 4150, 4100, 4094

Sample σ and cal BC(cal BP) ranges:

σ = 20	2272-2255(4221-4204)	2229-2219(4178-4168)	2206-2194(4155-4143)
	2164-2141(4113-4090)		
σ = 40	2287-2250(4236-4199)	2232-2138(4181-4087)	2078-2075(4027-4024)
	2051-2045(4000-3994)		
σ = 60	2293-2135(4242-4084)	2080-2072(4029-4021)	2059-2041(4008-3990)
σ = 80	2337-2322(4286-4271)	2312-2114(4261-4063)	2098-2095(4047-4044)
	2083-2038(4032-3987)		
σ = 100	2393-2383(4342-4332)	2350-2030(4300-3980)	
σ = 120	2451-2444(4400-4393)	2432-2422(4381-4371)	2402-2378(4351-4327)
	2367-2366(4316-4315)	2350-2030(4300-3980)	1989-1980(3938-3929)
σ = 160	2470-2010(4420-3960)	1995-1959(3944-3908)	
σ = 200	2470-1920(4420-3870)	1902-1891(3851-3840)	

RADIOCARBON AGE BP 3780 CALIBRATED AGES: cal BC 2270, 2257, 2227, 2224, 2205
cal BP 4219, 4206, 4176, 4173, 4154

Sample σ and cal BC(cal BP) ranges:

σ = 20	2289-2249(4238-4198)	2233-2199(4182-4148)	2155-2143(4104-4092)
σ = 40	2307-2306(4256-4255)	2293-2196(4242-4145)	2162-2141(4111-4090)
σ = 60	2338-2138(4287-4087)	2078-2075(4027-4024)	2051-2045(4000-3994)
σ = 80	2394-2382(4343-4331)	2348-2135(4297-4084)	2080-2072(4029-4021)
	2059-2041(4008-3990)		
σ = 100	2450-2040(4400-3990)		
σ = 120	2470-2030(4420-3980)		
σ = 160	2470-2010(4420-3960)	1992-1970(3941-3919)	
σ = 200	2490-1920(4440-3870)		

RADIOCARBON AGE BP 3800 CALIBRATED AGES: cal BC 2274, 2252, 2231
cal BP 4223, 4201, 4180

Sample σ and cal BC(cal BP) ranges:

σ = 20	2309-2203(4258-4152)	2147-2146(4096-4095)	
σ = 40	2339-2200(4288-4149)	2154-2144(4103-4093)	
σ = 60	2395-2382(4344-4331)	2349-2197(4298-4146)	2162-2141(4111-4090)
σ = 80	2453-2443(4402-4392)	2432-2422(4381-4371)	2403-2138(4352-4087)
	2078-2075(4027-4024)	2051-2045(4000-3994)	
σ = 100	2470-2130(4420-4080)	2080-2072(4029-4021)	2059-2042(4008-3991)
σ = 120	2470-2110(4420-4060)	2098-2095(4047-4044)	2083-2038(4032-3987)
σ = 160	2470-2030(4420-3980)	1989-1980(3938-3929)	
σ = 200	2490-2010(4440-3960)	1995-1959(3944-3908)	

Table 3-DDD

RADIOCARBON AGE BP 3820 CALIBRATED AGES: cal BC 2292, 2246, 2235
cal BP 4241, 4195, 4184

Sample σ and cal BC(cal BP) ranges:

σ = 20	2388-2386(4337-4335)	2342-2272(4291-4221)	2254-2229(4203-4178)
	2219-2207(4168-4156)		
σ = 40	2427-2426(4376-4375)	2395-2382(4344-4331)	2349-2204(4298-4153)
σ = 60	2454-2421(4403-4370)	2403-2200(4352-4149)	2153-2144(4102-4093)
σ = 80	2467-2197(4416-4146)	2161-2141(4110-4090)	
σ = 100	2470-2140(4420-4090)	2078-2075(4027-4024)	2050-2045(3999-3994)
σ = 120	2470-2130(4420-4080)	2080-2072(4029-4021)	2059-2042(4008-3991)
σ = 160	2490-2030(4440-3980)		
σ = 200	>2500-2010(>4450-3960)	1992-1971(3941-3920)	

RADIOCARBON AGE BP 3840 CALIBRATED AGES: cal BC 2334, 2323, 2311
cal BP 4283, 4272, 4260

Sample σ and cal BC(cal BP) ranges:

σ = 20	2429-2425(4378-4374)	2398-2380(4347-4329)	2351-2276(4300-4225)
	2250-2233(4199-4182)		
σ = 40	2456-2421(4405-4370)	2405-2273(4354-4222)	2253-2230(4202-4179)
	2217-2215(4166-4164)		
σ = 60	2467-2204(4416-4153)		
σ = 80	2469-2200(4418-4149)	2152-2144(4101-4093)	
σ = 100	2470-2200(4420-4150)	2161-2141(4110-4090)	
σ = 120	2470-2140(4420-4090)	2078-2075(4027-4024)	2050-2045(3999-3994)
σ = 160	2490-2110(4440-4060)	2097-2096(4046-4045)	2083-2038(4032-3987)
σ = 200	>2500-2030(>4450-3980)	1989-1980(3938-3929)	

RADIOCARBON AGE BP 3860 CALIBRATED AGES: cal BC 2392, 2383, 2347
cal BP 4341, 4332, 4296

Sample σ and cal BC(cal BP) ranges:

σ = 20	2459-2420(4408-4369)	2406-2295(4355-4244)	
σ = 40	2467-2290(4416-4239)	2248-2234(4197-4183)	
σ = 60	2469-2273(4418-4222)	2253-2230(4202-4179)	
σ = 80	2471-2269(4420-4218)	2259-2204(4208-4153)	
σ = 100	2470-2200(4420-4150)	2152-2144(4101-4093)	
σ = 120	2490-2200(4440-4150)	2161-2142(4110-4091)	
σ = 160	>2500-2140(>4450-4090)	2080-2072(4029-4021)	2058-2042(4007-3991)
σ = 200	>2500-2030(>4450-3980)		

RADIOCARBON AGE BP 3880 CALIBRATED AGES: cal BC 2450, 2445, 2431, 2423, 2402,
2378, 2354
cal BP 4399, 4394, 4380, 4372, 4351,
4327, 4303

Sample σ and cal BC(cal BP) ranges:

σ = 20	2468-2341(4417-4290)	2319-2314(4268-4263)	
σ = 40	2469-2309(4418-4258)	2299-2296(4248-4245)	
σ = 60	2471-2290(4420-4239)	2248-2234(4197-4183)	
σ = 80	2473-2273(4422-4222)	2252-2231(4201-4180)	
σ = 100	2490-2270(4440-4220)	2259-2204(4208-4153)	
σ = 120	2490-2200(4440-4150)	2152-2145(4101-4094)	
σ = 160	>2500-2140(>4450-4090)	2078-2075(4027-4024)	2049-2046(3998-3995)
σ = 200	>2500-2110(>4450-4060)	2097-2096(4046-4045)	2083-2038(4032-3987)

Table 3-EEE

RADIOCARBON AGE BP 3900 CALIBRATED AGES: cal BC 2467, 2417, 2414
cal BP 4416, 4366, 4363

Sample σ and cal BC(cal BP) ranges:

σ = 20	2470-2397(4419-4346)	2381-2350(4330-4299)	
σ = 40	2472-2344(4421-4293)	2317-2316(4266-4265)	
σ = 60	2473-2310(4422-4259)	2297-2296(4246-4245)	
σ = 80	2489-2291(4438-4240)	2247-2234(4196-4183)	
σ = 100	2490-2270(4440-4220)	2252-2231(4201-4180)	
σ = 120	>2500-2270(>4450-4220)	2259-2204(4208-4153)	
σ = 160	>2500-2200(>4450-4150)	2160-2142(4109-4091)	
σ = 200	>2500-2140(>4450-4090)	2080-2072(4029-4021)	2058-2042(4007-3991)

RADIOCARBON AGE BP 3920 CALIBRATED AGE: cal BC 2469
cal BP 4418

Sample σ and cal BC(cal BP) ranges:

σ = 20	2472-2458(4421-4407)	2440-2434(4389-4383)	2420-2406(4369-4355)
σ = 40	2474-2399(4423-4348)	2380-2352(4329-4301)	
σ = 60	2489-2345(4438-4294)	2317-2316(4266-4265)	
σ = 80	2493-2310(4442-4259)		
σ = 100	>2500-2290(>4450-4240)	2247-2235(4196-4184)	
σ = 120	>2500-2270(>4450-4220)	2252-2231(4201-4180)	
σ = 160	>2500-2200(>4450-4150)	2152-2145(4101-4094)	
σ = 200	>2500-2140(>4450-4090)	2078-2075(4027-4024)	2049-2046(3998-3995)

RADIOCARBON AGE BP 3940 CALIBRATED AGE: cal BC 2471
cal BP 4420

Sample σ and cal BC(cal BP) ranges:

σ = 20	2487-2486(4436-4435)	2474-2468(4423-4417)	
σ = 40	2490-2462(4439-4411)	2438-2435(4387-4384)	2419-2409(4368-4358)
σ = 60	2493-2400(4442-4349)	2379-2352(4328-4301)	
σ = 80	>2495-2346(>4444-4295)		
σ = 100	>2500-2310(>4450-4260)		
σ = 120	>2500-2290(>4450-4240)	2247-2235(4196-4184)	
σ = 160	>2500-2270(>4450-4220)	2258-2205(4207-4154)	
σ = 200	>2500-2200(>4450-4150)	2160-2142(4109-4091)	

RADIOCARBON AGE BP 3960 CALIBRATED AGE: cal BC 2473
cal BP 4422

Sample σ and cal BC(cal BP) ranges:

σ = 20	2491-2470(4440-4419)		
σ = 40	2494-2468(4443-4417)		
σ = 60	>2495-2464(>4444-4413)	2437-2436(4386-4385)	2418-2410(4367-4359)
σ = 80	>2495-2400(>4444-4349)	2379-2353(4328-4302)	
σ = 100	>2500-2350(>4450-4300)		
σ = 120	>2500-2310(>4450-4260)		
σ = 160	>2500-2270(>4450-4220)	2252-2231(4201-4180)	
σ = 200	>2500-2200(>4450-4150)	2151-2145(4100-4094)	

Table 3-FFF

RADIOCARBON AGE BP 3980 CALIBRATED AGES: cal BC 2489, 2482, 2475
cal BP 4438, 4431, 4424

Sample σ and cal BC(cal BP) ranges:

σ = 20	2494-2472(4443-4421)	
σ = 40	>2495-2470(>4444-4419)	
σ = 60	>2495-2468(>4444-4417)	
σ = 80	>2495-2465(>4444-4414)	2418-2411(4367-4360)
σ = 100	>2495-2400(>4444-4349)	2379-2353(4328-4302)
σ = 120	>2500-2350(>4450-4300)	
σ = 160	>2500-2290(>4450-4240)	2247-2235(4196-4184)
σ = 200	>2500-2270(>4450-4220)	2258-2205(4207-4154)

RADIOCARBON AGE BP 4000 CALIBRATED AGE: cal BC 2492
cal BP 4441

Sample σ and cal BC(cal BP) ranges:

σ = 20	>2495-2474(>4444-4423)	
σ = 40	>2495-2472(>4444-4421)	
σ = 60	>2495-2470(>4444-4419)	
σ = 80	>2495-2468(>4444-4417)	
σ = 100	>2495-2465(>4444-4414)	2418-2411(4367-4360)
σ = 120	>2495-2400(>4444-4349)	2379-2353(4328-4302)
σ = 160	>2500-2310(>4450-4260)	
σ = 200	>2500-2270(>4450-4220)	2252-2231(4201-4180)

RADIOCARBON AGE BP 4020 CALIBRATED AGE: cal BC 2496
cal BP 4445

Sample σ and cal BC(cal BP) ranges:

σ = 20	>2495-2490(>4444-4439)	2478-2476(4427-4425)
σ = 40	>2495-2474(>4444-4423)	
σ = 60	>2495-2472(>4444-4421)	
σ = 80	>2495-2470(>4444-4419)	
σ = 100	>2495-2468(>4444-4417)	
σ = 120	>2495-2465(>4444-4414)	2418-2412(4367-4361)
σ = 160	>2500-2350(>4450-4300)	
σ = 200	>2500-2290(>4450-4240)	2247-2235(4196-4184)

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HIGH-PRECISION ^{14}C MEASUREMENT OF IRISH OAKS TO SHOW THE NATURAL ^{14}C VARIATIONS FROM AD 1840 TO 5210 BC

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ABSTRACT. High-precision measurement of dendrochronologically dated Irish oak at bi-decade/decade intervals has continued in the Belfast laboratory, extending the ^{14}C data base from ca AD 1840 to 5210 BC. The dendrochronology is now considered absolute (see Belfast dendrochronology this conference) (Brown *et al*, 1986) and a continuous detailed curve is presented, showing the natural variations in the atmospheric concentration of ^{14}C over >7000 years. Each data point has a precision of <2.5‰, and some 4500 years have now been compared with Seattle, giving excellent agreement. Discussion of this data base and the justification of the claimed accuracy is given together with a comparison of other chronologies. Some of the advantages and limitations of the above are discussed.

INTRODUCTION

High-precision (ca ± 2‰) measurements of dendrochronologically dated wood have shown in detail the short-term variation of ^{14}C in atmospheric carbon. Some 6000 years of bi-decade measurements were presented by Pearson and Baillie (1983) and Pearson, Pilcher and Baillie (1983) but were not considered absolute dendrochronologically from ca 500 BC → ca 4000 BC. The natural variations illustrated here are shown against an absolute dendro-axis and the ^{14}C measurements are demonstrated to be accurate internally, giving consistent replication over the whole time period presented and externally by comparison with ca 4500 years of Seattle measurements (Stuiver & Pearson, 1986; Pearson & Stuiver, 1986).

The achievement of high precision in liquid scintillation counting was detailed in Pearson (1979, 1980), but an updating of the corrections used, together with their effect on accuracy when omitted are discussed below. Greater detail of the variables giving rise to the above corrections and the parameters monitored to ascertain the variation, are given in Pearson (1983).

HIGH-PRECISION ^{14}C MEASUREMENT (BY LIQUID SCINTILLATION COUNTING OF BENZENE)

This method of analysis has been discussed in previous publications (Pearson, 1979, 1980, 1983; Pearson & Baillie, 1983). The fundamental requirements for high-precision analysis are 1) to have a pure uncontaminated sample, and 2) to measure this under stable standardized conditions. Rigorous pretreatment of samples (wood) (Dresser, 1970) and careful conversion to benzene can provide pure samples with relatively high conversion yields. To achieve stable standardized conditions of counting, many factors that influence both the efficiency of detection and the 'background' contribution to sample counts, determine the need for corrective measures. In high-precision counting, all variables that have a significance of >0.025% (Pearson, 1979, 1980) have to be resolved by correction or eliminated as variables. A list of those resolved by correction and the parameters monitored to derive the corrections is given in Table 1, together with the residual and estimated errors, if such a correction was ignored.

Potential variables such as 1) vial differences that may give inconsistent efficiencies and/or background, 2) plastic caps that do not allow accurate weighing because of their differential moisture absorption, dependent upon ambient conditions, 3) ^{222}Rn contamination from laboratory water supply, and 4) memory effects in the lithium reactor are eliminated. This is achieved for 1) by the selection of identical vials, 2) by the change of vial caps to a low radioactive lead alloy, 3) by specially selecting a water containing minimal amounts of ^{222}Rn, then completely degassing by boiling and standing the sample benzene for at least a month before measurement, and finally, 4) the memory effects are reduced to an insignificant level by using 'clean-out' samples (samples of similar age to the one under analysis) which condition the reactor.

The above list shows that the variables and potential variables are many and it is expected that with very few exceptions these would apply to most liquid scintillation counting systems, although with differing emphasis. Some of the variables may be avoided by the quasi-simultaneous counting of identically prepared standards and background, although it is statistically advantageous to be able to take mean values of these over longer periods than normal sample measurements.

Only one value of standard count rate was used for the calculations presented here. The standard and samples were measured over a 10-year period, allowing a precise value for the standard to be obtained. The actual standard deviation based on 55 duplicate analyses was calculated using the relationship $\hat{\sigma} = SS/2n$ where SS = Sum of the (difference between duplicates)^2, n = No. of duplicated measurements, and $\hat{\sigma}$ is the derived average standard deviation which can then be compared to the mean standard deviation ($\bar{\sigma}$) quoted on the 110 individual measurements. The actual calculated standard deviation value was $\hat{\sigma} = \pm 19.0$ yr. The mean quoted error on the individual measurements was evaluated from $\bar{\sigma} = [\Sigma_{i-1}^{n} (\sigma_1)^2/n]^{1/2}$, and gave a value of $\bar{\sigma} = \pm 15.4$ yr, thus suggesting that the quoted error is underestimated by ca 23%, or an error multiplier of 1.23 is required.

RADIOCARBON TIME-SCALE CALIBRATION

During the past decade high-precision techniques have been used to measure dendrochronologically dated wood samples to provide a record of the natural ^{14}C variations; this information has been used primarily for time-scale calibration with a quoted mean measurement error of <±20 yr. The longest previously published high-precision BC calibration (Pearson, Pilcher & Baillie, 1983) was based on a provisional fixing of a Belfast floating dendrochronologic sequence; consequently, for this period, it was probably more prudent to use the lower precision measurements of absolutely dated samples such as the calibration presented by Klein *et al* (1982).

The ^{14}C measurements presented here are derived from decade/bi-decade contiguous samples of mainly Irish oak. The decade sample measurements were combined, and are presented with bi-decade measurements in Table 2 and also separately in Table 3. Since the announcement of the continuous European dendrochronologic sequence in 1984 (Pilcher *et al*, 1984), the entire sequence in the BC era has been re-worked and dendrochronologically checked and is totally internally consistent. The links with the German chronologies have further been confirmed by cross-dating, between established chronologies from North Germany, England, and Northern Ireland (Pilcher *et al*, 1984). There are >700 trees in the section of chronology from 116 BC to 5289 BC and over most of this time span the replication is very good. The justification for the chronology at the few remaining places where replication is weakest, is given (Baillie, Pilcher & Pearson, 1983; Brown *et al*, 1986).

Some 7000 years of Irish oak have now been measured as decade or bi-decade contiguous samples, providing the longest single high-precision calibration of the ^{14}C time scale and the results are illustrated in Figure 1. Although much of it has been published before, (Pearson & Baillie, 1983; Pearson, Pilcher & Baillie, 1983) all measurements have been recalculated using updated corrections to give improved accuracy. Duplicate analyses on many samples have allowed reduction in their quoted precision, although this was shown above to be possibly underestimated by ca 23%. Tables 2 and 3 give the laboratory number of the bi-decade/decade sample respectively, together with the center dendro-year and its ^{14}C age in years BP, based on the Libby half-life of 5568 years. Also included are the equivalent Δ values and one standard deviation error limits on both the ^{14}C age and Δ values; this is the estimated error and includes all correction errors together with the counting statistics; it does not include the error multiplier discussed above.

The international validity of any calibration can only be proved by the independent analysis of other absolutely dated wood samples from other parts of the world. If the agreement between two such data sets is within statistical expectation, then it seems reasonable that such a calibration would be more internationally acceptable. Such a comparison is possible over 4500 years of calibration between Belfast and Seattle. Some 214 measurements were compared and the resulting differences closely fit a Gaussian distribution with a standard deviation of 25.6 years (Stuiver & Pearson, 1986) and a mean difference of 0.6 years. This agreement shows that no significant bias exists. The replicate analyses as discussed above suggest an error multiplier of ca 1.23 for the Belfast data. A similar approach yields an overall error 1.6 times the standard deviation in combining statistics for the Seattle data (Stuiver & Pearson, 1986). Application of these error multipliers result in an average standard deviation of the 214 points of 22.9 years. Thus, the Seattle and Belfast overall laboratory precision accounts for nearly the entire variability found between both data sets.

CONCLUSION

The fine detail of the natural ^{14}C variation curve will be of considerable interest to many workers in astrophysics, solar physics, geophysics, etc, but perhaps the most immediate use will be as a high-precision ^{14}C time-scale calibration.

It has been shown above that it is now possible by combining Seattle and Belfast data to provide an internationally acceptable calibration curve within a 1σ envelope of ca ± 14 years, covering a time period of some 4500 years. The remaining Belfast curve from 2500–5210 BC would be valid using an error multiplier of 1.23 to give an average calibration band-width of $< \pm 20$ years.

The high-precision curve is essential for converting high-precision analysis and it has already proved useful in sorting out some archaeologic dating problems from the late Bronze age/early Iron age where the calibration curve is almost horizontal from 400–800 BC. Samples dated ca 2350 BP, eg, with precisions of ca ± 100 years could not be converted to a calendar age band with any greater resolution than 480 years (750–270 BC). Using high-precision measurement ca ± 20 years, this band width for the above sample can be reduced to almost 10 years. Single high-precision analysis of samples can give calendric band widths which are similar to the ^{14}C quoted error range over considerable portions of the calibration.

The use of 'wiggle matching' (Pearson, 1986) can give narrow calendric band widths for certain samples with a known deposition rate or growth period where wiggles would normally cause the reporting of large calendric band widths.

Thus, it can be concluded that high-precision analysis can provide fine calendric resolution to the archaeologic chronology, providing, of course, the samples submitted have the same credentials in terms of precise association and integrity, allowing for correct interpretation.

ACKNOWLEDGMENTS

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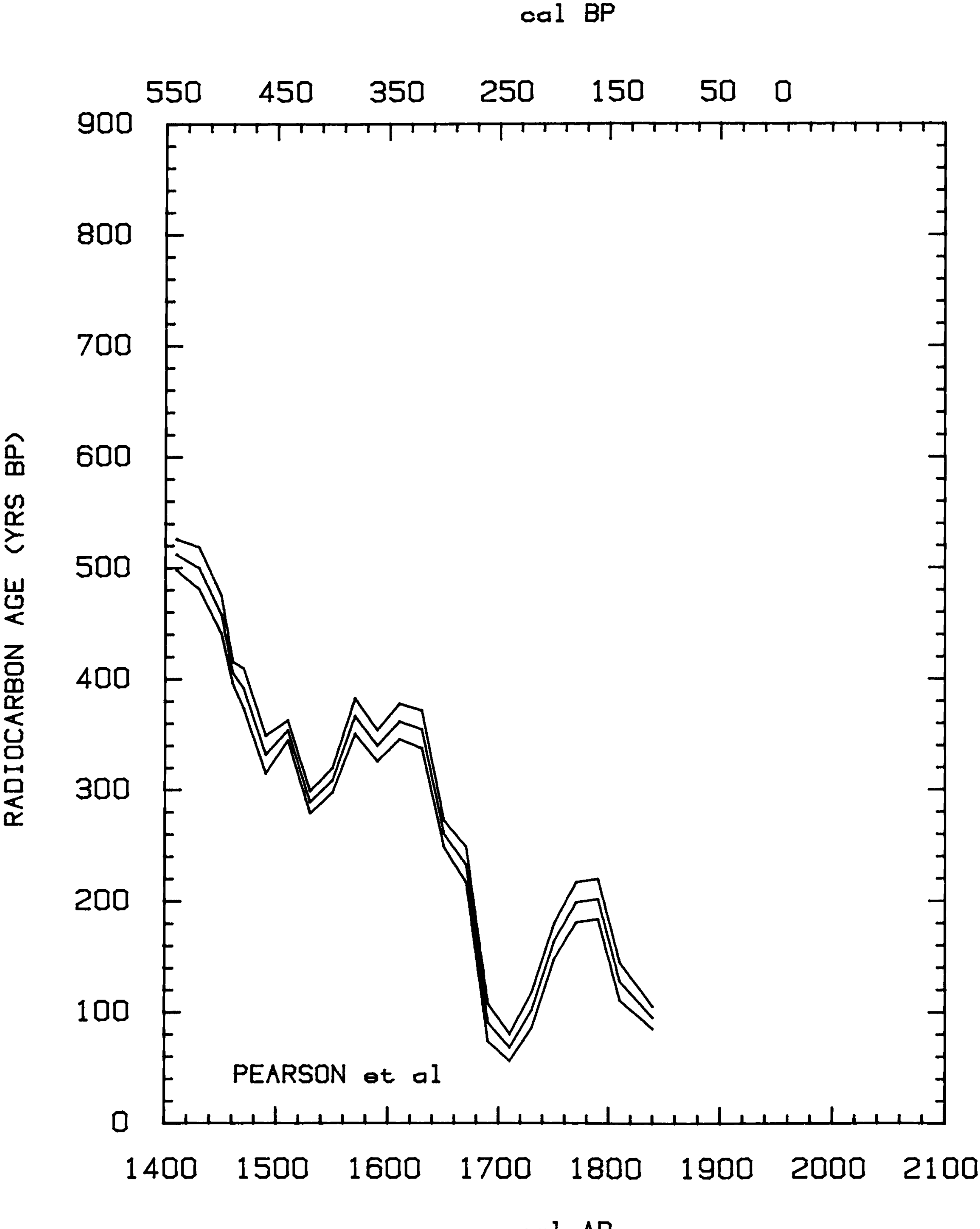


Fig 1A

Figs 1A–1O. Radiocarbon time-scale calibration from AD 1840 to 5210 BC

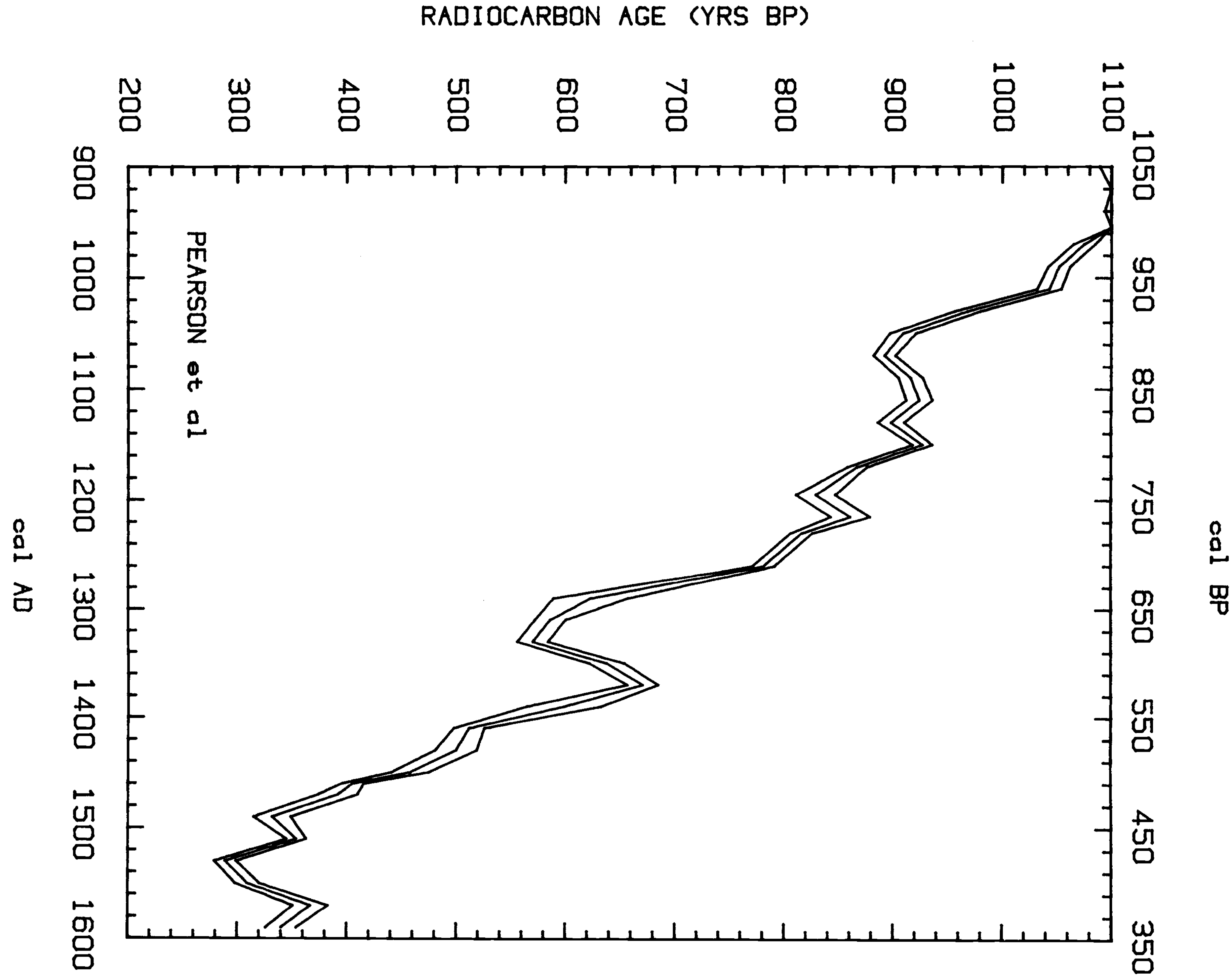

RADIOCARBON AGE (YRS BP)
200
300
400
500
600
700
800
900
1000
1100
cal BP
1050
950
850
750
650
550
450
350
PEARSON et al
900
1000
1100
1200
1300
1400
1500
1600
cal AD

Fig 1B

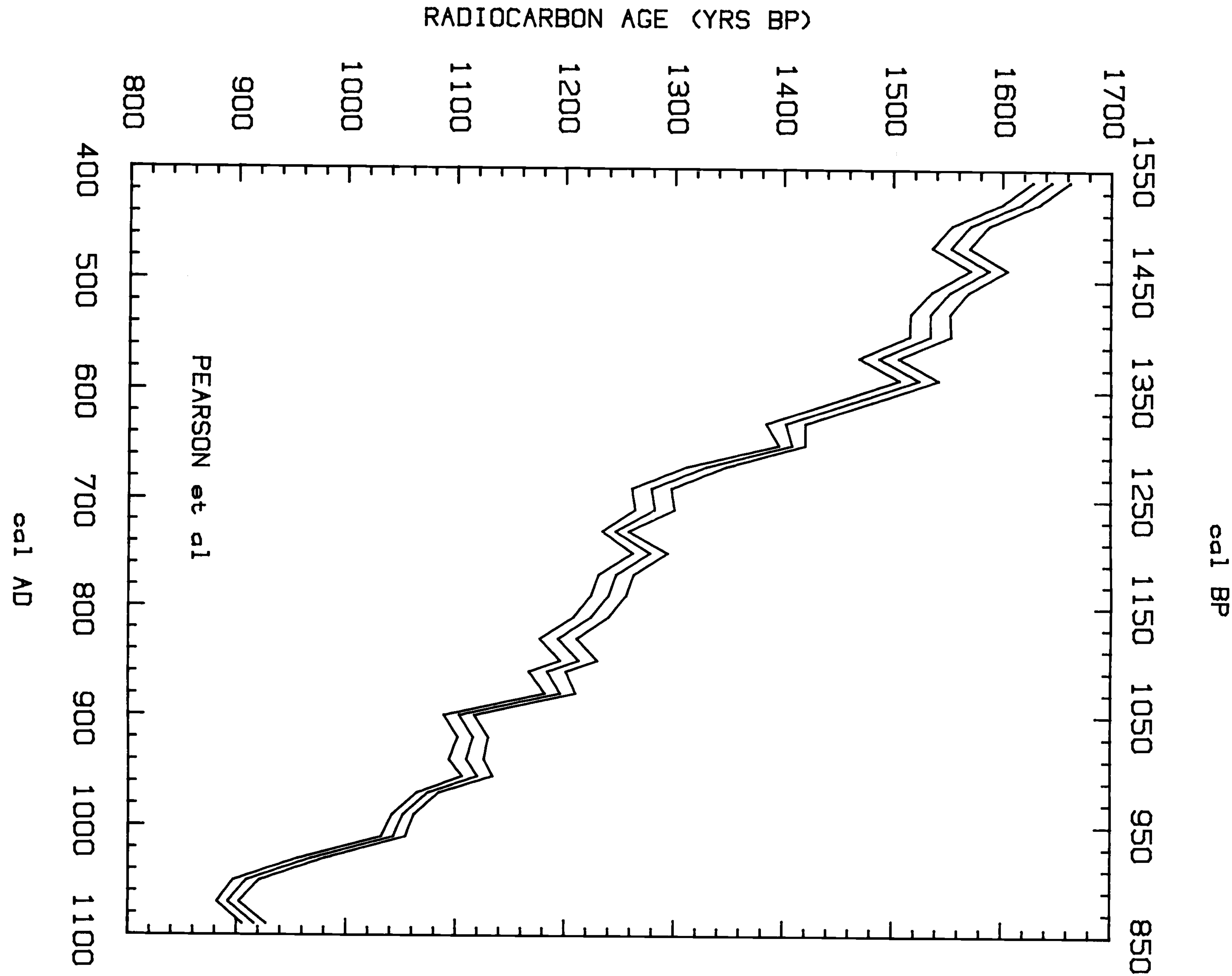
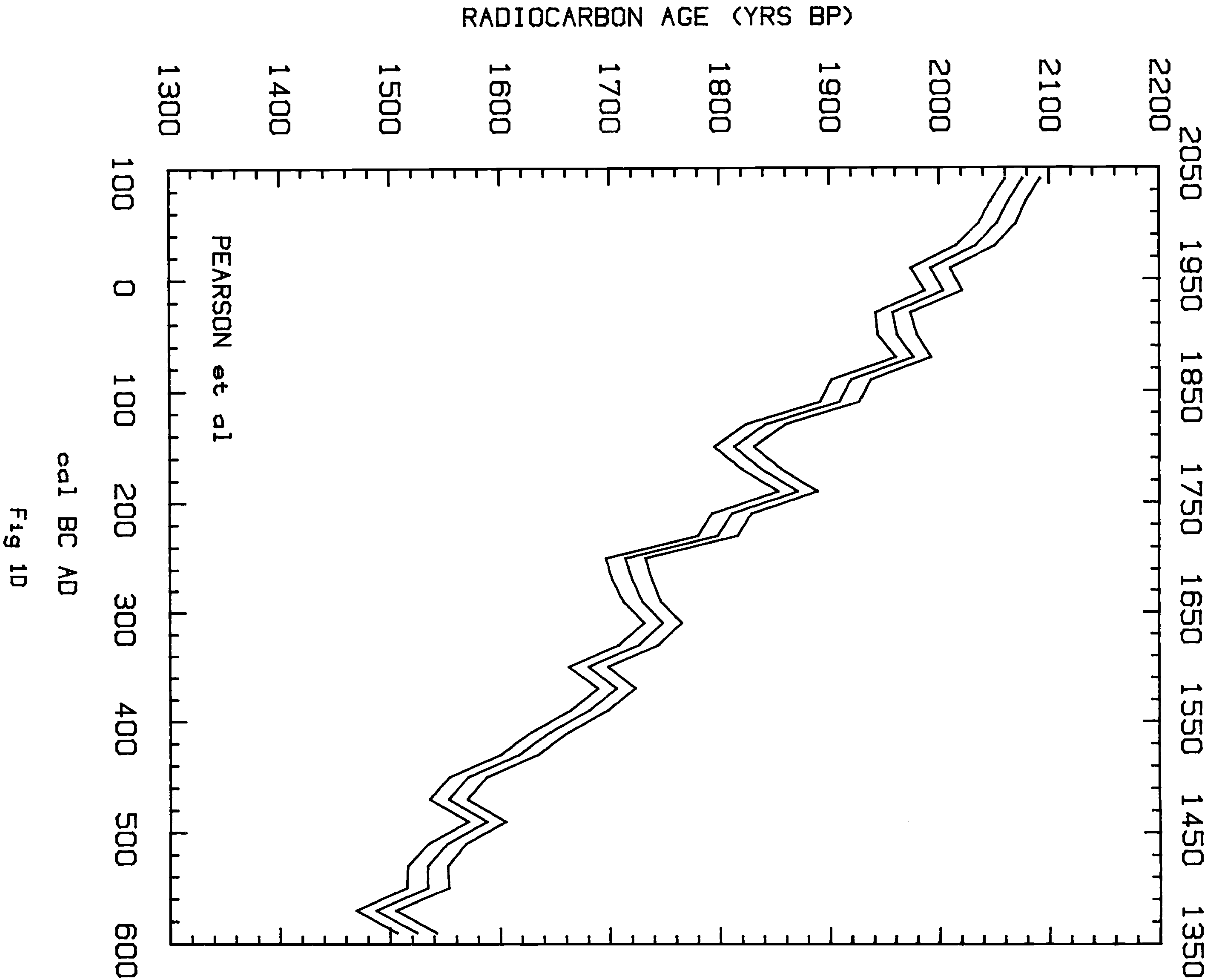

RADIOCARBON AGE (YRS BP)
800
900
1000
1100
1200
1300
1400
1500
1600
1700
cal BP
1550
1450
1350
1250
1150
1050
950
850
400
500
600
700
800
900
1000
1100
cal AD
PEARSON et al

Fig 1C


RADIOCARBON AGE (YRS BP)
cal BP
PEARSON et al
cal BC AD
Fig 1D

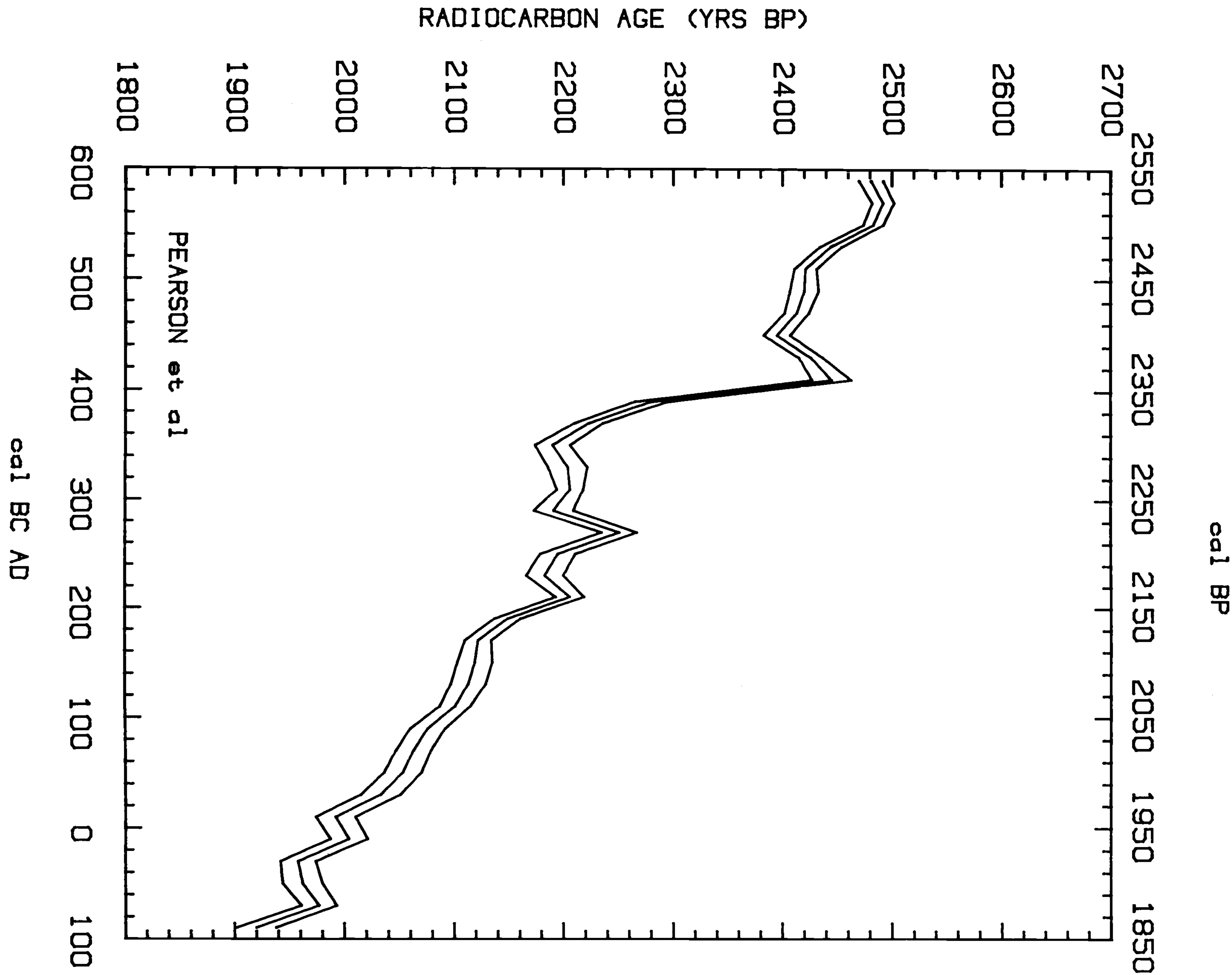

RADIOCARBON AGE (YRS BP)
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
cal BP
2550
2450
2350
2250
2150
2050
1950
1850
PEARSON et al
600
500
400
300
200
100
0
100
cal BC AD

Fig 1E

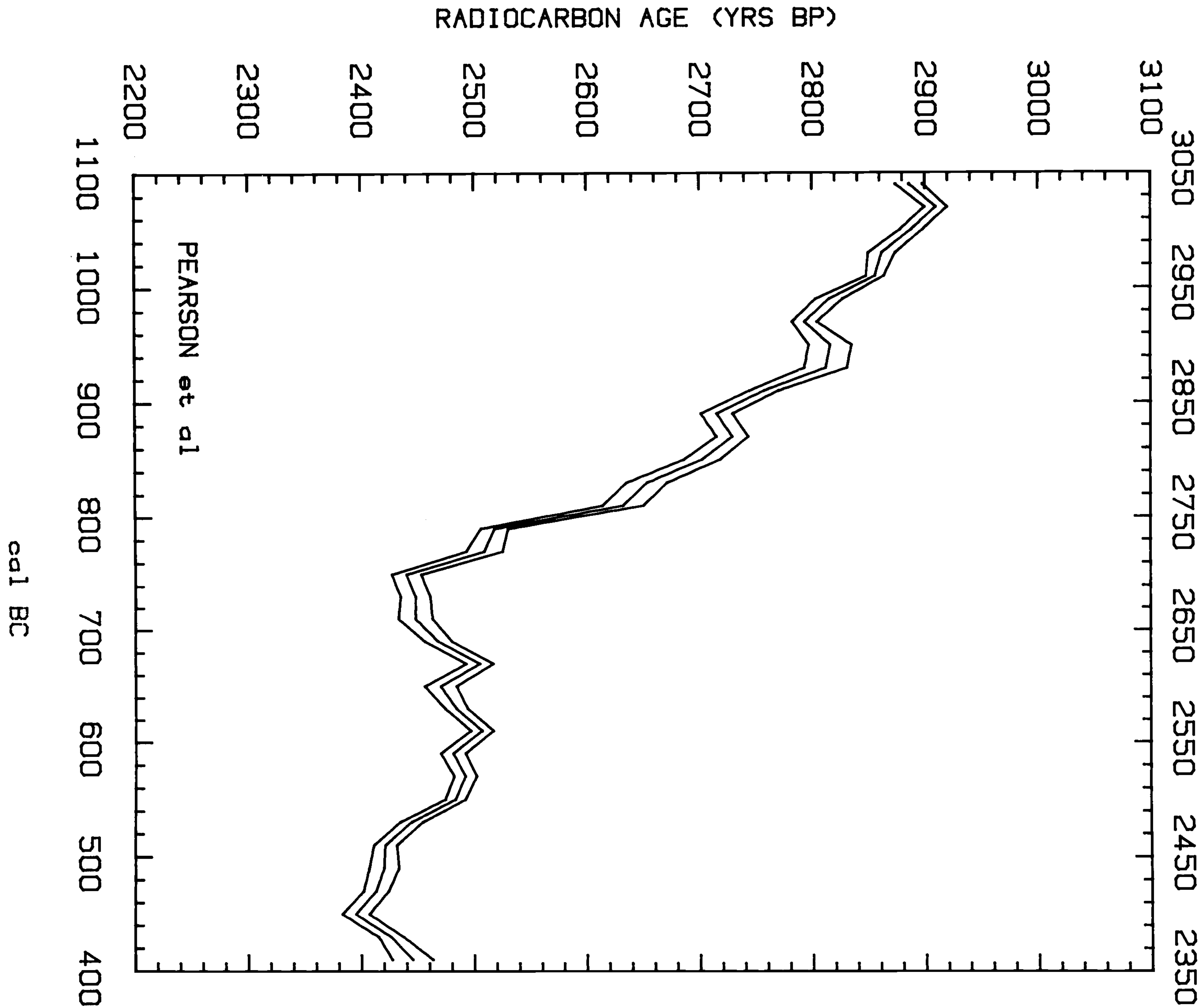
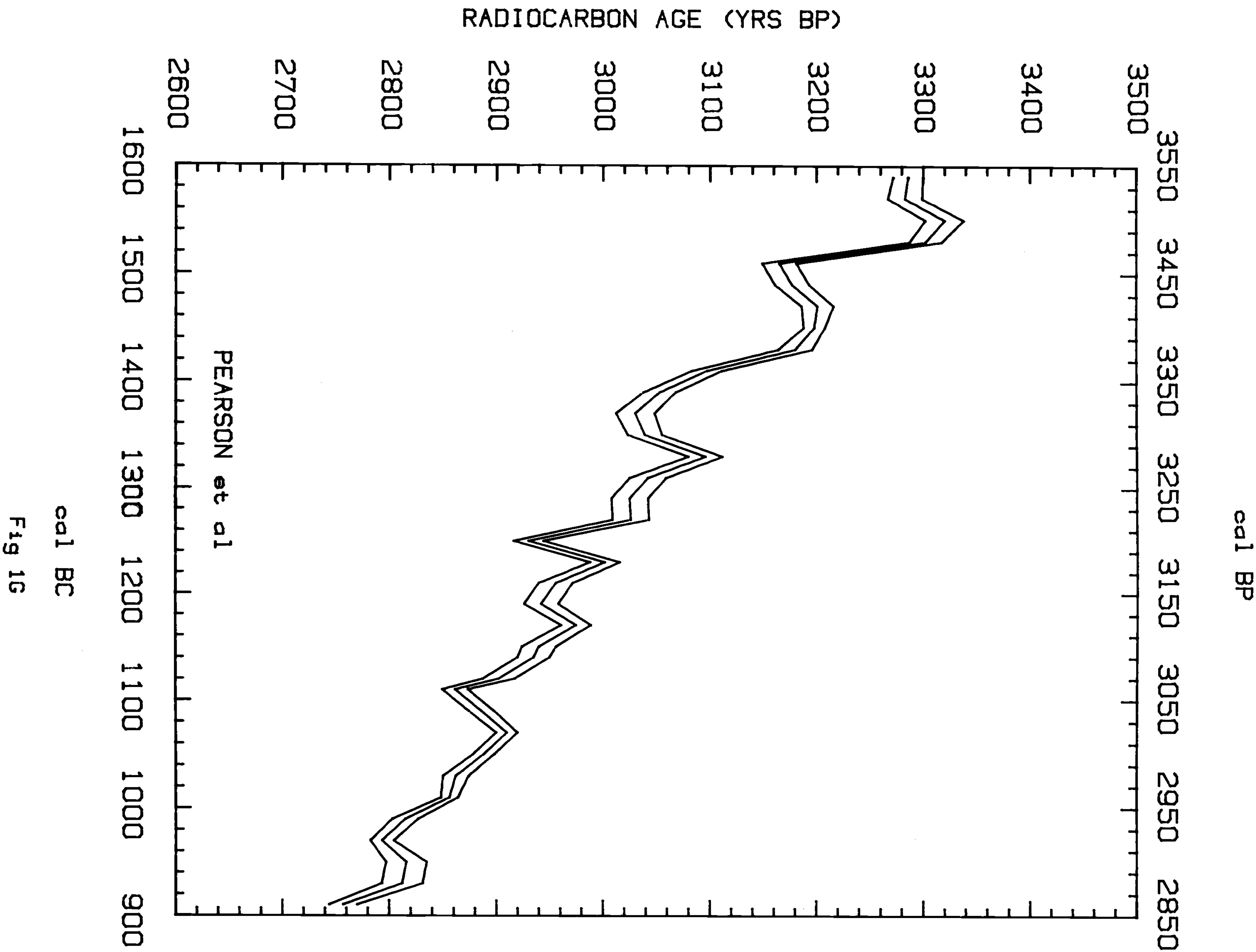

RADIOCARBON AGE (YRS BP)
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
cal BP
3050
2950
2850
2750
2650
2550
2450
2350
PEARSON et al
1100
1000
900
800
700
600
500
400
cal BC

Fig 1F


RADIOCARBON AGE (YRS BP)
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
cal BP
3550
3450
3350
3250
3150
3050
2950
2850
1600
1500
1400
1300
1200
1100
1000
900
PEARSON et al
cal BC
Fig 1G

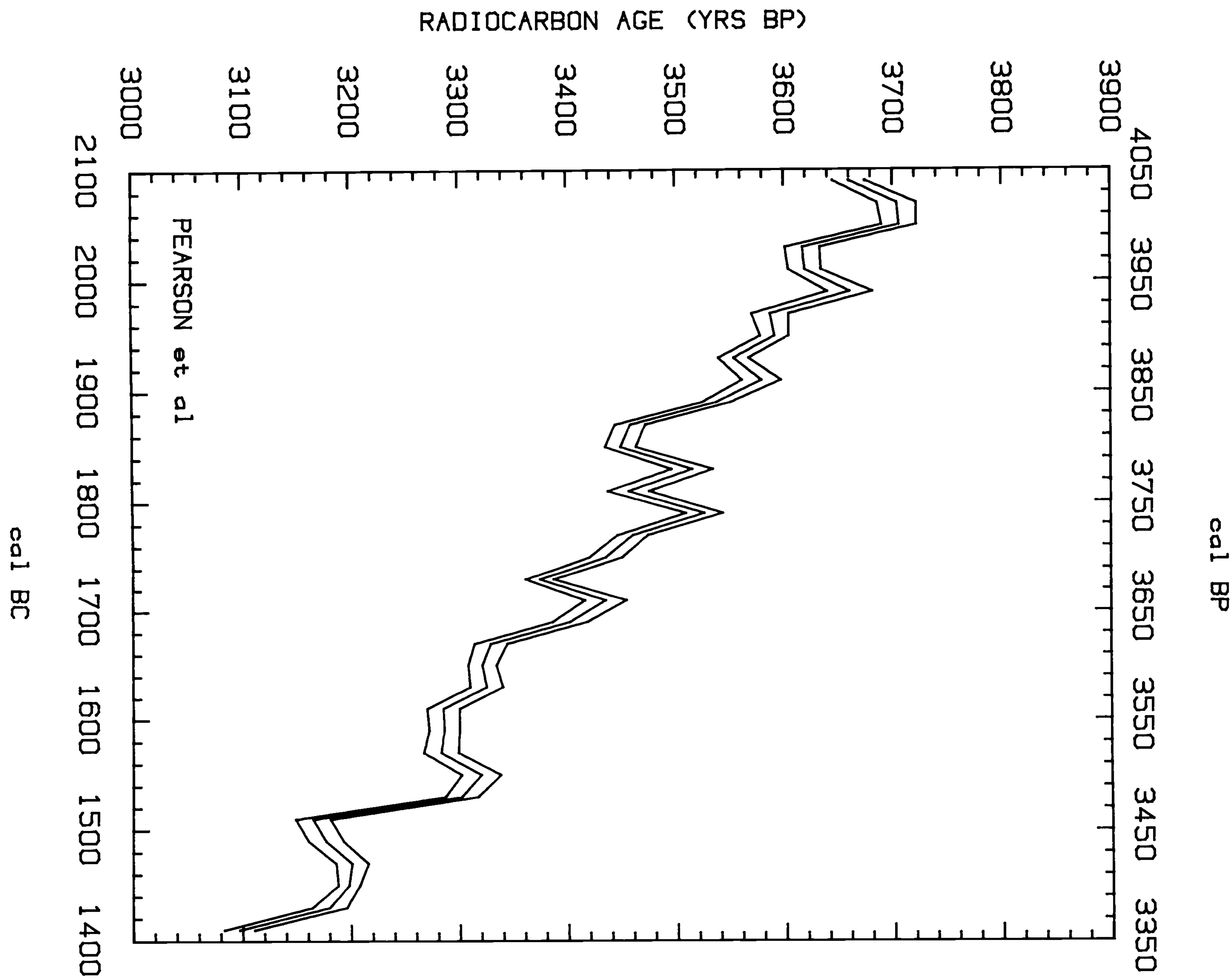

RADIOCARBON AGE (YRS BP)
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
cal BP
4050
3950
3850
3750
3650
3550
3450
3350
cal BC
2100
2000
1900
1800
1700
1600
1500
1400
PEARSON et al

Fig 1H

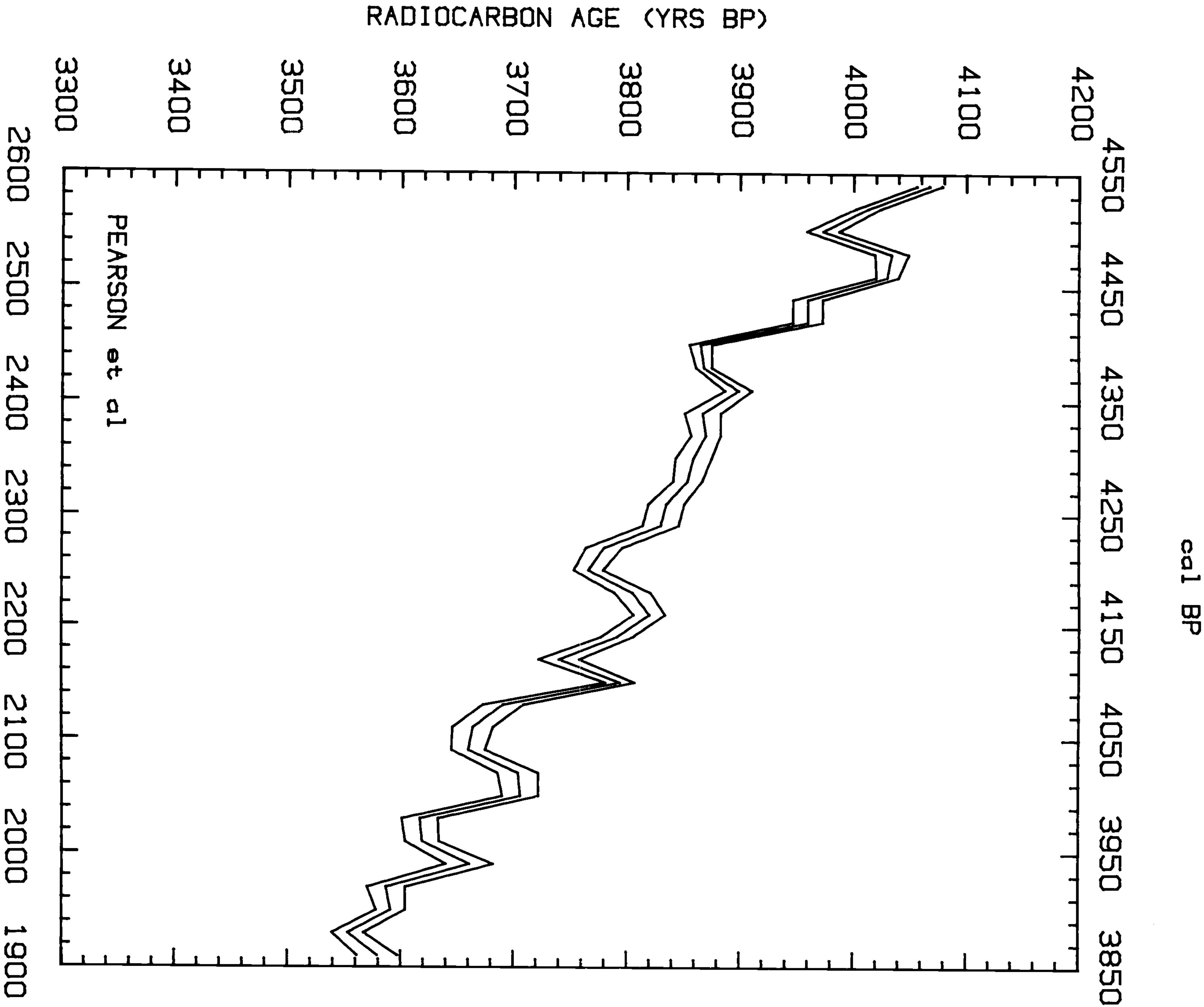

RADIOCARBON AGE (YRS BP)
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
cal BP
4550
4450
4350
4250
4150
4050
3950
3850
cal BC
2600
2500
2400
2300
2200
2100
2000
1900
PEARSON et al

Fig 1I

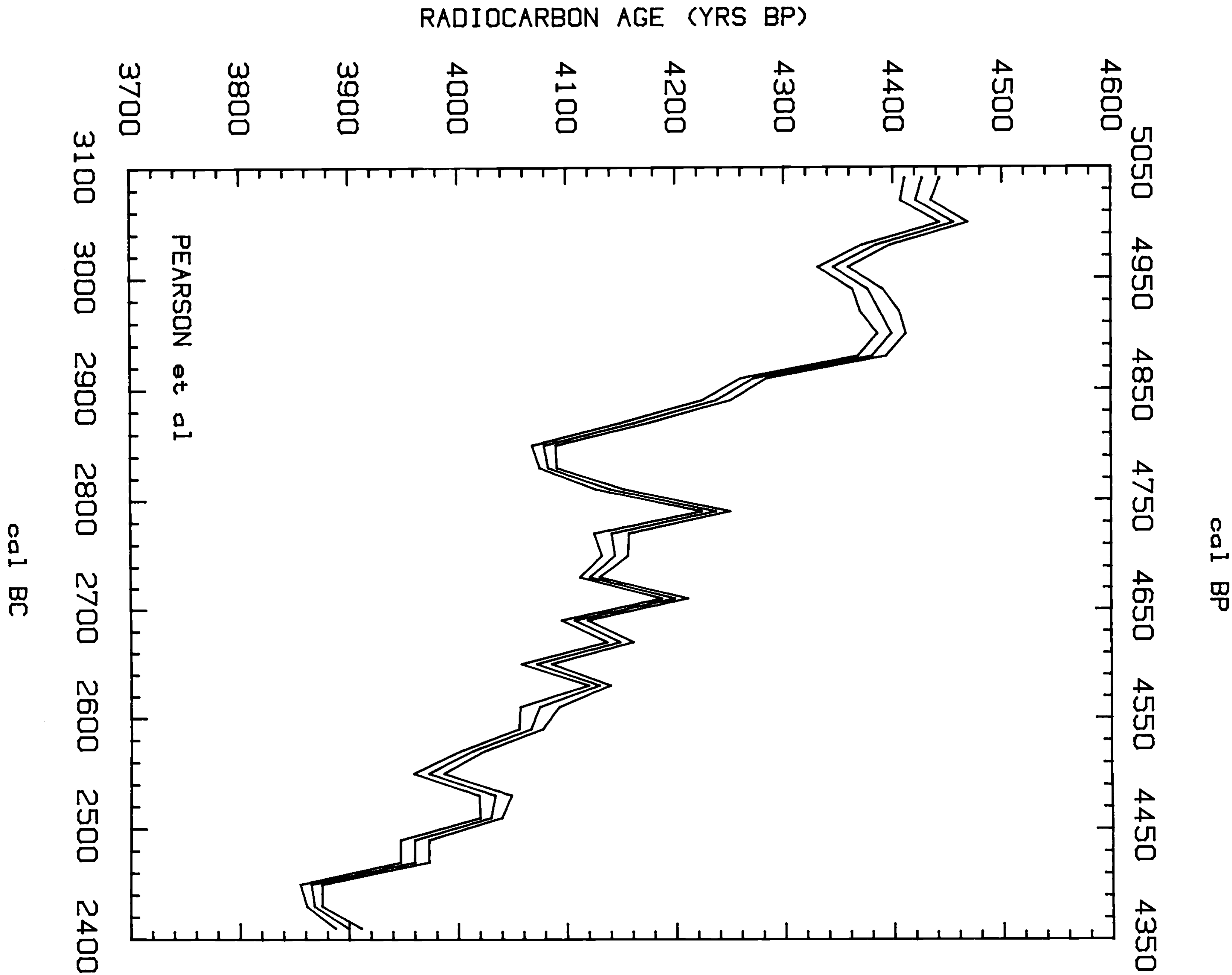
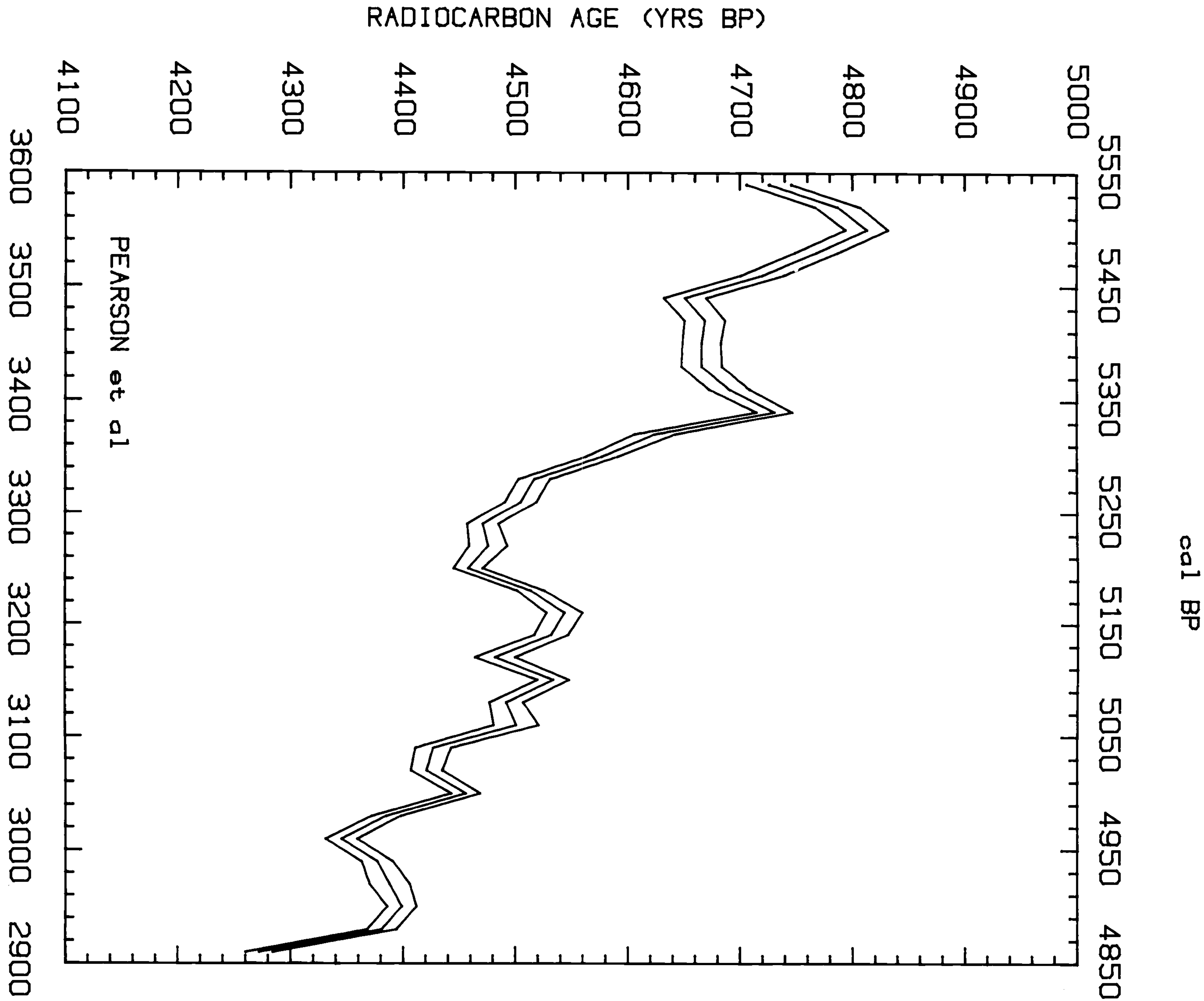

RADIOCARBON AGE (YRS BP)
3700
3800
3900
4000
4100
4200
4300
4400
4500
4600
cal BP
5050
4950
4850
4750
4650
4550
4450
4350
cal BC
3100
3000
2900
2800
2700
2600
2500
2400
PEARSON et al

Fig 1J


RADIOCARBON AGE (YRS BP)
4100
4200
4300
4400
4500
4600
4700
4800
4900
5000
5550
5450
5350
5250
5150
5050
4950
4850
cal BP
3600
3500
3400
3300
3200
3100
3000
2900
PEARSON et al

cal BC

Fig 1K

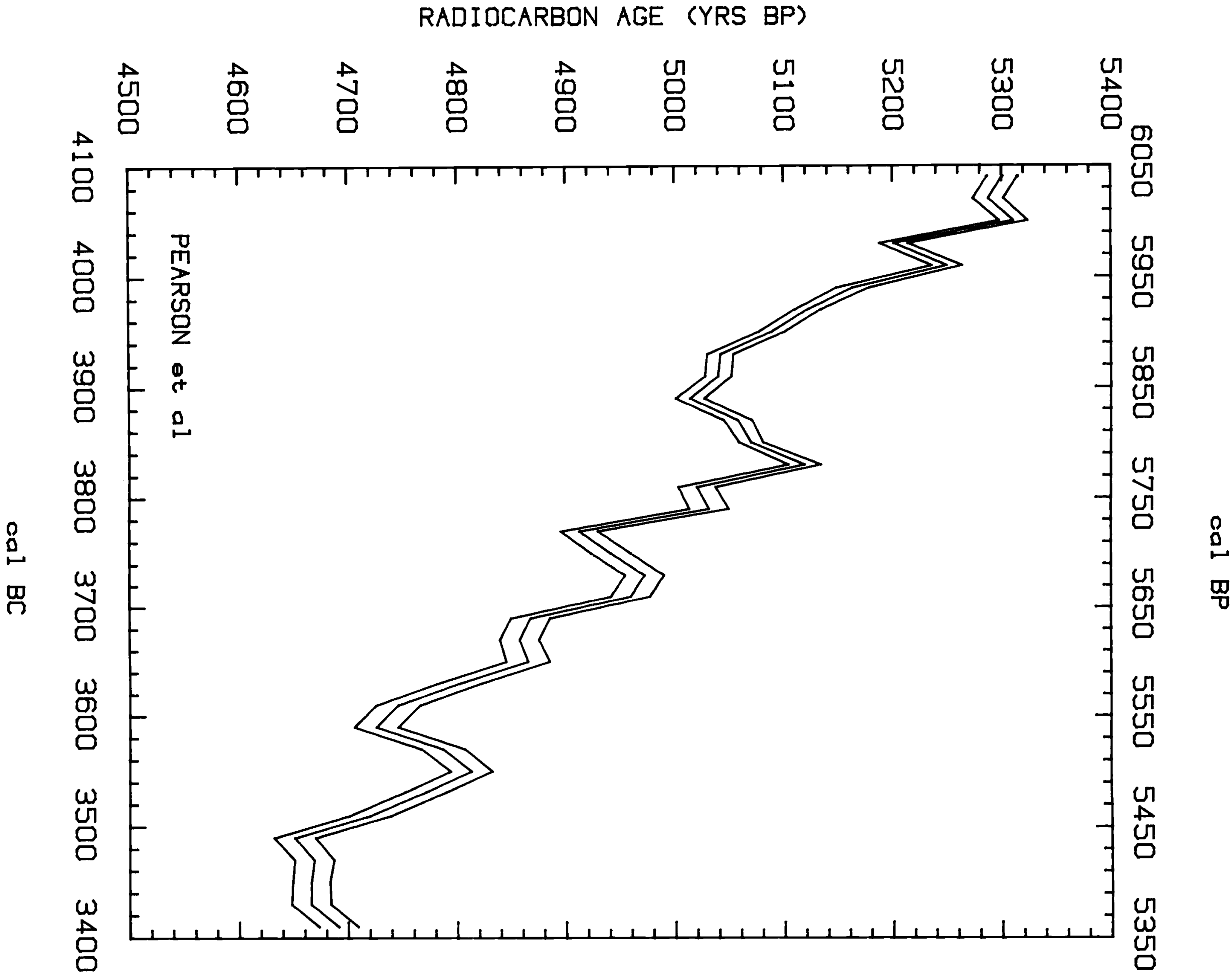

RADIOCARBON AGE (YRS BP)
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400
cal BP
6050
5950
5850
5750
5650
5550
5450
5350
cal BC
4100
4000
3900
3800
3700
3600
3500
3400
PEARSON et al

Fig 1L

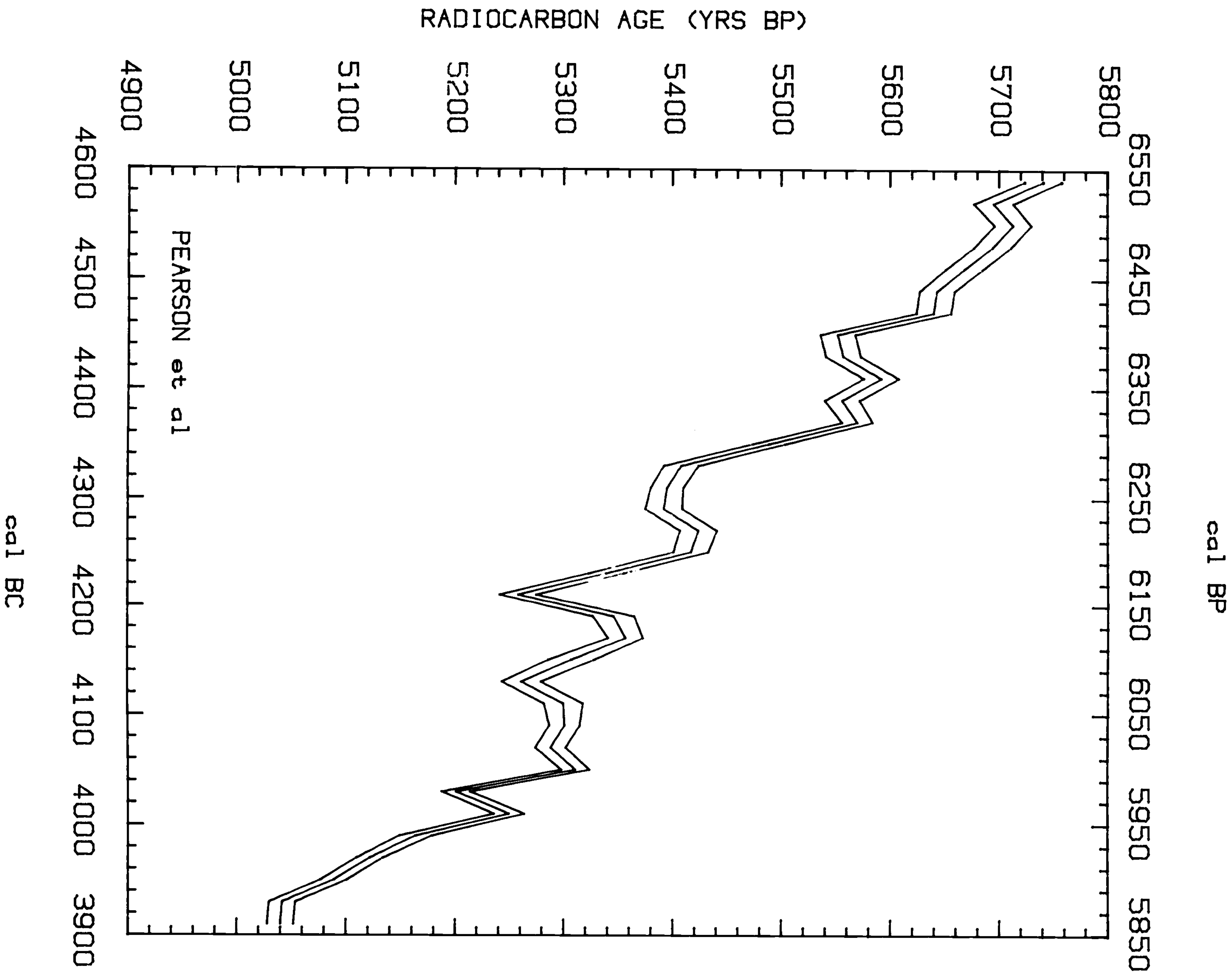

RADIOCARBON AGE (YRS BP)
4900
5000
5100
5200
5300
5400
5500
5600
5700
5800
cal BP
6550
6450
6350
6250
6150
6050
5950
5850
PEARSON et al
4600
4500
4400
4300
4200
4100
4000
3900
cal BC

Fig 1M

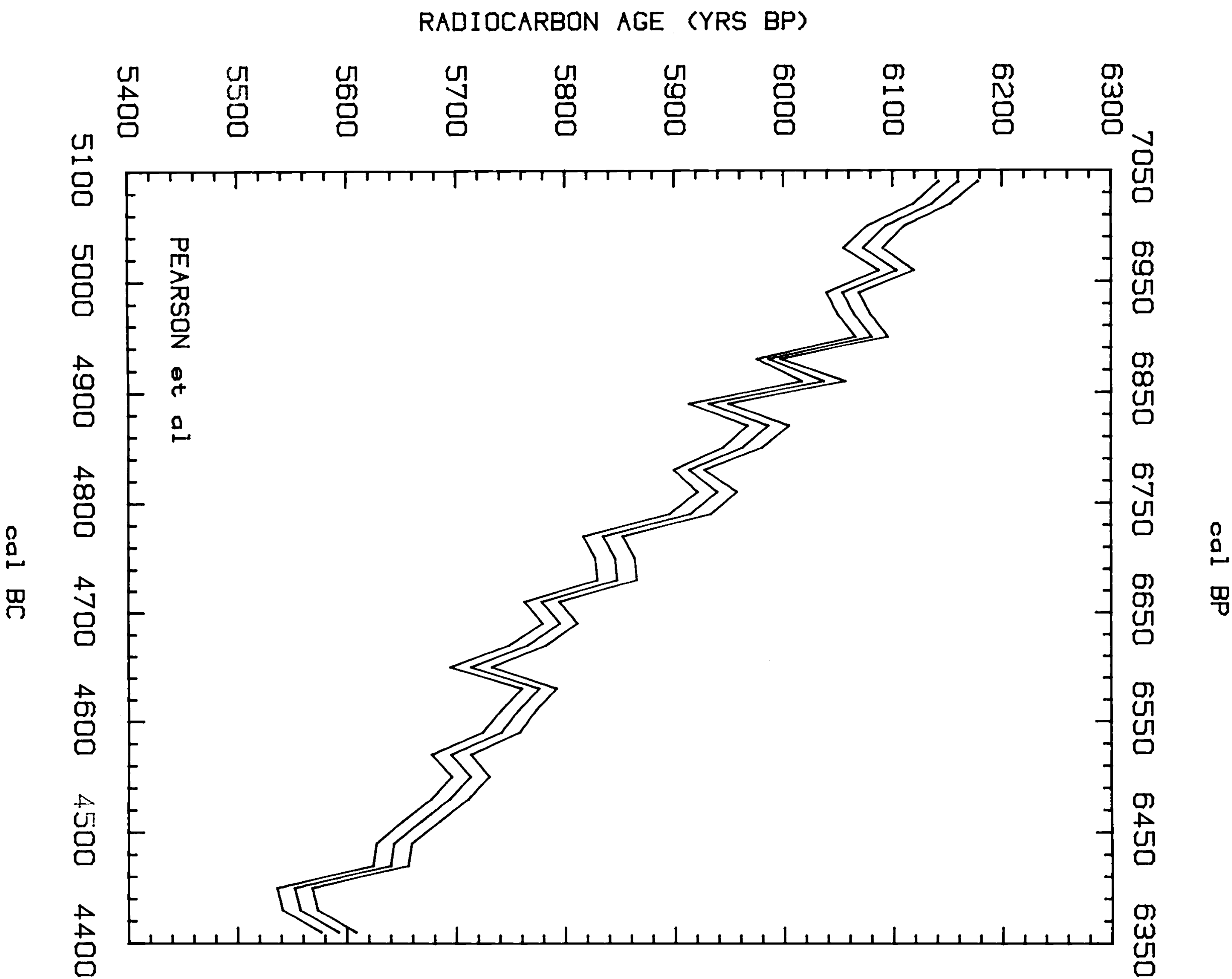

RADIOCARBON AGE (YRS BP)
5400
5500
5600
5700
5800
5900
6000
6100
6200
6300
cal BP
7050
6950
6850
6750
6650
6550
6450
6350
PEARSON et al
5100
5000
4900
4800
4700
4600
4500
4400
cal BC

Fig 1N

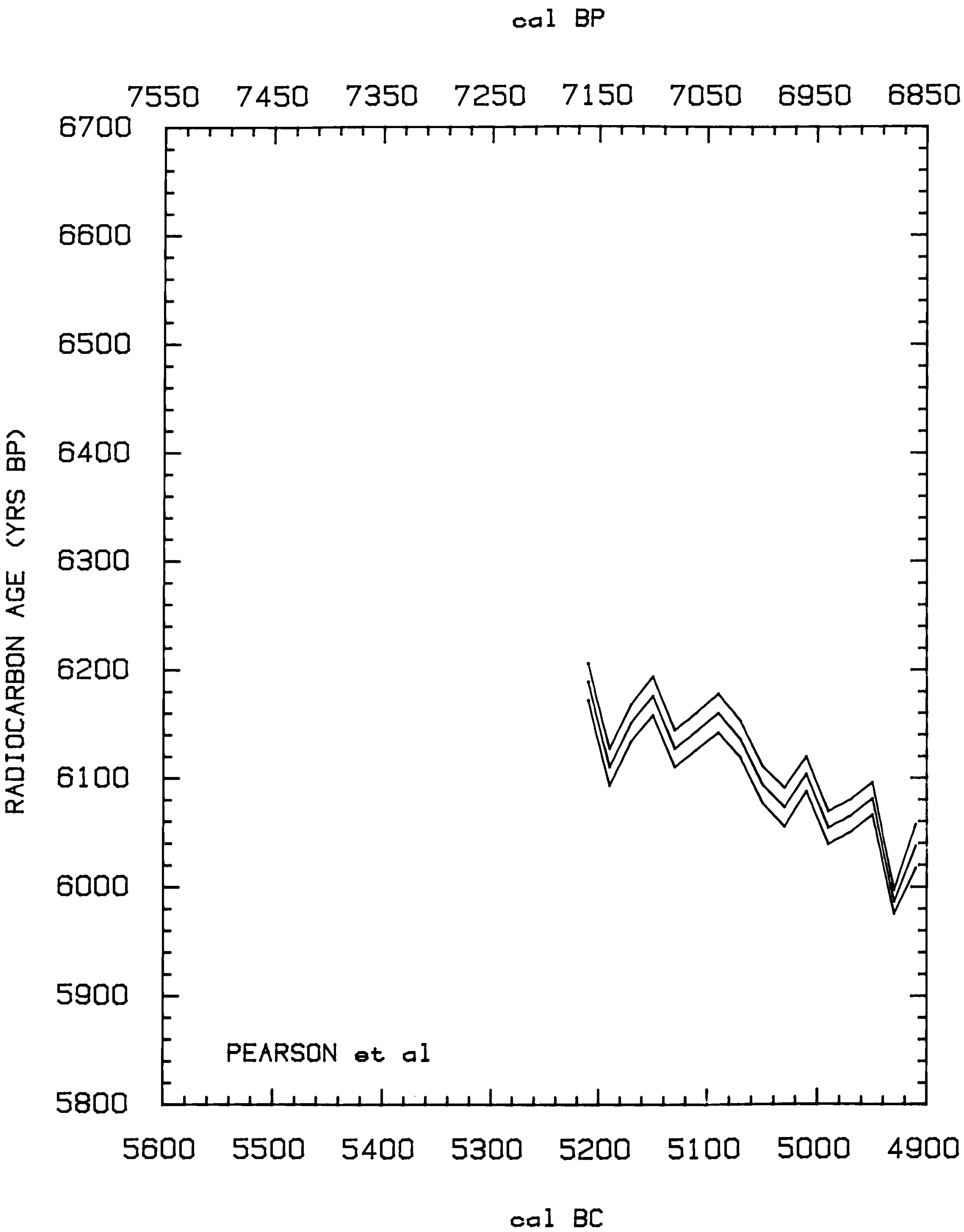

cal BP
7550 7450 7350 7250 7150 7050 6950 6850
RADIOCARBON AGE (YRS BP)
6700 6600 6500 6400 6300 6200 6100 6000 5900 5800
PEARSON et al
5600 5500 5400 5300 5200 5100 5000 4900
cal BC

Fig 10

TABLE 1
Corrections applied to scintillation counting results

ERROR SOURCE	PARAMETER MONITORED	DERIVATION OF CORRECTION	NORMALISED VALUE	ERROR ESTIMATED ON SAMPLE COUNTS ONLY: ESTIMATED RESIDUAL ERROR IN YEARS cf SAMPLE = T^2 NET SAMPLE = 60 CPM	ERROR ESTIMATED ON SAMPLE COUNTS ONLY: ESTIMATED ERROR IN YEARS IF UNCORRECTED cf SAMPLE = T^2 NET SAMPLE = 60 CPM
Background variation with 'purity'	Channel ratio of external ^{133}Ba source	Correction is in two parts:- Constant component = 0.013 cpm Variable component = 0.008 cpm for each 0.01 rise in channels ratio	Channels ratio = 1.95	Estimated at 0.03% cf T^2 ie ± 2.5 years	Channels ratio variation = ± 0.05 ≡ ± 0.1 cpm ie ± 13 years
Background variation with weight loss from vial	Vial weighing; average weight loss calculated	Background count rate variation with volume curve Slope = 0.289 cpm/g loss	Weight of standard contents=14.2666 g. 13.1325 g of C6H6	Weighing error ± 1 mg ≡ ± 0.000289 cpm ie 0.04 years	Normal losses are about 1 mg per day. On a 14 day count this would give an error of ± 0.6 years.
Efficiency variation with weight loss from vial	Vial weighing; average weight loss calculated	Linear regression of efficiency on weight loss over a 1 g fall Slope = 0.0016%/mg fall in weight	Filling weight = 14.2666 g	Error in weighing = ± 1 mg ≡ ± 0.00096 cpm ie ± 0.13 years	Loss of 1 mg/day ≡ 0.013 cpm ie ≈ 2 years
Differential loss of benzene and toluene from counting mixture	as above	Experimentally derived 97.65% loss is benzene	Filling weight of benzene = 13.1325 g	Error in weighing = ± 1 mg Weight loss of sample = ± 0.98 mg ≡ ± 0.004 cpm ie ± 0.6 years	Loss of 1 mg/day ≡ 0.06 cpm ie ≈ 8 years This loss can be up to 10 mg/day
Background variation with atmospheric depth, solar radiation and neutron flux	Height of atmosphere at 100 mb pressure level. Solar radio transmission at 9500 MHz. Neutron flux as monitored by Leeds University	Triple linear regression using the three parameters with BG corrected for BP Slopes: −0.0002 cpm/metre − 0.0007 cpm/unit flux 0.0233 cpm/unit flux	100 mb pressure level height = 16019 metres. Solar radio transmission = 303.688 units Neutron flux = 92.778/Au	These estimates are based on the ability to read parameters at levels indicated 100 mb PLH ± 10 metres ≡ ± 0.002 cpm ie ± 0.25 years. SRT ± 4 units ≡ ± 0.0007 cpm ie ± 0.25 years Neutron flux ± 0.1 units ie ± 0.25 years	Range errors 100 mb PLH ± 500 m ≡ ±0.1 cpm ie ± 13 years SRT ± 40 units ≡ 0.028 cpm ie ± 4 yrs Neutron flux ± 4/Au ≡ ± 0.093 ie ± 13 years
Background variation with barometric pressure	Barometric pressure	Linear regression of BG count rate (sealed vial) on BP. Slope = −0.0127 cpm/mb increase in pressure	1010 millibars	Barograph reading ± 0.05 mb ie ± 0.8 years	Pressure range ± 25 mb Error ≈ ± 0.32 cpm ie ± 42 years
Background variation with ^{133}Ba contribution	Known contribution $A = A' - \left(e^{-0.0077t}\right)0.35$ where A = corrected BG cpm A' =observed BG	The contribution was determined by source removal. There is a variation applied to this correction for 'purity' change (see correction below)	To zero contribution	Estimated at ± 0.02 cpm ie ≡ ± 2.5 years	Variable contribution 0.18 cpm ie ≡ 24 years although most of this would have been included in BG/Purity
Efficiency variation with gain 'purity'	Channels ratio of ^{133}Ba external source	The loss of counts is proportional to the increasing area of a triangle: the height varies as a function of the purity. The equation is:- $A=A_1(1+(\frac{x^2}{8})0.0015)$ where A = corrected cpm A_1=observed cpm (previously corr) x = change in channels ratio x 100	Channels ratio = 1.95	Channels ratio ± 0.01 ≡ ± 0.019% ≡ ± 0.011 cpm ie ± 1.5 years	Channels ratio ±0.05 ≡ ± 0.46% ≡ ± 0.28 cpm ie ± 38 years
Efficiency variation with counting time	Continuous quality control	Exponential regression of corrected standard cpm with time	Mid point of counting time	None	Loss of standard counts ≈ 0.005 cpm per day ≡ 0.67 years per day difference between sample & standard counting time

TABLE 2 A–G

Calibration table data (See legend, Table 2G)

TABLE 2A

cal AD/BC	cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 1840[1]	BP 110	1.5 ± 1.3	95 ± 10
AD 1810	BP 140	1.0 ± 2.1	128 ± 17
AD 1790	BP 160	-5.8 ± 2.2	202 ± 18
AD 1770	BP 180	-3.0 ± 2.2	199 ± 18
AD 1750	BP 200	3.8 ± 2.0	164 ± 16
AD 1730	BP 220	14.0 ± 2.0	102 ± 16
AD 1710	BP 240	20.8 ± 1.5	68 ± 12
AD 1690	BP 260	20.3 ± 2.2	91 ± 17
AD 1670	BP 280	4.9 ± 2.0	233 ± 16
AD 1650	BP 300	3.8 ± 1.5	261 ± 12
AD 1630	BP 320	-5.5 ± 2.1	355 ± 17
AD 1610	BP 340	-3.9 ± 2.0	362 ± 16
AD 1590	BP 360	1.2 ± 1.7	340 ± 14
AD 1570	BP 380	0.3 ± 2.0	367 ± 16
AD 1550[1]	BP 400	10.0 ± 1.4	309 ± 11
AD 1530[4]	BP 420	14.9 ± 1.3	289 ± 10
AD 1510[4]	BP 440	9.2 ± 1.1	354 ± 9
AD 1490	BP 460	14.4 ± 2.2	332 ± 17
AD 1470	BP 480	9.3 ± 2.3	392 ± 18
AD 1460[6]	BP 490	8.8 ± 1.3	406 ± 10
AD 1450	BP 500	3.5 ± 2.1	458 ± 17
AD 1430	BP 520	0.7 ± 2.4	500 ± 19
AD 1410	BP 540	1.6 ± 1.8	512 ± 14
AD 1390	BP 560	-6.8 ± 4.2	599 ± 34
AD 1370	BP 580	-13.3 ± 1.7	671 ± 14
AD 1350	BP 600	-6.8 ± 2.0	638 ± 16
AD 1330	BP 620	4.1 ± 1.8	570 ± 14
AD 1310	BP 640	4.5 ± 1.8	586 ± 14
AD 1290	BP 660	2.3 ± 4.2	623 ± 34
AD 1260[4]	BP 690	-13.7 ± 1.2	781 ± 10
AD 1230[3]	BP 720	-14.4 ± 1.2	816 ± 10
AD 1215[7]	BP 735	-18.1 ± 2.2	861 ± 18
AD 1195[7]	BP 755	-11.8 ± 2.2	829 ± 18
AD 1170[3]	BP 780	-13.5 ± 1.1	867 ± 9
AD 1150[3]	BP 800	-18.5 ± 1.1	927 ± 9
AD 1130[3]	BP 820	-12.5 ± 1.5	898 ± 12
AD 1110[3]	BP 840	-13.3 ± 1.5	924 ± 12
AD 1090[3]	BP 860	-10.0 ± 1.4	916 ± 11
AD 1070[3]	BP 880	-4.6 ± 1.2	892 ± 10
AD 1050[3]	BP 900	-4.3 ± 1.5	909 ± 12
AD 1030[3]	BP 920	-9.2 ± 1.5	968 ± 12
AD 1010[3]	BP 940	-16.0 ± 1.4	1043 ± 11
AD 990[3]	BP 960	-17.1 ± 1.2	1052 ± 10
AD 970[3]	BP 980	-15.2 ± 1.2	1075 ± 10
AD 955[7]	BP 995	-18.9 ± 1.7	1120 ± 14
AD 940	BP 1010	-15.9 ± 2.0	1110 ± 16
AD 920	BP 1030	-14.2 ± 1.7	1116 ± 14
AD 900	BP 1050	-10.2 ± 1.7	1103 ± 14
AD 880	BP 1070	-19.3 ± 1.7	1196 ± 14
AD 860	BP 1090	-15.4 ± 2.1	1184 ± 17
AD 850	BP 1100	-17.8 ± 2.1	1213 ± 17
AD 830	BP 1120	-13.1 ± 2.1	1194 ± 17
AD 810	BP 1140	-14.4 ± 2.0	1224 ± 16
AD 790	BP 1160	-14.0 ± 2.0	1240 ± 16
AD 770	BP 1180	-12.4 ± 2.0	1247 ± 16
AD 750	BP 1200	-13.8 ± 2.0	1278 ± 16

TABLE 2B

cal AD/BC	cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 730[1]	BP 1220	-7.5 ± 1.5	1246 ± 12
AD 710	BP 1240	-9.6 ± 2.2	1282 ±
AD 690	BP 1260	-6.8 ± 2.2	1279 ± 18
AD 670	BP 1280	-10.6 ± 2.2	1329 ± 18
AD 650[1]	BP 1300	-17.9 ± 1.5	1408 ± 12
AD 630	BP 1320	-14.8 ± 2.2	1402 ± 18
AD 610	BP 1340	-19.8 ± 2.2	1463 ± 18
AD 590	BP 1360	-24.9 ± 2.2	1524 ± 18
AD 570	BP 1380	-18.0 ± 2.2	1487 ± 18
AD 550	BP 1400	-21.4 ± 2.3	1534 ± 19
AD 530	BP 1420	-19.0 ± 2.2	1534 ± 18
AD 510	BP 1440	-18.8 ± 2.1	1552 ± 17
AD 490	BP 1460	-20.9 ± 2.1	1588 ± 17
AD 470	BP 1480	-14.2 ± 2.1	1553 ± 17
AD 450	BP 1500	-14.0 ± 2.1	1571 ± 17
AD 430	BP 1520	-17.3 ± 2.1	1617 ± 17
AD 410	BP 1540	-18.3 ± 2.1	1645 ± 17
AD 390	BP 1560	-20.4 ± 2.1	1681 ± 17
AD 370	BP 1580	-21.0 ± 2.1	1706 ± 17
AD 350	BP 1600	-15.5 ± 2.2	1680 ± 18
AD 330	BP 1620	-18.7 ± 2.2	1726 ± 18
AD 310	BP 1640	-19.0 ± 2.1	1748 ± 17
AD 290	BP 1660	-14.3 ± 2.1	1729 ± 17
AD 270	BP 1680	-10.8 ± 2.2	1720 ± 18
AD 250	BP 1700	-7.7 ± 2.2	1714 ± 18
AD 230	BP 1720	-15.7 ± 2.2	1798 ± 18
AD 210	BP 1740	-14.9 ± 2.2	1811 ± 18
AD 190	BP 1760	-19.8 ± 2.2	1871 ± 18
AD 170	BP 1780	-13.4 ± 2.2	1838 ± 18
AD 150	BP 1800	-7.9 ± 2.2	1813 ± 18
AD 130	BP 1820	-9.1 ± 2.2	1842 ± 18
AD 110	BP 1840	-15.0 ± 2.2	1909 ± 18
AD 90	BP 1860	-13.9 ± 2.2	1920 ± 18
AD 70	BP 1880	-18.5 ± 2.0	1977 ± 16
AD 50	BP 1900	-14.3 ± 2.2	1962 ± 18
AD 30	BP 1920	-11.4 ± 2.0	1958 ± 16
AD 10	BP 1940	-14.7 ± 2.1	2004 ± 17
BC 10	BP 1960	-10.8 ± 2.2	1992 ± 18
BC 30	BP 1980	-13.5 ± 2.2	2033 ± 18
BC 50	BP 2000	-13.6 ± 2.1	2053 ± 17
BC 70	BP 2020	-12.4 ± 2.0	2063 ± 16
BC 90	BP 2040	-11.6 ± 2.0	2076 ± 16
BC 110	BP 2060	-12.3 ± 1.7	2101 ± 14
BC 130	BP 2080	-11.4 ± 2.0	2113 ± 16
BC 150	BP 2100	-9.7 ± 2.0	2119 ± 16
BC 170[3]	BP 2120	-7.7 ± 1.5	2122 ± 12
BC 190[3]	BP 2140	-8.6 ± 1.5	2149 ± 12
BC 210[3]	BP 2160	-13.3 ± 1.6	2206 ± 13
BC 230	BP 2180	-8.0 ± 2.1	2183 ± 17
BC 250	BP 2200	-7.1 ± 2.0	2195 ± 16
BC 270	BP 2220	-11.6 ± 2.0	2251 ± 16
BC 290	BP 2240	-1.8 ± 2.2	2191 ± 18
BC 310[1]	BP 2260	-1.2 ± 1.6	2206 ± 13
BC 330	BP 2280	1.4 ± 2.2	2204 ± 18
BC 350	BP 2300	5.6 ± 2.0	2190 ± 16
BC 370	BP 2320	3.9 ± 1.6	2223 ± 13

Table 2C

cal AD/BC / cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 390 / BP 2340	-0.8 ± 1.9	2280 ± 15
BC 410 / BP 2360	-18.7 ± 2.2	2445 ± 18
BC 430[4] / BP 2380	-14.0 ± 1.4	2426 ± 11
BC 450[4] / BP 2400	-7.8 ± 1.5	2395 ± 12
BC 470[4] / BP 2420	-7.6 ± 1.4	2413 ± 11
BC 490[4] / BP 2440	-6.1 ± 1.6	2420 ± 13
BC 510[4] / BP 2460	-3.8 ± 1.2	2421 ± 10
BC 530[4] / BP 2480	-4.3 ± 1.2	2444 ± 10
BC 550[4] / BP 2500	-6.7 ± 1.1	2483 ± 9
BC 570[4] / BP 2520	-5.4 ± 1.2	2492 ± 10
BC 590[4] / BP 2540	-1.6 ± 1.4	2481 ± 11
BC 610[4] / BP 2560	-2.4 ± 1.2	2507 ± 10
BC 630[4] / BP 2580	2.9 ± 1.3	2484 ± 10
BC 650 / BP 2600	7.1 ± 1.8	2470 ± 14
BC 670[1] / BP 2620	5.1 ± 1.5	2505 ± 12
BC 690[1] / BP 2640	12.2 ± 1.5	2468 ± 12
BC 710 / BP 2660	17.2 ± 1.9	2448 ± 15
BC 730 / BP 2680	19.6 ± 1.7	2448 ± 13
BC 750 / BP 2700	23.1 ± 1.7	2440 ± 13
BC 770 / BP 2720	16.8 ± 2.0	2509 ± 16
BC 790[1] / BP 2740	18.1 ± 1.5	2518 ± 12
BC 810 / BP 2760	6.2 ± 2.3	2632 ± 18
BC 830 / BP 2780	6.0 ± 2.3	2653 ± 18
BC 850 / BP 2800	2.3 ± 2.0	2702 ± 16
BC 870[1] / BP 2820	1.4 ± 1.8	2729 ± 14
BC 890[1] / BP 2840	5.6 ± 1.8	2715 ± 14
BC 910 / BP 2860	2.8 ± 1.6	2757 ± 13
BC 930 / BP 2880	-1.7 ± 2.4	2812 ± 19

cal AD/BC / cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 950 / BP 2900	0.2 ± 2.4	2816 ± 19
BC 970[1] / BP 2920	5.5 ± 1.4	2793 ± 11
BC 990[1] / BP 2940	5.2 ± 1.5	2815 ± 12
BC 1010[2] / BP 2960	2.5 ± 1.0	2856 ± 8
BC 1030[1] / BP 2980	4.2 ± 1.5	2862 ± 12
BC 1050[1] / BP 3000	3.4 ± 1.3	2888 ± 10
BC 1070[2] / BP 3020	3.1 ± 1.3	2910 ± 10
BC 1090[1] / BP 3040	8.5 ± 1.5	2886 ± 12
BC 1110[1] / BP 3060	14.1 ± 1.5	2861 ± 12
BC 1120[3] / BP 3070	10.2 ± 1.9	2902 ± 15
BC 1140[3] / BP 3090	8.4 ± 1.9	2935 ± 15
BC 1150 / BP 3100	9.0 ± 2.0	2940 ± 16
BC 1170 / BP 3120	7.1 ± 1.8	2975 ± 14
BC 1190 / BP 3140	13.7 ± 2.0	2942 ± 16
BC 1210 / BP 3160	14.4 ± 2.0	2956 ± 16
BC 1230 / BP 3180	11.0 ± 1.8	3002 ± 14
BC 1250 / BP 3200	22.6 ± 1.8	2930 ± 14
BC 1270 / BP 3220	12.9 ± 2.1	3026 ± 17
BC 1290 / BP 3240	15.5 ± 2.2	3025 ± 17
BC 1310 / BP 3260	15.8 ± 2.2	3042 ± 17
BC 1330 / BP 3280	11.4 ± 2.0	3096 ± 16
BC 1350 / BP 3300	21.1 ± 2.0	3039 ± 16
BC 1370 / BP 3320	24.7 ± 2.3	3030 ± 18
BC 1390 / BP 3240	24.3 ± 1.9	3053 ± 15
BC 1410 / BP 3360	21.1 ± 1.8	3097 ± 14
BC 1430 / BP 3380	13.1 ± 2.0	3180 ± 16
BC 1450[1] / BP 3400	13.3 ± 1.3	3198 ± 10
BC 1470 / BP 3420	15.3 ± 1.9	3201 ± 15

Table 2D

cal AD/BC / cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 1490 / BP 3440	20.8 ± 2.0	3177 ± 16
BC 1510 / BP 3460	24.8 ± 2.0	3165 ± 16
BC 1530 / BP 3480	10.0 ± 1.9	3302 ± 15
BC 1550 / BP 3500	10.1 ± 2.3	3320 ± 18
BC 1570 / BP 3520	17.3 ± 2.0	3283 ± 16
BC 1590 / BP 3540	19.3 ± 1.8	3286 ± 14
BC 1610 / BP 3560	21.9 ± 1.9	3285 ± 15
BC 1630 / BP 3580	19.3 ± 1.9	3325 ± 15
BC 1650 / BP 3600	22.3 ± 1.7	3321 ± 13
BC 1670 / BP 3620	23.8 ± 1.9	3329 ± 15
BC 1690 / BP 3640	16.9 ± 2.0	3402 ± 16
BC 1710 / BP 3660	15.2 ± 2.4	3435 ± 19
BC 1730 / BP 3680	25.4 ± 1.7	3374 ± 13
BC 1750 / BP 3700	20.2 ± 1.9	3435 ± 15
BC 1770 / BP 3720	19.5 ± 1.8	3460 ± 14
BC 1790 / BP 3740	13.6 ± 2.2	3526 ± 17
BC 1810 / BP 3760	24.9 ± 2.4	3456 ± 19
BC 1830 / BP 3780	19.9 ± 2.4	3515 ± 19
BC 1850 / BP 3800	30.8 ± 1.8	3449 ± 14
BC 1870 / BP 3820	32.1 ± 1.8	3458 ± 14
BC 1890 / BP 3840	24.5 ± 1.7	3537 ± 13
BC 1910 / BP 3860	21.6 ± 2.3	3579 ± 18
BC 1930 / BP 3880	27.4 ± 1.8	3553 ± 14
BC 1950 / BP 3900	25.0 ± 1.7	3591 ± 13
BC 1970 / BP 3920	28.0 ± 2.2	3587 ± 17
BC 1990 / BP 3940	21.1 ± 2.7	3661 ± 21
BC 2010 / BP 3960	28.9 ± 1.9	3619 ± 15

cal AD/BC / cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 2030 / BP 3980	31.7 ± 2.1	3617 ± 16
BC 2050 / BP 4000	22.8 ± 2.0	3706 ± 16
BC 2070 / BP 4020	25.5 ± 2.3	3704 ± 18
BC 2090 / BP 4040	33.6 ± 1.9	3660 ± 15
BC 2110 / BP 4060	35.6 ± 2.3	3664 ± 18
BC 2130 / BP 4080	34.6 ± 2.3	3691 ± 18
BC 2150[1] / BP 4100	23.9 ± 1.7	3794 ± 13
BC 2170 / BP 4120	33.3 ± 2.3	3740 ± 18
BC 2190 / BP 4140	29.3 ± 1.8	3791 ± 14
BC 2210 / BP 4160	28.1 ± 1.8	3820 ± 14
BC 2230 / BP 4180	32.5 ± 2.1	3805 ± 16
BC 2250 / BP 4200	40.0 ± 1.7	3766 ± 13
BC 2270 / BP 4220	40.7 ± 2.1	3780 ± 16
BC 2290 / BP 4240	36.8 ± 2.1	3830 ± 16
BC 2310 / BP 4260	38.6 ± 2.1	3835 ± 16
BC 2330 / BP 4280	38.7 ± 1.7	3854 ± 13
BC 2350 / BP 4300	40.6 ± 2.1	3859 ± 16
BC 2370 / BP 4320	41.6 ± 1.7	3870 ± 13
BC 2390 / BP 4340	44.6 ± 2.1	3867 ± 16
BC 2410 / BP 4360	42.9 ± 1.6	3899 ± 12
BC 2430[1&4] / BP 4380	49.5 ± 0.9	3868 ± 7
BC 2450 / BP 4400	52.4 ± 1.3	3865 ± 10
BC 2470 / BP 4420	42.6 ± 1.7	3960 ± 13
BC 2490 / BP 4440	45.1 ± 1.7	3960 ± 13
BC 2510 / BP 4460	38.5 ± 1.3	4030 ± 10
BC 2530 / BP 4480	40.5 ± 1.9	4034 ± 15
BC 2550 / BP 4500	51.0 ± 1.8	3973 ± 14

TABLE 2E

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 2570 BP 4520	48.3 ± 1.4	4013 ± 11	BC 3110 BP 5060	53.1 ± 2.6	4501 ± 20
BC 2590[1] BP 4540	43.8 ± 1.4	4067 ± 11	BC 3130 BP 5080	56.9 ± 2.0	4492 ± 15
BC 2610 BP 4560	45.3 ± 2.3	4075 ± 18	BC 3150 BP 5100	53.9 ± 1.8	4534 ± 14
BC 2630 BP 4580	40.7 ± 1.3	4130 ± 10	BC 3170 BP 5120	63.3 ± 2.4	4482 ± 18
BC 2650 BP 4600	50.8 ± 1.8	4072 ± 14	BC 3190[1] BP 5140	59.3 ± 2.0	4532 ± 15
BC 2670 BP 4620	43.3 ± 1.6	4149 ± 12	BC 3210 BP 5160	60.3 ± 2.1	4544 ± 16
BC 2690 BP 4640	51.3 ± 1.6	4107 ± 12	BC 3230[1] BP 5180	66.8 ± 1.6	4514 ± 12
BC 2710 BP 4660	41.8 ± 1.6	4199 ± 12	BC 3250[1] BP 5200	76.9 ± 1.7	4458 ± 13
BC 2730[1] BP 4680	54.4 ± 1.2	4121 ± 9	BC 3270 BP 5220	77.1 ± 2.3	4476 ± 17
BC 2750 BP 4700	54.7 ± 1.6	4144 ± 12	BC 3290 BP 5240	80.3 ± 1.9	4471 ± 14
BC 2770 BP 4720	57.0 ± 2.1	4141 ± 16	BC 3310 BP 5260	78.4 ± 1.9	4505 ± 14
BC 2790 BP 4740	47.0 ± 1.7	4237 ± 13	BC 3330 BP 5280	79.4 ± 1.9	4517 ± 14
BC 2810 BP 4760	62.3 ± 1.7	4140 ± 13	BC 3350 BP 5300	73.9 ± 1.9	4577 ± 14
BC 2830[1&4] BP 4780	72.4 ± 1.1	4083 ± 8	BC 3370 BP 5320	70.3 ± 2.4	4624 ± 18
BC 2850[4] BP 4800	75.6 ± 1.5	4079 ± 11	BC 3390 BP 5340	58.7 ± 2.1	4731 ± 16
BC 2870[3] BP 4820	67.1 ± 1.7	4162 ± 13	BC 3410 BP 5360	66.5 ± 2.4	4691 ± 18
BC 2890 BP 4840	59.7 ± 1.7	4237 ± 13	BC 3430 BP 5380	72.4 ± 2.4	4666 ± 18
BC 2910 BP 4860	57.7 ± 1.6	4272 ± 12	BC 3450 BP 5400	75.0 ± 2.3	4666 ± 17
BC 2930 BP 4880	46.0 ± 1.7	4381 ± 13	BC 3470 BP 5420	77.2 ± 2.4	4669 ± 18
BC 2950 BP 4900	46.1 ± 1.7	4399 ± 13	BC 3490 BP 5440	82.3 ± 2.6	4651 ± 19
BC 2970 BP 4920	50.1 ± 2.4	4388 ± 18	BC 3510 BP 5460	75.6 ± 2.5	4720 ± 19
BC 2990 BP 4940	54.1 ± 1.8	4377 ± 14	BC 3530 BP 5480	71.8 ± 2.5	4768 ± 19
BC 3010 BP 4960	60.9 ± 1.9	4345 ± 14	BC 3550 BP 5500	68.4 ± 2.5	4813 ± 19
BC 3030 BP 4980	58.2 ± 1.7	4385 ± 13	BC 3570 BP 5520	74.4 ± 2.7	4787 ± 20
BC 3050 BP 5000	51.4 ± 1.7	4456 ± 13	BC 3590 BP 5540	85.3 ± 2.7	4726 ± 20
BC 3070 BP 5020	58.5 ± 1.8	4421 ± 14	BC 3610 BP 5560	85.2 ± 2.7	4746 ± 20
BC 3090 BP 5040	60.3 ± 2.1	4427 ± 16	BC 3630 BP 5580	80.3 ± 2.7	4802 ± 20

TABLE 2F

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 3650 BP 5600	74.4 ± 2.7	4865 ± 20	BC 4190 BP 6140	80.3 ± 2.6	5346 ± 19
BC 3670 BP 5620	78.1 ± 2.4	4857 ± 18	BC 4210 BP 6160	94.8 ± 2.3	5258 ± 17
BC 3690 BP 5640	79.4 ± 2.4	4867 ± 18	BC 4230 BP 6180	86.5 ± 2.2	5339 ± 16
BC 3710 BP 5660	69.6 ± 2.4	4959 ± 18	BC 4250 BP 6200	78.6 ± 2.2	5417 ± 16
BC 3730 BP 5680	70.5 ± 2.4	4972 ± 18	BC 4270 BP 6220	80.2 ± 2.3	5424 ± 17
BC 3750 BP 5700	77.2 ± 2.4	4941 ± 18	BC 4290 BP 6240	87.2 ± 2.3	5392 ± 17
BC 3770 BP 5720	83.8 ± 2.3	4912 ± 17	BC 4310 BP 6260	89.4 ± 2.0	5395 ± 15
BC 3790 BP 5740	70.4 ± 2.4	5031 ± 18	BC 4330 BP 6280	90.3 ± 2.2	5408 ± 16
BC 3810 BP 5760	74.5 ± 2.3	5020 ± 17	BC 4350 BP 6300	81.9 ± 2.0	5489 ± 15
BC 3830 BP 5780	63.9 ± 2.0	5119 ± 15	BC 4370 BP 6320	73.7 ± 1.9	5570 ± 14
BC 3850[5] BP 5800	73.0 ± 1.5	5070 ± 11	BC 4390 BP 6340	78.2 ± 2.2	5556 ± 16
BC 3870[5] BP 5820	77.2 ± 1.7	5058 ± 13	BC 4410 BP 6360	75.9 ± 2.1	5592 ± 16
BC 3890[5] BP 5840	85.7 ± 1.8	5014 ± 13	BC 4430 BP 6380	83.3 ± 2.2	5557 ± 16
BC 3910[5] BP 5860	84.9 ± 1.6	5040 ± 12	BC 4450 BP 6400	86.6 ± 2.2	5552 ± 16
BC 3930[5] BP 5880	87.2 ± 1.6	5042 ± 12	BC 4470 BP 6420	77.3 ± 2.2	5640 ± 16
BC 3950[5] BP 5900	83.5 ± 1.6	5089 ± 12	BC 4490 BP 6440	79.5 ± 2.2	5643 ± 16
BC 3970[5] BP 5920	81.6 ± 1.6	5122 ± 12	BC 4510 BP 6460	78.8 ± 2.3	5668 ± 17
BC 3990 BP 5940	78.6 ± 2.0	5164 ± 15	BC 4530 BP 6480	77.9 ± 2.3	5694 ± 17
BC 4010 BP 5960	69.7 ± 1.9	5250 ± 14	BC 4550 BP 6500	78.0 ± 2.3	5713 ± 17
BC 4030 BP 5980	78.9 ± 1.8	5201 ± 13	BC 4570 BP 6520	83.0 ± 2.4	5695 ± 18
BC 4050 BP 6000	66.8 ± 1.7	5311 ± 13	BC 4590 BP 6540	79.4 ± 2.3	5741 ± 17
BC 4070 BP 6020	72.4 ± 1.9	5288 ± 14	BC 4610 BP 6560	79.9 ± 2.2	5757 ± 16
BC 4090 BP 6040	73.3 ± 1.9	5301 ± 14	BC 4630 BP 6580	79.9 ± 2.2	5776 ± 16
BC 4110 BP 6060	76.0 ± 2.4	5300 ± 18	BC 4650 BP 6600	91.1 ± 2.6	5713 ± 19
BC 4130 BP 6080	83.9 ± 2.4	5261 ± 18	BC 4670 BP 6620	86.7 ± 2.3	5765 ± 17
BC 4150 BP 6100	80.3 ± 2.8	5307 ± 21	BC 4690 BP 6640	85.2 ± 2.2	5795 ± 16
BC 4170 BP 6120	76.2 ± 2.1	5357 ± 16	BC 4710 BP 6660	90.2 ± 2.2	5778 ± 16

Table 2G

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 4730 BP 6680	83.5 ± 2.4	5847 ± 18	BC 4990 BP 6940	89.6 ± 2.0	6054 ± 15
BC 4750 BP 6700	86.4 ± 2.4	5845 ± 18	BC 5010 BP 6960	85.5 ± 2.2	6104 ± 16
BC 4770 BP 6720	90.5 ± 2.4	5834 ± 18	BC 5030 BP 6980	92.3 ± 2.5	6073 ± 18
BC 4790 BP 6740	82.2 ± 2.6	5914 ± 19	BC 5050 BP 7000	92.1 ± 2.3	6094 ± 17
BC 4810 BP 6760	81.6 ± 2.4	5939 ± 18	BC 5070 BP 7020	89.1 ± 2.3	6136 ± 17
BC 4830 BP 6780	87.7 ± 1.9	5913 ± 14	BC 5090 BP 7040	88.4 ± 2.4	6160 ± 18
BC 4850 BP 6800	83.7 ± 2.4	5962 ± 18	BC 5110 BP 7060	93.4 ± 2.3	6143 ± 17
BC 4870 BP 6820	83.1 ± 2.6	5986 ± 19	BC 5130 BP 7080	98.2 ± 2.3	6127 ± 17
BC4890 BP 6840	93.1 ± 2.6	5931 ± 18	BC 5150 BP 7100	94.2 ± 2.5	6176 ± 18
BC 4910 BP 6860	81.4 ± 2.7	6037 ± 20	BC 5170 BP 7120	100.3 ± 2.3	6151 ± 17
BC 4930[1] BP 6880	91.0 ± 1.5	5986 ± 11	BC 5190 BP 7140	108.6 ± 2.4	6110 ± 17
BC 4950 BP 6900	80.7 ± 2.0	6081 ± 15	BC 5210 BP 7160	100.4 ± 2.3	6189 ± 17
BC 4970 BP 6920	85.5 ± 2.0	6065 ± 15			

Legend

cal AD/BC / cal BP : Mid-point of bi-decade sample unless otherwise stated

Superscript:
[1] A weighted mean of the bi-decade results of a complete duplicate analysis
[2] A weighted mean of the bi-decade results of a complete triplicate analysis
[3] A weighted mean of two decades to give a bi-decade value
[4] Two decades meaned to give a bi-decade value which is then meaned with a bi-decade measurement, appropriately weighted
[5] Overlapping bi-decade results combined to give a weighted mean bi-decade value
[6] A weighted mean of the bi-decade results of a complete duplicate analysis combined with overlapping bi-decade values, appropriately weighted
[7] Decade result only

$$\Delta^{14}C : \Delta = \left[\frac{A_{SN}e^{\lambda(y-x)}}{A_{ABS}} - 1\right] 1000‰$$

calculated using the mean ^{14}C age (where applicable) $\pm 1\sigma$
(Stuiver & Polach, 1977)

Radiocarbon age BP : Age of bi-decade sample unless otherwise stated (see superscript) $\pm 1\sigma$

Table 3 A–B

Decade samples only (either extracted from or additional to Table 2)
(See legend, Table 3B)

Table 3A

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
AD 1535 BP 415	11.2 ± 2.0	314 ± 16	AD 1015 BP 935	-13.8 ± 2.1	1020 ± 17
AD 1525 BP 425	17.6 ± 1.8	273 ± 14	AD 1005 BP 945	-17.3 ± 1.7	1058 ± 14
AD 1515 BP 435	9.7 ± 1.8	345 ± 14	AD 995 BP 955	-13.1 ± 1.7	1034 ± 14
AD 1505 BP 445	6.8 ± 1.8	378 ± 14	AD 985 BP 965	-16.2 ± 1.7	1069 ± 14
AD 1265 BP 685	-12.5 ± 2.0	767 ± 16	AD 975 BP 975	-12.2 ± 1.7	1046 ± 14
AD 1255 BP 695	-15.3 ± 1.7	799 ± 14	AD 965 BP 985	-18.1 ± 1.7	1104 ± 14
AD 1235 BP 715	-11.2 ± 2.1	785 ± 17	AD 955 BP 995	-18.9 ± 1.7	1120 ± 14
AD 1225 BP 725	-15.6 ± 1.5	831 ± 12	BC 165 BP 2115	-8.4 ± 2.0	2123 ± 16
AD 1215 BP 735	-18.1 ± 2.2	861 ± 18	BC 175 BP 2125	-7.0 ± 2.1	2121 ± 17
AD 1195 BP 755	-11.8 ± 2.2	829 ± 18	BC 185 BP 2135	-7.3 ± 2.0	2133 ± 16
AD 1175 BP 775	-12.1 ± 1.5	851 ± 12	BC 195 BP 2145	-10.5 ± 2.2	2169 ± 18
AD 1165 BP 785	-14.9 ± 1.5	883 ± 12	BC 205 BP 2155	-12.9 ± 2.1	2198 ± 17
AD 1155 BP 795	-16.7 ± 1.5	908 ± 12	BC 215 BP 2165	-13.5 ± 2.1	2213 ± 17
AD 1145 BP 805	-20.1 ± 1.5	945 ± 12	BC 295 BP 2245	-2.1 ± 2.0	2198 ± 16
AD 1135 BP 815	-11.4 ± 2.0	884 ± 16	BC 425 BP 2375	-16.6 ± 2.0	2442 ± 16
AD 1125 BP 825	-13.6 ± 2.0	912 ± 16	BC 435 BP 2385	-11.7 ± 2.3	2412 ± 19
AD 1115 BP 835	-16.0 ± 2.0	941 ± 16	BC 445 BP 2395	-7.8 ± 2.2	2390 ± 18
AD 1105 BP 845	-10.6 ± 2.0	907 ± 16	BC 455 BP 2405	-4.6 ± 2.4	2374 ± 19
AD 1095 BP 855	-11.3 ± 2.0	922 ± 16	BC 465 BP 2415	-5.5 ± 2.2	2391 ± 18
AD 1085 BP 865	-8.7 ± 1.7	911 ± 14	BC 475 BP 2425	-5.4 ± 2.2	2400 ± 18
AD 1075 BP 875	-9.1 ± 1.7	924 ± 14	BC 485 BP 2435	-6.9 ± 2.4	2422 ± 19
AD 1065 BP 885	0.1 ± 1.7	859 ± 14	BC 495 BP 2445	-5.4 ± 2.2	2419 ± 18
AD 1055 BP 895	-2.0 ± 2.0	886 ± 16	BC 505 BP 2455	-2.8 ± 2.2	2408 ± 18
AD 1045 BP 905	-6.4 ± 2.0	931 ± 16	BC 515 BP 2465	-5.6 ± 1.9	2440 ± 15
AD 1035 BP 915	-8.5 ± 2.0	958 ± 16	BC 525 BP 2475	-3.2 ± 2.0	2431 ± 16
AD 1025 BP 925	-10.1 ± 2.1	980 ± 17	BC 535 BP 2485	-3.3 ± 2.0	2441 ± 16

TABLE 3B

cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP	cal AD/BC cal BP	$\Delta^{14}C$	Radiocarbon age BP
BC 545 BP 2495	-4.7 ± 2.0	2462 ± 16	BC 1145 BP 3095	10.3 ± 2.5	2925 ± 20
BC 555 BP 2505	-7.3 ± 2.0	2493 ± 16	BC 2375 BP 4325	32.1 ± 2.7	3949 ± 21
BC 565 BP 2515	-6.6 ± 2.0	2497 ± 16	BC 2395 BP 4345	39.7 ± 2.7	3909 ± 21
BC 575 BP 2525	-8.0 ± 2.0	2518 ± 16	BC 2415 BP 4365	39.9 ± 2.7	3927 ± 21
BC 585 BP 2535	-3.5 ± 2.2	2491 ± 18	BC 2425 BP 4375	49.8 ± 1.8	3861 ± 14
BC 595 BP 2545	-1.3 ± 2.2	2483 ± 18	BC 2435 BP 4385	42.8 ± 2.7	3924 ± 21
BC 605 BP 2555	-4.8 ± 2.2	2521 ± 18	BC 2825 BP 4775	70.2 ± 2.4	4095 ± 18
BC 615 BP 2565	0.2 ± 2.0	2491 ± 16	BC 2835 BP 4785	76.4 ± 2.4	4058 ± 18
BC 625 BP 2575	1.4 ± 2.0	2491 ± 16	BC 2845 BP 4795	76.7 ± 2.4	4066 ± 18
BC 635 BP 2585	0.6 ± 2.0	2507 ± 16	BC 2855 BP 4805	67.5 ± 2.4	4144 ± 18
BC 645 BP 2595	6.1 ± 1.8	2473 ± 14	BC 2865 BP 4815	66.3 ± 2.4	4163 ± 18
BC 1115 BP 3065	10.9 ± 2.5	2891 ± 20	BC 2875 BP 4825	68.0 ± 2.4	4160 ± 18
BC 1125 BP 3075	9.5 ± 2.5	2912 ± 20	BC 2885 BP 4835	64.1 ± 2.4	4199 ± 18
BC 1135 BP 3085	6.6 ± 2.6	2945 ± 21			

Legend

cal AD/BC / cal BP : Mid-point of single decade sample

$$\Delta^{14}C : \Delta = \left[\frac{A_{SN}e^{\lambda(y-x)}}{A_{ABS}} - 1\right] 1000‰$$

calculated using the ^{14}C age ± 1σ
(Stuiver & Polach, 1977)

Radiocarbon age BP : Age of single decade sample ±1σ

[RADIOCARBON, VOL 28, NO. 2B, 1986, P 935–938]

RADIOCARBON FLUCTUATIONS DURING THE THIRD MILLENNIUM BC

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ABSTRACT. Precision ^{14}C analyses have been performed on samples comprising 1 to 4 annual rings from the south-central European dendrochronologic sequence of sub-fossil oak wood covering the period 1930 to 3100 BC. Apart from a major deviation in the 29th century BC, the ^{14}C fluctuations have amplitudes of ca 10‰ and a possible periodicity of 90 years. A ^{14}C peak at 2190 BC has a rise- and decay-time of <20 years indicating rather abrupt changes in the production rate of ^{14}C. The ^{14}C calibration curve derived from these data can be used for precise dating of the Early Bronze Age in the Near East.

The 3rd millennium BC is that early historic period to which ^{14}C dating can make a positive contribution. It covers, roughly, the time from Dynasty I to the beginning of Dynasty XII in Egypt and the Dynasties of Sumer and Akkad in Mesopotamia, *viz*, a period during which absolute historic dates are by no means secure. Precision ^{14}C dating, properly applied to archaeologic sites and events in the Near East, could thus be used to refine the historical time scale for this Early Bronze Age period.

With this objective in mind, a high-precision calibration curve for ^{14}C dates is being constructed for the time span 1930 to 3100 BC. From a geophysical point of view, this period (1900–2800 BC) is also of interest because it has been reported as showing no large fluctuations in ^{14}C (Suess, 1980; Pearson, Pilcher & Baillie, 1983). By analyzing individual annual tree rings from a dendrochronologically-dated sequence, it was hoped to gain more insight into the nature of such a "quiet" period of ^{14}C production.

The samples investigated were annual rings taken from the south-central European sub-fossil oak sequence (Becker, 1979) which has recently been dated absolutely by cross-calibration with a similar Irish oak series (Pilcher *et al*, 1984). In cases where the rings were narrow, 2 to 4 rings were combined for a sample; otherwise single annual rings were used. The spacing between samples was 10 or 20 years, but several intermediate samples were also measured to define the trends with greater precision. For the purpose of constructing a calibration curve for ^{14}C dates, the use of integrated samples of, say, 20 annual rings may be more appropriate (eg, Pearson & Baillie, 1983), but since details of short-term variations in ^{14}C would thus be lost, individual rings were preferred.

The samples were reduced to matchstick-size pieces and purified by the de Vries method, *viz*, they were extracted respectively with 2% HCl, 2% NaOH, and 2% HCl at 70°C overnight. The weight loss was normally ca 50%. Tests showed that only ca 1% by weight could be removed by additional extraction with ethanol/benzene and ethanol in a soxlett. Since it has repeatedly been shown that this organically soluble matter cannot influence the results noticeably (eg, Tans, de Jong & Mook, 1978), the procedure was not applied to the bulk of the samples.

The purified wood was converted to carbon dioxide which, after purification, was measured in a gas proportional counter for at least two periods of 3 or 4 days. The ^{13}C content of the counter gas was determined before and after counting. The statistical uncertainty of the ^{14}C analyses was in the order of 2‰, while the combined error in the determination of gas volume and the uncertainty in the corrections for differences in purity of the gas is estimated to be ca 0.7‰. This latter error thus contributes only 1 or 2 years to the inaccuracy of the derived age. At present, the count rate of the NBS oxalic acid standard is known within ±0.5‰, while the ratio to the Heidelberg enriched standard, $A_{Hdb}/.95A_{ox}$ = 10.1994 ± .006. The ratio between the old and new NBS oxalic acid, both normalized to $\delta^{13}C$ = −19‰, as measured in this counter is 1.2884 ± .0009, which compares well with the average obtained by nine different laboratories, *viz*, 1.2893 ± .0004 (Mann, 1983).

An error in the estimate of the activity of the NBS oxalic acid as well as an error in the background value can cause a systematic difference between analyses done in different counters and especially in different laboratories. The intercalibration of laboratories remains a problem and systematic differences of 20 to 30 years are probably not unusual.

The results obtained thus far are listed in Table 1. In Figure 1, the conventional ^{14}C age is plotted against the dendrochronologic date of the wood samples. Between 2800 and 2900 BC a relatively large deviation in the ^{14}C content occurs, but for the rest of the millennium (1900–2800 BC) the amplitude of the ^{14}C fluctuations is small. In Figure 2, the deviations from the average trend in ^{14}C are plotted to reveal the nature of these medium-term variations. Some of the scatter in the curve will be due to the analytical uncertainty of ca 2‰ for the individual points, but in those cases where deviations from the mean are substantiated by several measurements, the "wiggles" must be accepted as real. Except for the major fluctuation during the 29th century BC, the amplitudes are ca 10‰.

To investigate whether distinct periodicities occur, the series was subjected to Fourier analysis. The limited number of points and their unequal spacing, however, complicates the analysis and the results are influenced by the specific procedure adopted. Nevertheless, a predominant period of ca 90 years does seem to emerge for our data covering the 3rd millennium BC. This is in contrast with the times during which larger fluctuations occur, eg, in the 2nd millennium AD when amplitudes of 20‰ and a period of ca 200 years are obvious (de Vries, 1958; Stuiver, 1982) or during the 1st millennium AD and the 4th millennium BC when a periodicity of 150–180 years has been observed (Bruns, Münnich & Becker, 1980; de Jong & Mook, 1980). Using his own data Suess (1980) found a predominant period of 202 years for the whole time span since 6000 BC. The recurrence period of 90 years during most of the 3rd millennium BC seems to suggest that the smaller amplitudes of 10‰ are not the result of damping of two nearly similar periodicities in the region of 200 years.

Of special interest is the rapidity with which some of the maxima decay. In Figure 3, the two "wiggles" between 2140 and 2320 BC are shown in detail. The second peak at 2190 BC has both a rise and a decay time of <20 years, suggesting that the production rate of ^{14}C must have changed even faster than this. In fact, the decay time is similar to that of the atom bomb ^{14}C in the atmosphere, the production of which was abruptly discontinued in 1962 (Levin *et al*, 1985). A more gradual change in the natural production rate would inevitably increase the rate at which the ^{14}C concentration decreases. It thus seems that in this instance at least we are observing a rather abrupt event. The question arises as to how common such rapid changes have been and further detailed measurement of other "wiggles" in the sequence would undoubtedly increase our understanding of the nature of their underlying causes. Such measurements need to be undertaken on a year-to-year basis since samples comprising, say, 20 annual rings will obscure the rapid changes that seem to be present.

In order to use the data presented here for the calibration of ^{14}C dates, it must be understood that most samples actually consist of a mixture of biogenic material covering several decades. Different calibration curves constructed from running averages over 20, 40, or 80 years, as the case may be, would thus provide the most accurate conversion date (de Jong, 1981). The optimal use of such curves will, however, require that much more care be taken in the selection of the sample material for dating.

In addition, account needs to be taken of the latitudinal gradient in the ^{14}C content of the atmosphere. The previous finding, that wood samples from 42°S Lat contain (4.5 ± 1)‰ less ^{14}C than synchronous wood grown at 42°N Lat (Lerman, Mook & Vogel, 1970), has been verified by comparing 6 pairs of annual rings from two trees grown in the Netherlands (53° N Lat) and Cape Town (34° S Lat), respectively. The results are shown in Table 2. The average difference between the ^{14}C content is (4.56 ± .85)‰, which amply confirms the earlier results. The implication of this is that apparent ^{14}C dates for mid-southern latitudes would all be ca 36 years younger than those for mid-northern latitudes. Since the dendrochronologic series on which calibration curves are based derive from the northern hemisphere, 36 years should be subtracted from southern hemisphere dates before conversion to the absolute (historic) time scale.

At present, the measurements are being extended to link up with the series analyzed by de Jong, which covers the years 3200 to 3900 BC (de Jong & Mook, 1980). Once this has been done, suitable integrated calibration curves spanning the time from the Late Chalcolithic to the beginning of the Middle Bronze Age in the ancient Near East can be constructed. Such curves could then be used for detailed dating of selected archaeologic sites in the region.

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TABLE 1
Conventional ^{14}C ages of samples from the south-central European oak sequence

Lab. No. Pta-	Dendroyear BC	^{14}C age BP	$\delta^{13}C$ ‰
Steinheim 7			
2745	1935-36	3575 ± 11	-25.4
2884	1942-45	3596 ± 17	-25.2
2738	1955-56	3616 ± 14	-25.9
3333	1964-65	3640 ± 20	-25.3
2734	1975-76	3609 ± 14	-26.4
3332	1982-83	3646 ± 16	-25.8
2726	1995-96	3644 ± 15	-26.1
Unterleiterbach 10			
3328	2005-06	3621 ± 19	-24.8
2751	2015-16	3635 ± 16	-25.8
3127	2025-26	3659 ± 18	-24.7
2787	2034-35	3688 ± 14	-25.8
2792	2056	3693 ± 15	-25.5
2799	2075-76	3707 ± 13	-25.4
Vohberg 19			
2856	2093	3705 ± 14	-25.2
3135	2105	3687 ± 20	-26.0
2892	2115	3680 ± 14	-25.5
3132	2124	3701 ± 18	-26.6
2900	2134-35	3707 ± 19	-24.9
3126	2145-46	3760 ± 21	-24.3
2928	2155	3797 ± 14	-24.4
3327	2165	3783 ± 16	-23.7
2983	2175	3779 ± 16	-24.5
3454	2180	3741 ± 16	-24.2
3321	2185	3735 ± 15	-23.5
3469	2190	3715 ± 25	-24.2
2996	2195	3750 ± 18	-25.2
3115	2205	3801 ± 17	-25.3
3006	2215	3855 ± 17	-23.9
Nersingen 40			
3014	2236	3839 ± 16	-25.2
3338	2245	3868 ± 17	-24.5
3016	2255-56	3833 ± 18	-25.3
3303	2265	3807 ± 20	-24.9
3120	2275	3795 ± 19	-26.0
3335	2284	3812 ± 18	-25.2
3123	2295	3855 ± 17	-24.4
Hochstadt-Staustufe 3			
3769	2280-82	3833 ± 20	-26.6
3846	2290-92	3836 ± 19	-26.9
Vohberg 34			
3503	2300-02	3888 ± 17	-26.6
3532	2320-22	3902 ± 21	-26.0
3496	2327-30	3859 ± 13	-26.2
3502	2337-40	3872 ± 14	-25.3
3541	2350-52	3926 ± 15	-25.3
3599	2370-72	3905 ± 15	-25.4
3606	2390-92	3904 ± 22	-26.0
Christiansworth 2			
3514	2407-10	3897 ± 19	-24.9
3519	2417-20	3890 ± 20	-24.6
3525	2427-30	3905 ± 16	-24.6
3539	2437-40	3931 ± 20	-25.6
3552	2447-50	3914 ± 17	-25.5
3568	2467-70	3941 ± 15	-25.6
3593	2490-92	4016 ± 17	-24.6
3613	2510-12	4047 ± 20	-24.5
3607	2510-12	4057 ± 21	-24.9
3619	2530-32	4060 ± 18	-25.6
Pettstadt 48			
3626	2550-52	4033 ± 19	-23.1
3630	2570-72	4053 ± 19	-23.6
3638	2590-92	4114 ± 15	-23.5
3751	2600-02	4119 ± 17	-23.8
3644	2610-12	4072 ± 18	-23.9
3776	2620-22	4116 ± 18	-24.1
3657*	2630-32	4063 ± 26	-23.2
Nersingen 51			
3670	2652-55	4124 ± 20	-25.2
3676	2672-75	4134 ± 18	-26.0
3681	2692-95	4151 ± 18	-25.9
3685	2712-15	4198 ± 18	-26.2
3740	2732-35	4126 ± 15	-25.8
3746	2752-55	4152 ± 21	-25.8
Blindheim 37			
4011	2711-14	4149 ± 18	-25.7
3909	2731-34	4146 ± 20	-26.7
3914	2751-54	4169 ± 20	-25.9
4024	2761-64	4197 ± 18	-25.7
Blindheim 57			
3920	2771-74	4168 ± 18	-26.2
3951	2791-94	4159 ± 21	-26.1
Blindheim 35			
3952	2811-14	4148 ± 16	-24.5
3953	2831-34	4124 ± 18	-24.4
3963	2841-44	4159 ± 15	-24.1
3850	2861-64	4182 ± 19	-24.9
3856	2881-84	4262 ± 21	-24.2
3854	2901-04	4281 ± 19	-25.3
Pettstadt 4			
3861	2921-24	4337 ± 21	-25.6
3878	2941-44	4347 ± 17	-25.6
3867	2961-64	4364 ± 19	-25.4
Bamberg 1			
3885	2981-84	4399 ± 25	-25.0
3888	3001-04	4375 ± 16	-24.7
3901	3021-24	4416 ± 19	-24.7
3904	3041-44	4451 ± 19	-24.9
3968	3061-64	4418 ± 19	-24.7
3979	3081-84	4427 ± 24	-25.1
3991	3096-99	4484 ± 19	-24.1

TABLE 2
Difference between ^{14}C contents of annual rings from an oak grown in northern Netherlands (53°N Lat) and a pine grown in Cape Town (34°S Lat).

Dendroyear AD	Dutch Oak $\Delta^{14}C$ ‰	Cape Town Pine $\Delta^{14}C$ ‰	Difference ‰
1840	-5.0 ± 1.7	- 8.6 ± 1.9	3.6 ± 2.6
1850	-4.2 ± 1.7	- 6.2 ± 1.4	2.0 ± 2.0
1860	-4.8 ± 1.7	- 8.9 ± 1.6	4.1 ± 2.3
1870	-2.8 ± 1.5	-12.3 ± 1.4	9.4 ± 2.1
1879-80	-5.5 ± 1.6	- 9.9 ± 0.9	4.4 ± 1.8
1890	-7.6 ± 1.6	-11.4 ± 1.1	3.9 ± 1.9
		Ave	4.56 ± 0.85

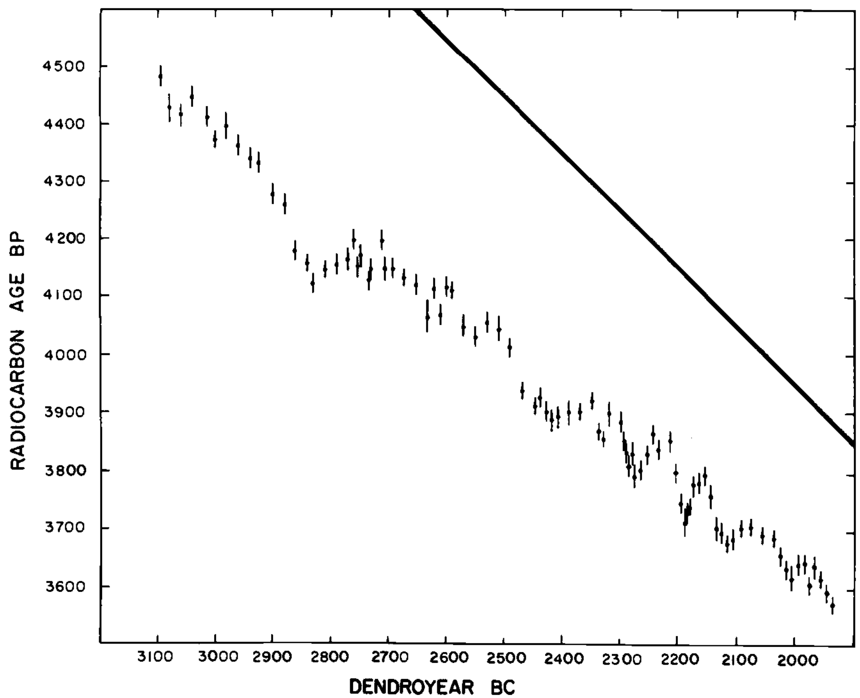

Fig 1. Conventional ^{14}C age plotted against the dendro-age of oak wood from southern Germany (48°N Lat).

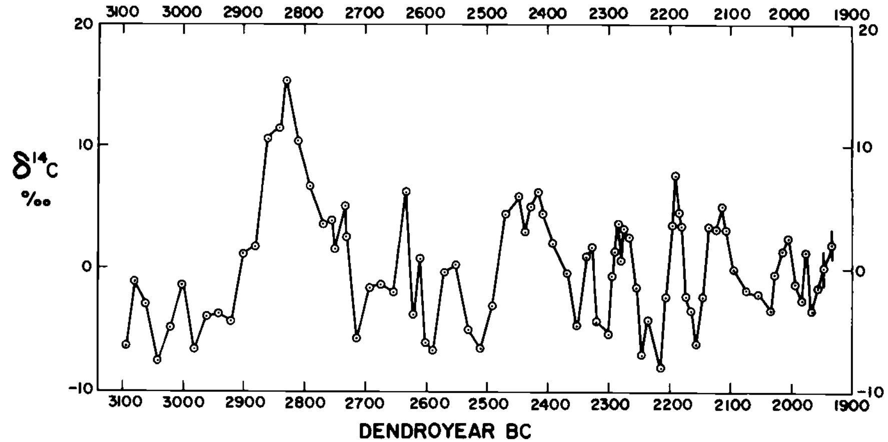

Fig 2. Deviations from the mean trend in the ^{14}C content between 1930 and 3100 BC

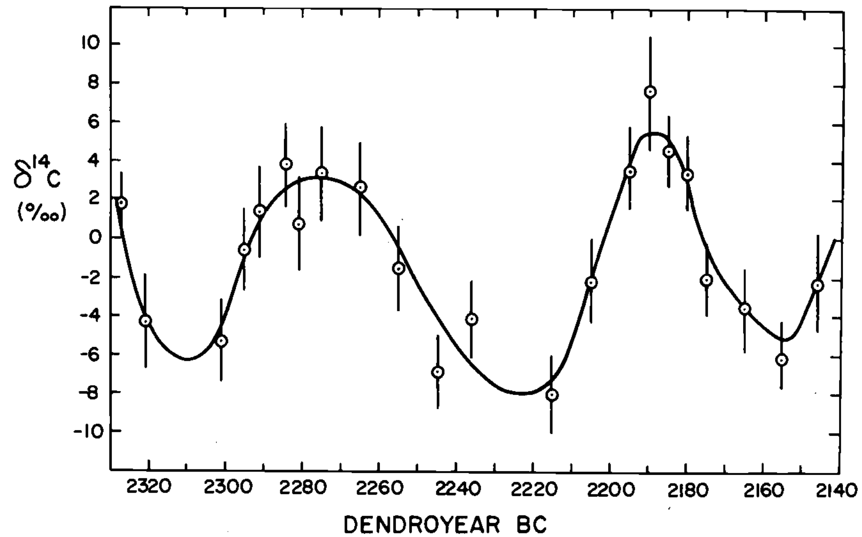

Fig 3. Fluctuations in the ^{14}C content between 2140 and 2320 BC

[Radiocarbon, Vol 28, No. 2B, 1986, P 939–941]

HIGH-PRECISION CALIBRATION OF THE RADIOCARBON TIME SCALE, 3930–3230 cal BC

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This paper contains ^{14}C results obtained by the special high-precision proportional gas counter, designed by Tans and Mook (1978), on tree rings from the South German oak chronologies: Donau 7, 3, 10, and 12, originating from the Danube River basin (48° 24′ N, 10° 5′ E).

^{14}C and ^{13}C results were published earlier (De Jong, Mook & Becker, 1979; De Jong & Mook, 1980; De Jong, 1981). However, the historical time scale was then given as a floating series of tree-ring numbers, while an estimate of absolute scale was derived from wiggle-matching with the bristlecone curve of Suess (1978). Since the absolute Hohenheim master chronology could be extended to include this period (Linick, Suess & Becker, 1985) we can attach absolute values to the historical scale. Because the resulting curve of Figure 1 is to be used as a ^{14}C calibration curve, we presented this historical time scale in cal BC.

The tree-ring samples (ca 100g) were pretreated according to the AAA procedure, consisting of 1) extraction with 4% hydrochloric acid solution at 80°C for 24 hours to remove resinous material; 2) extraction with 4% sodium hydroxide solution at 80°C for 24 hours to remove tannic acids; 3) treatment with 4% hydrochloric acid solution at 80°C for several hours to remove atmospheric carbon dioxide, possibly absorbed during step 2.

After each step, the samples were thoroughly washed with demineralized water to pH = 7. Further technical details were given by De Jong (1981).

The ^{14}C results, corrected for ^{13}C, are presented in Table 1 and Figure 1, where the thin lines refer to 1 σ values from counting statistics only, the other contributions being negligibly small.

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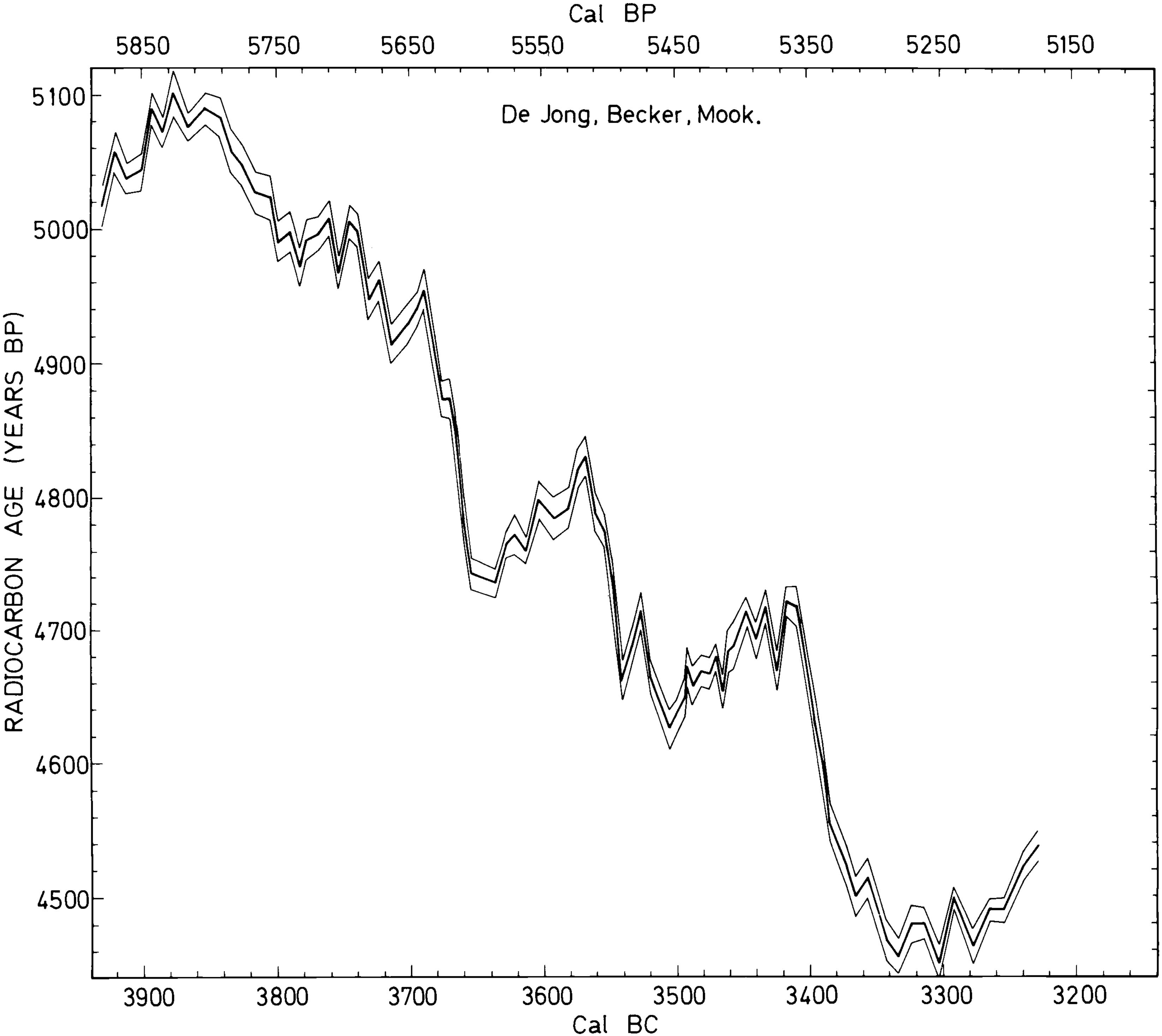

Fig 1. Radiocarbon calibration curve for the period 3930–3230 cal BC. The thin lines refer to 1 σ errors from counting statistics.

TABLE 1

Results of ^{13}C (*vs* PDB) and ^{14}C analyses on tree rings from South German oak chronologies Donau 7, 3, 10, and 12. The absolute historical values are from the absolute master chronology (Becker & Kromer, 1986). The ^{14}C results are conventional ages (5568 yr half-life), corrected for ^{13}C.

GrN no.	Tree no.	Tree-ring no.	Dendro date BC	^{14}C age (BP)	$\delta^{13}C$ (‰)
9163	E1	136	3930	5017 ± 15	−26.18
9162	E1	145	3921	5057 ± 15	−25.90
9161	E1	154	3912	5037 ± 11	−26.01
9160	E1	165	3901	5043 ± 15	−25.42
9066	E1	173	3893	5090 ± 12	−25.51
9065	E1	181	3885	5072 ± 11	−25.54
9159	F1	189	3877	5101 ± 17	−24.50
9063	F1	200	3866	5076 ± 11	−25.17
9158	G1	213	3853	5090 ± 12	−26.16
9025	G1	224	3842	5083 ± 15	−25.21
9024	H1	232	3834	5058 ± 16	−25.05
9023	H1	241	3825	5047 ± 15	−25.46
9022	H1	251	3815	5027 ± 15	−25.36
9021	H1	262	3804	5023 ± 16	−25.54
9008	H1	268	3798	4991 ± 15	−25.55
9007	H1	277	3789	4998 ± 15	−25.30
9006	H1	284	3782	4973 ± 15	−25.37
9005	H1	289	3777	4992 ± 15	−24.93
9004	H1	298	3768	4997 ± 12	−25.06
9002	H1	306	3760	5008 ± 13	−24.30
9001	H1	313	3753	4968 ± 12	−24.65
8837	H1	321	3745	5006 ± 12	−24.40
8836	H1	327	3739	4999 ± 12	−24.54
8835	H1	335	3731	4948 ± 15	−25.37
8834	H1	343	3723	4962 ± 15	−24.53
8833	H1	352	3714	4915 ± 15	−24.79
8832	H1	358	3708	4922 ± 15	−24.73
8831	H1	365	3701	4930 ± 15	−24.68
8830	H1	372	3694	4941 ± 13	−24.53
8779	I1	377	3689	4955 ± 15	−24.54
8778	I1	384	3682	4907 ± 14	−24.82
8777	I1	390	3676	4874 ± 13	−24.90
8776	I1	396	3670	4874 ± 15	−24.59
8775	I1	400	3666	4853 ± 12	−25.09
8774	I1	406	3660	4785 ± 15	−24.84
8773	I1	412	3654	4743 ± 12	−25.26
8771	I1	430	3636	4736 ± 11	−25.27
8766	I1	438	3628	4765 ± 20	−25.27
8764	I1	445	3621	4773 ± 15	−24.81
8751	I1	453	3613	4761 ± 10	−24.37
8750	K1	463	3603	4799 ± 14	−24.49
8749	K1	474	3592	4785 ± 16	−24.69
8748	K1	485	3581	4793 ± 15	−24.68
8742	K1	492	3574	4822 ± 15	−24.76
8741	K1	498	3568	4831 ± 15	−24.65
8740	K1	505	3561	4790 ± 14	−25.06
8730	K1	512	3554	4775 ± 12	−24.90
8729	K1	518	3548	4739 ± 15	−24.60
8727	K1	525	3541	4662 ± 15	−24.43
8726	K1	532	3534	4688 ± 14	−25.31
8725	K1	539	3527	4714 ± 14	−25.21
8724	L1	546	3520	4664 ± 11	−25.02
8570	M1	553	3513	4644 ± 13	−25.54
8569	M1	560	3506	4625 ± 14	−24.71
8568	M1	566	3500	4635 ± 12	−25.03
8549	M1	572	3494	4649 ± 15	−26.12
8728	N1	574	3492	4672 ± 15	−23.99
8548	O1	578	3488	4658 ± 15	−25.66
8547	O1	585	3481	4669 ± 12	−25.69
8546	O1	591	3475	4667 ± 12	−25.58
8532	O1	596	3470	4679 ± 11	−25.09
8531	O1	601	3465	4654 ± 13	−24.60
8530	P1	605	3461	4684 ± 16	−25.33
8529	P1	609	3457	4688 ± 17	−24.95
8528	Q1	614	3452	4702 ± 15	−24.98
8527	Q1	619	3447	4714 ± 11	−25.13
8524	Q1	626	3440	4693 ± 15	−25.77
8523	Q1	633	3433	4718 ± 13	−25.35
8522	R1	641	3425	4669 ± 15	−25.46
8521	R1	649	3417	4722 ± 11	−25.26
8520	R1	656	3410	4718 ± 15	−25.63
8475	R1	661	3405	4692 ± 13	−25.44
8474	S1	669	3397	4631 ± 13	−25.46
8473	S1	676	3390	4600 ± 12	−25.27
8472	S1	687	3385	4556 ± 14	−24.84
8366	S1	694	3372	4522 ± 15	−24.79
8365	T1	700	3366	4500 ± 15	−24.20
8346	T1	709	3357	4514 ± 15	−24.43
8345	T1	723	3343	4468 ± 15	−24.05
8299	T1	732	3334	4456 ± 13	−24.81
8298	U1	742	3324	4480 ± 14	−24.98
8273	V1	752	3314	4480 ± 11	−24.53
8272	V1	763	3303	4451 ± 13	−25.37
8271	V1	774	3292	4499 ± 8	−24.57
8270	W1	788	3278	4463 ± 13	−24.67
8269	W1	801	3265	4490 ± 8	−24.41
8268	W1	812	3254	4490 ± 9	−25.28
8267	W1	826	3240	4523 ± 11	−25.03
8266	W1	837	3229	4538 ± 11	−25.28

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HIGH-PRECISION RADIOCARBON DATING OF BRISTLECONE PINE FROM 6554 TO 5350 BC

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ABSTRACT. New results of radiocarbon dating of ca 100 decadal bristlecone pine samples from 6554 BC to 6084 BC and from 5820 to 5350 BC are presented. Using 3 new 2.5L counters filled to ca 3atm with carbon dioxide, high-precision dating has been performed by this laboratory for more than two years. Demonstration of the precision and accuracy of these counters is presented using ±2‰ measurements from the Spörer minimum period. For the older samples, ±3‰ measurements were made using ca 12-day counting times. Results are presented both as ^{14}C age BP *vs* dendro-year BC, particularly for calibration purposes, and as $\Delta^{14}C$ *vs* time.

INTRODUCTION

Radiocarbon analysis of bristlecone pine tree rings of known age has been one of the primary projects of the University of Arizona's conventional radiocarbon lab for many years (Damon, Long & Grey, 1966; Damon, Long & Wallick, 1972; Damon, Lerman & Long, 1978; Klein *et al*, 1980). Similar work was in progress at the La Jolla radiocarbon lab (eg, see Suess, 1970, 1978, 1980; Bruns *et al*, 1983; Linick, Suess & Becker, 1985) until the cessation of the operation of that lab in 1982. The purpose of this work is two-fold: 1) to provide a calibration of the ^{14}C time scale for the conversion of ages in ^{14}C years BP to ranges of true calendar years; 2) to study the variations of atmospheric ^{14}C levels with time as a matter of geophysical interest to examine the causes of these secular variations, *ie*, changes in the strength of the earth's magnetic field and changes in the flux of solar and cosmic rays.

In 1979, new 2.5L copper counters using the design of Minze Stuiver (Stuiver, Robinson & Yang, 1979) were built and installed in our shield to enable high-precision analysis ($\sigma_{\Delta^{14}C} \leq 3‰$) of the ^{14}C concentration in tree rings of known age. There are 3 of these counters, 3 smaller gas counters, and a liquid scintillation counter in the lab now; nearly 4000 samples have been measured with them.

CELLULOSE EXTRACTION PROCEDURE

In order to isolate the most reliable, least mobile fraction of the wood, it is our practice to extract the holocellulose from the 40g bristlecone pine samples received from the Laboratory of Tree-Ring Research at our institution. The decadal wood samples are cut into matchstick-sized pieces and are then ground to 20 mesh size in a Wiley mill. The chemical pretreatment starts with resin extraction. Using a Soxhlet apparatus, the sample is treated for ca 20 hours with a solvent mixture consisting of 250ml of toluene and 125ml of 100% ethanol heated to ca 170°C. The next day, the apparatus is allowed to cool, and the sample is air-dried. The sample is treated with 350ml 100% ethanol for another 20 hours, using the Soxhlet device. The next day, the apparatus is again allowed to cool, and the sample is again air-dried. The sample is rinsed for several hours with warm distilled water in a beaker. To perform the actual cellulose extraction, the sample is placed in a beaker and covered with distilled water to which 15 drops of glacial acetic acid and ca 5ml volume of sodium chlorite (technical or reagent grade) is added. This solution is heated to 70°C. This bleaching procedure is repeated every 2 to 3 hours until the sample is white. The sample/solution mixture is allowed to sit overnight; if the sample is not yet white, the bleaching procedure is repeated. After the wood has been satisfactorily bleached, it is rinsed with distilled water repeatedly, until one cannot smell the acetic acid, the solution is clear, and the sample is white. The sample is then dried in an oven at ca 110°C until completely dry.

CARBON DIOXIDE SAMPLE PREPARATION PROCEDURE

Combustion of the cellulose is performed in a high-pressure combustion bomb. Ca 11g of the cellulose is pressed into a pellet which is placed in the combustion bomb with an ignition wire embedded into the pellet. A small tray of potassium permanganate solution is placed inside of the bomb. The bomb is then sealed, evacuated, and pressurized with oxygen. After electrically igniting the sample, the resulting carbon dioxide, oxygen, water vapor gas mixture is slowly bled through the gas purification system. This system, modeled after that of Roy Switsur (pers commun), consists of a trap immersed in dry ice/ethanol slush, a trap containing silver powder heated to 250°C, a trap containing cupric oxide heated to 700°C, a trap containing vanadia catalyst heated to 500°C (to convert SO_2 to SO_3), and a long tubing pathway trap immersed in dry ice slush to trap out sulfur oxides and water. The carbon dioxide is then isolated in a trap immersed in liquid nitrogen, with the excess oxygen pumped off at a rate fast enough to maintain a pressure low enough to avoid condensation of oxygen in the trap. When the entire gaseous contents of the bomb have been passed through this system, a procedure taking a few hours, the carbon dioxide is pumped to high vacuum. The carbon dioxide is then allowed to sublime slowly, passing through phosphorus pentoxide powder to complete the drying, and then frozen into a cold finger located on the final purification apparatus; after again pumping the sample to high vacuum, the carbon dioxide is then allowed to expand into a large volume convective recirculation tower with elemental copper turnings heated to 475°C to remove remaining traces of oxygen, a system modeled after that of Minze Stuiver. After remaining in the glass tower for at least 6 days, the sample is frozen into a stainless steel cylinder for storage. To allow for decay of ^{222}Rn, the sample remains in its cylinder for a minimum of 30 days before counting, a length of time found to be sufficient for these cellulose samples.

COUNTING PRACTICES

The three 2.5L counters are filled to a pressure of 45psi at a shield temperature of 30°C. The counters are very stable, and all three have very similar counting characteristics. The anti-coincidence circuit used here

† Deceased March 24, 1986.

includes individual proportional counter tubes lining the inside of the iron shield, with two layers of such tubes on the top; in addition, the six gas counters are themselves included in the anti-coincidence circuit to lower further the background counting rates. There is also lead to improve shielding, including lead sheeting surrounding the high-precision counters. The background count rate of each of these three counters is somewhat different, apparently dependent on the location within the shield. The average background count rates of the counters are ca 4.5, 3.6, and 4.9cpm. The corrected modern (1950) count rates based on analyses of both batches of NBS oxalic acid range from 44.5 to 45.0cpm. The counting characteristics of the counters are so similar that a single main high voltage supply is used for all three, with additional biases of up to 100 volts adjustable separately for each counter to attain constant ratios of meson events in the two energy channels, to compensate for small variations in gas purity.

In practice, with tree-ring samples from ca 8000 yr BP, most of the samples analyzed to high precision are measured for 9 to 15 days, in periods of 3 days at a time in each counter, all samples counted for at least one such period in each of the 3 counters. The counting sequence generally consists of 3-day countings of 2 samples, then a background, 2 more samples, and then a standard. Data from all gas counters are recorded on computer diskette every 20 minutes. In the daily data reduction, a Chauvenet rejection procedure is used to delete any 20-minute interval of any counter's data which has a probability of occurring naturally of $< 1/2N$, where N is the number of intervals; typically, any one counter has an interval rejected only once every 2 to 3 days.

The background to be applied to any 1-day counting of a sample or standard is calculated as follows: a linear regression of background count rate *vs* guard count rate is performed using the data collected from 3 months before through 3 months after the sample or standard count. A background value is applied based on the guard count rate on the day of sample analysis.

Several preparations of (old) oxalic acid-I and (new) oxalic acid-II have been used for determining the standard value for each counter. Again, for each day's sample counting, the mean of standards measured during the three months before and after the sample counting is applied.

Finally, 3 months after the sample counting, a final weighted average mean of the single-day results is calculated. The Chauvenet rejection procedure is applied to the single measurements for each sample.

CONFIRMATION OF HIGH-PRECISION CAPABILITY OF COUNTERS

In order to prove that the 2.5L counters, filled to ca 3atm, would produce data of high precision and accuracy, we performed a test. We wished to obtain uncertainties in $\Delta^{14}C$ of ca 2‰ for relatively modern material and ca 3‰ for the 6554 to 5350 BC samples we planned to measure in this project. Seven samples of bristlecone pine ranging through the Spörer minimum period were provided by one of us (CWF). The ^{14}C data from analysis of these samples were compared with those of Stuiver and Quay (1980). The data comparison is presented as Figure 1. As can readily be seen, the agreement of the Arizona and Seattle data is excellent, giving us confidence in the capability of these detectors.

EXTENSION OF THE BRISTLECONE PINE CHRONOLOGY TO 6554 BC

Six years ago, CWF collected a specimen of bristlecone pine that could be cross-dated to his existing chronology; this specimen of wood provided decadal samples (min 40g) from the range 6554 to 6084 BC (4 yr older than original assignment due to finding of "missing rings" in the 6084 to 5820 BC range). CWF was also able to provide decadal samples from another specimen covering the range 5820 to 5350 BC. Several years ago, CWF had provided both the Arizona and La Jolla radiocarbon labs with some samples from the period in the gap 6080 to 5820 BC, but the precision of the measurement of these samples was not high (±5 to 8‰), the internal scatter of each lab's data was excessive, and the data from the two labs were in poor agreement. Unfortunately, there was insufficient wood remaining from that period to re-measure in this project and we have chosen not to use the lower precision data just to fill the gap.

RADIOCARBON RESULTS FOR WOOD FROM 6554 TO 5350 BC

It has taken us over two years to complete the measurement of the 106 samples ultimately provided to us. A while after the testing of the then new high-precision counters, gas purity problems arose, so that four of the samples were unmeasurable. The results of our analyses of the remaining 102 samples are given in Table 1. The $\delta^{13}C$ values are in ‰, relative to the PDB standard. The ^{14}C ages are in years BP, calculated with the conventional 5568-yr ^{14}C half-life. The decay correction used to calculate the $\Delta^{14}C$ values is based on the 5730-yr ^{14}C half-life, as is conventional for this purpose. The uncertainties of the ^{14}C measurements are the one standard deviation errors of the weighted means, choosing the larger of the error based purely on counting statistical grounds and that based on the standard deviation of the single-day data. In 5 cases, the ^{14}C results originally obtained were checked by analyzing duplicate samples from these decades; in 2 cases, the previous data were confirmed, while in the other 3 (for which the original data agreed poorly with that from surrounding decades) the data from the new samples were much more in line with those from the surrounding decades. We have chosen, on statistical grounds, to delete those 3 results from further use; we have no explanation for these deviant data.

We have plotted the data in various formats for examination and use in different ways. Figure 2 is a plot of $\Delta^{14}C$ *vs* time (dendro-year BC). The plot of data from this period looks much the same as from other periods of time. As a general trend, ^{14}C levels increase with more recent times, especially in the most modern centuries shown in Figure 2; this agrees with previous measurements and the trend of an 11,300-yr sinusoidal curve (Bruns *et al*, 1983). There are some clear wiggles in the curve: maxima are apparent at ca 6410, 6360, 5720, 5610, and 5460 BC. Minima are at ca 6480, 6250, 5750, and 5665 BC.

The data points are presented as ^{14}C age in years BP *vs* true calendar year (dendro-year cal BC) in Figure 3 for the 6554 to 5350 BC range. The same features observable in Figure 2 are present in this plot, but may be less clear because of the scale. For use in calibration of ^{14}C ages BP, plots similar to those given as Figure 3 of Stuiver (1982) are presented here as Figure 4, using only Arizona high-precision data. Figure 4A covers the dendro-year range of data from 6600 to 5900 cal BC. Figure 4B covers 6100 to 5400 cal BC, and Figure 4C covers 5600 to 4900 cal BC. These plots give 1σ bands based on the individual data points, presented as ^{14}C age in years BP *vs* dendro-year cal BC. At this time, the bristlecone pine chronology is the only tree-ring chronology that continues unbroken to 6554 BC, although there is only one gap apparently remaining in the German oak chronology (Becker, pers commun; Linick, Suess & Becker, 1985), which would extend to ca 7200 BC if this gap was filled in. A detailed examination of the entire tree-ring ^{14}C record, with reference to the observable periodicities and their causes, was performed by Damon & Linick (1986).

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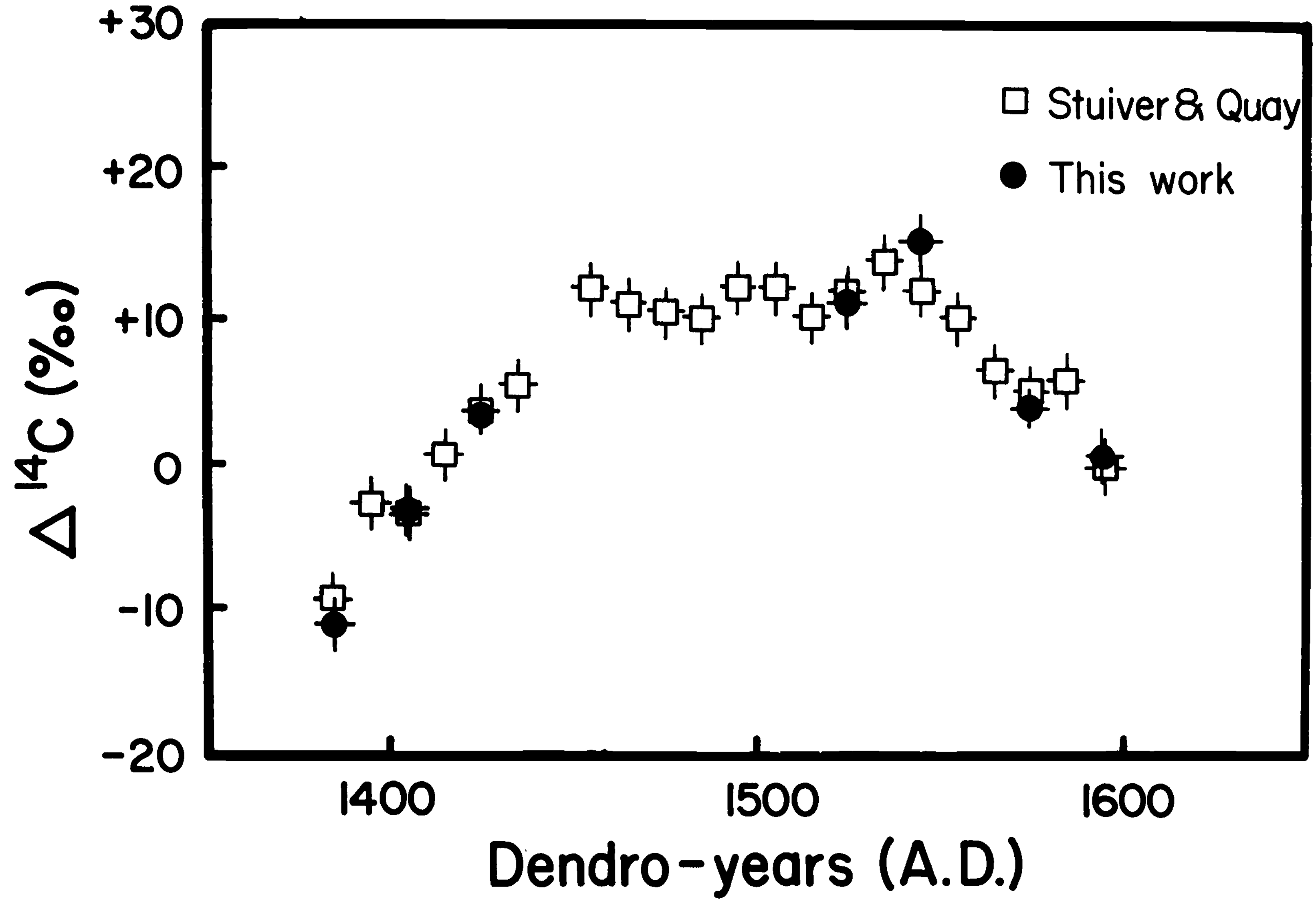

Fig 1. Comparison of Arizona and Seattle (Stuiver & Quay, 1980) measurements of $\Delta^{14}C$ *vs* time during the Spörer minimum

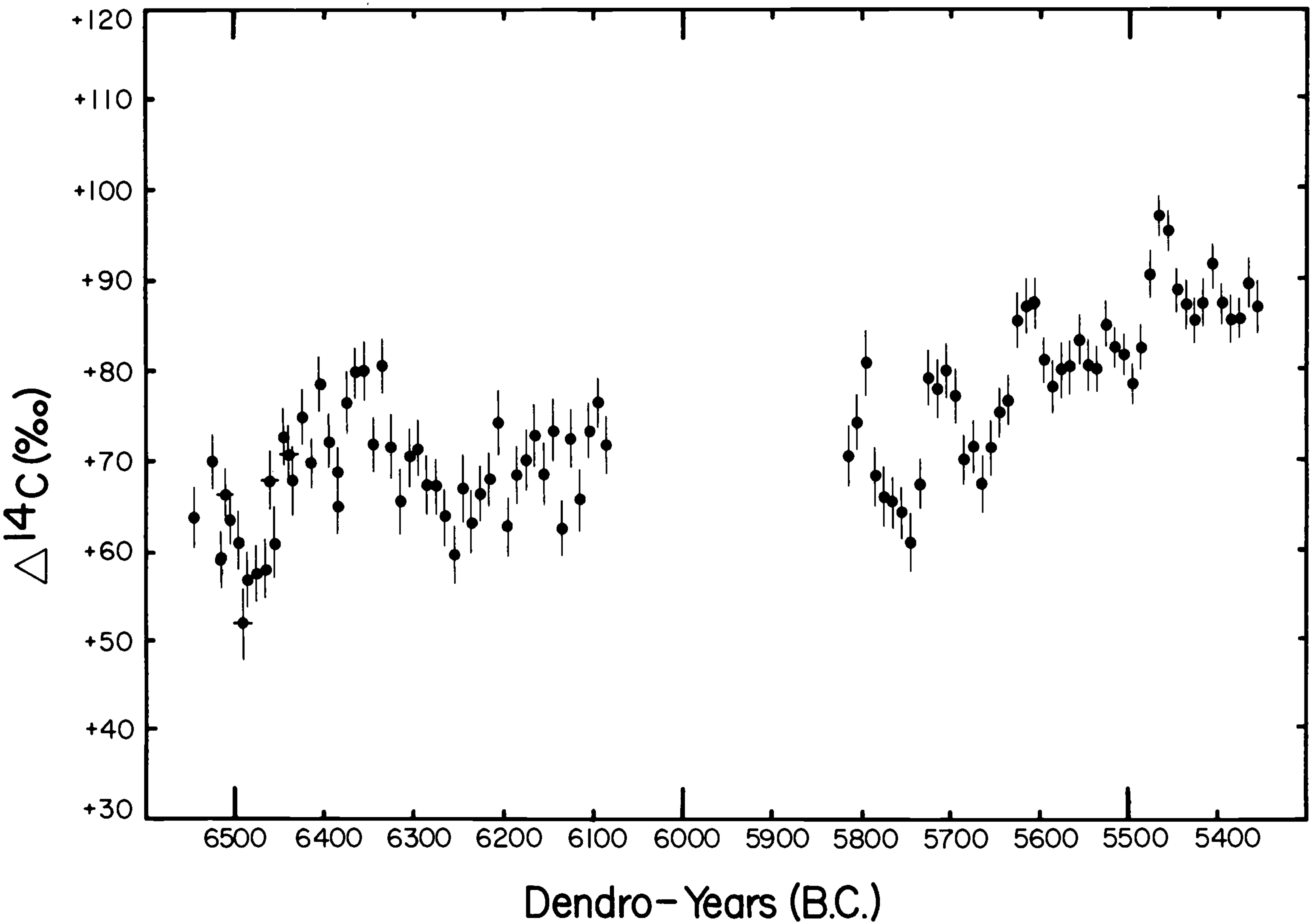

Fig 2. Temporal variation of $\Delta^{14}C$ for the time ranges 6554 to 6084 BC and 5820 to 5350 BC, based on high-precision Arizona measurements of decadal bristlecone pine samples

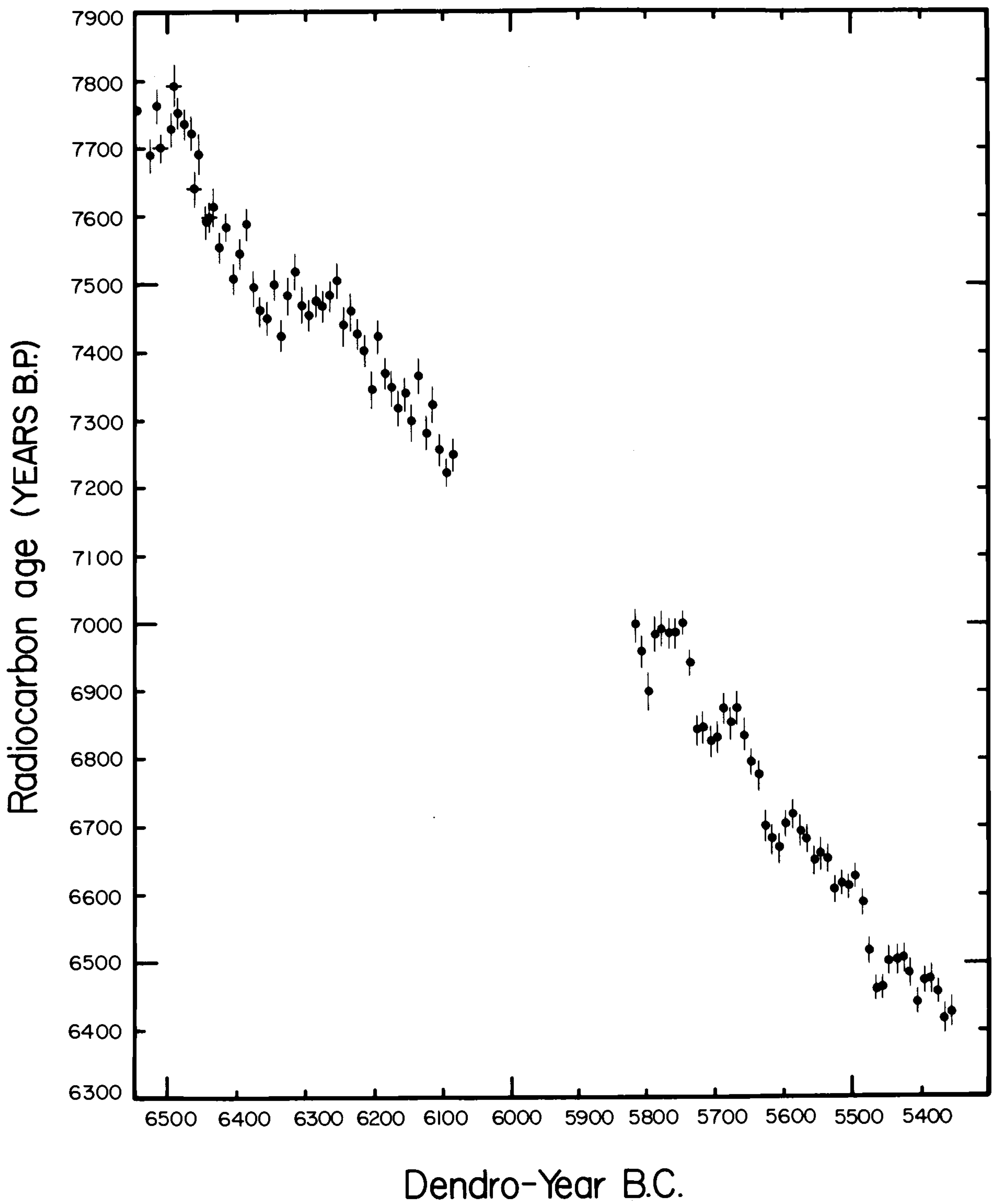

Fig 3. Conventional ^{14}C ages in years BP *vs* true calendar years of growth for decadal bristlecone pine samples from 6554 to 5350 BC

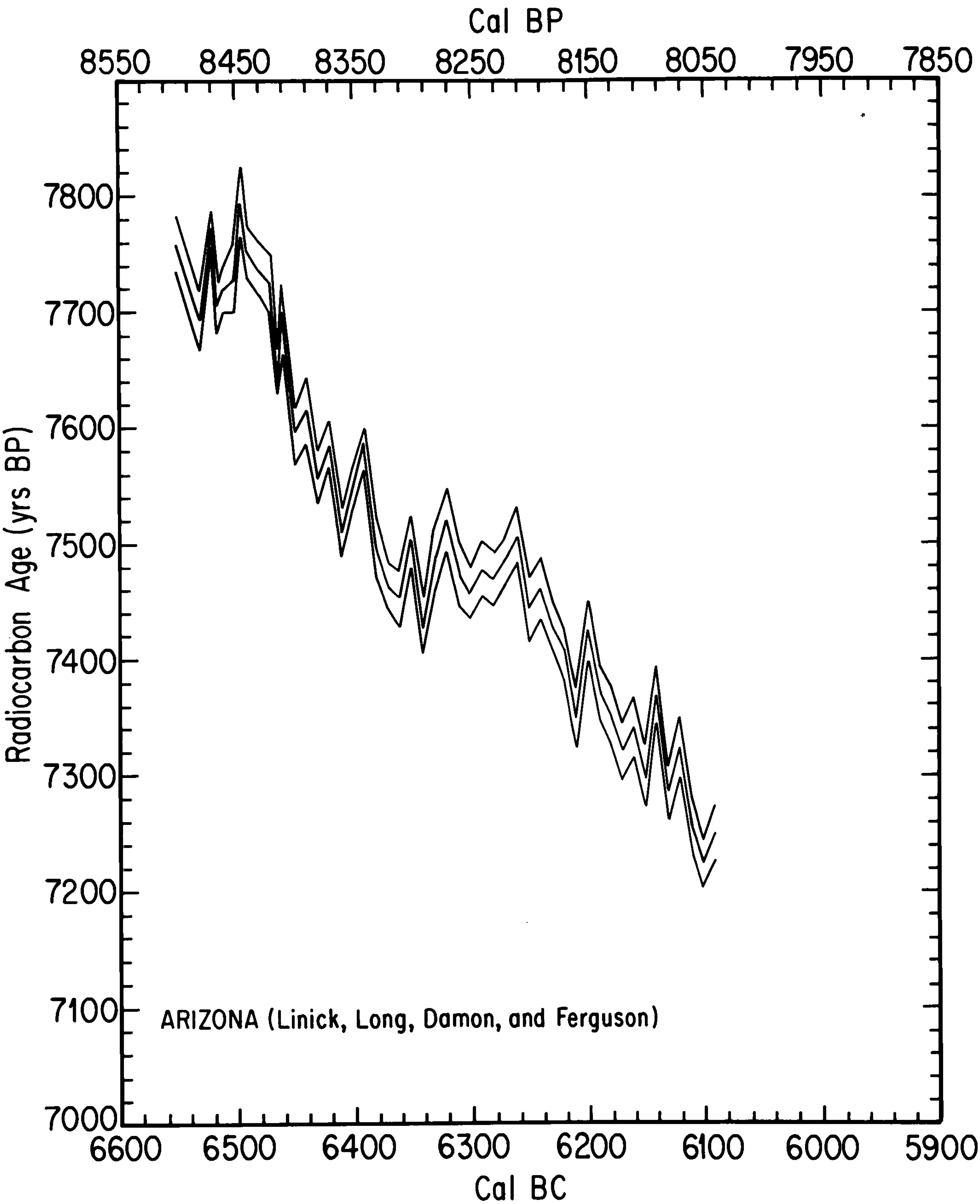

Fig 4A, B, C. ^{14}C age BP *vs* cal dendro-year for the decadal sample measurements shown in Fig 3. On each plot, the center line was drawn by connecting each of the individual decadal sample ^{14}C ages. The surrounding lines correspond to the 1σ statistical uncertainties above and below each datum.

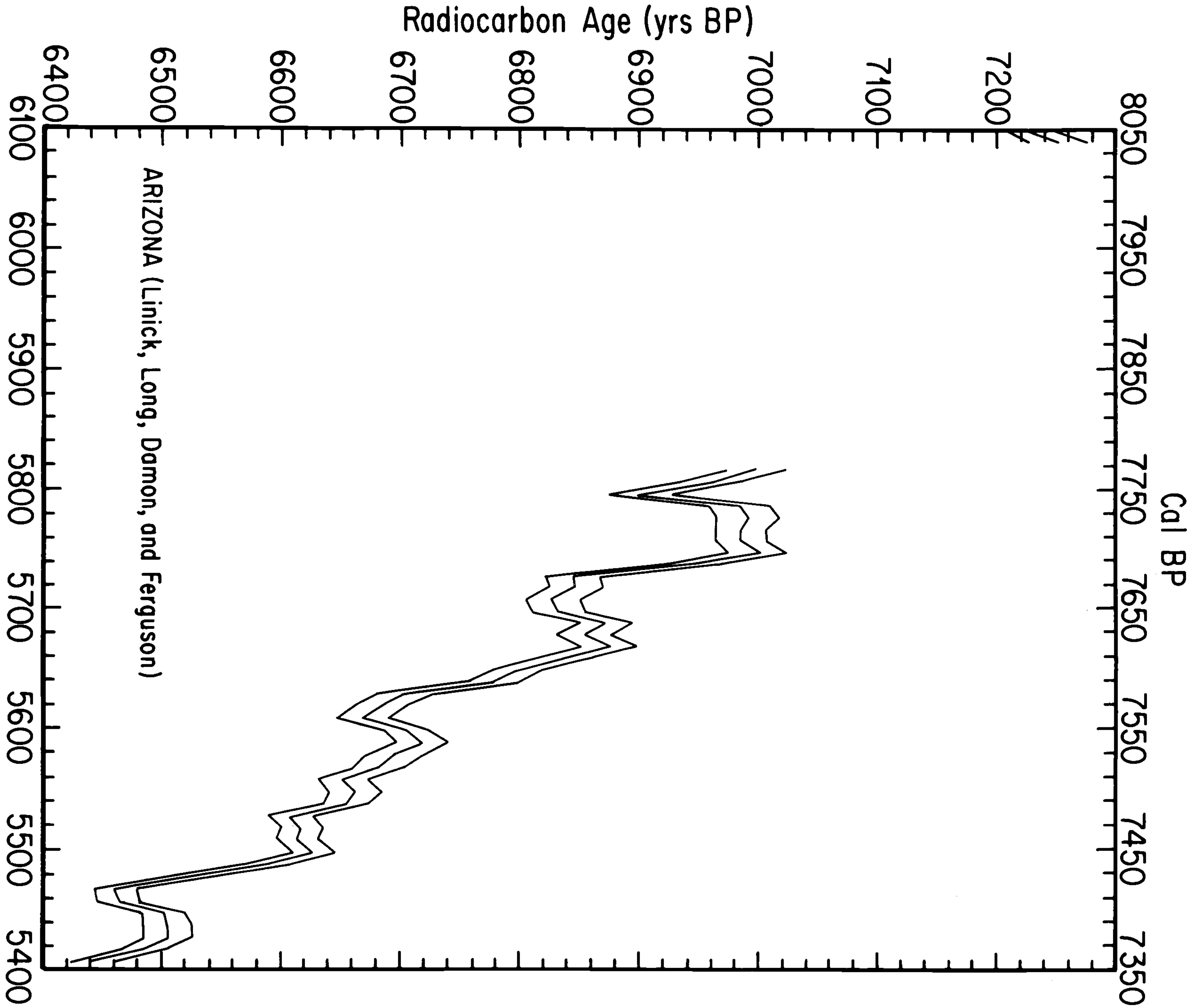
Radiocarbon Age (yrs BP)
6400
6500
6600
6700
6800
6900
7000
7100
7200
8050
7950
7850
7750
7650
7550
7450
7350
Cal BP
6100
6000
5900
5800
5700
5600
5500
5400
Cal BC
ARIZONA (Linick, Long, Damon, and Ferguson)

Fig 4B

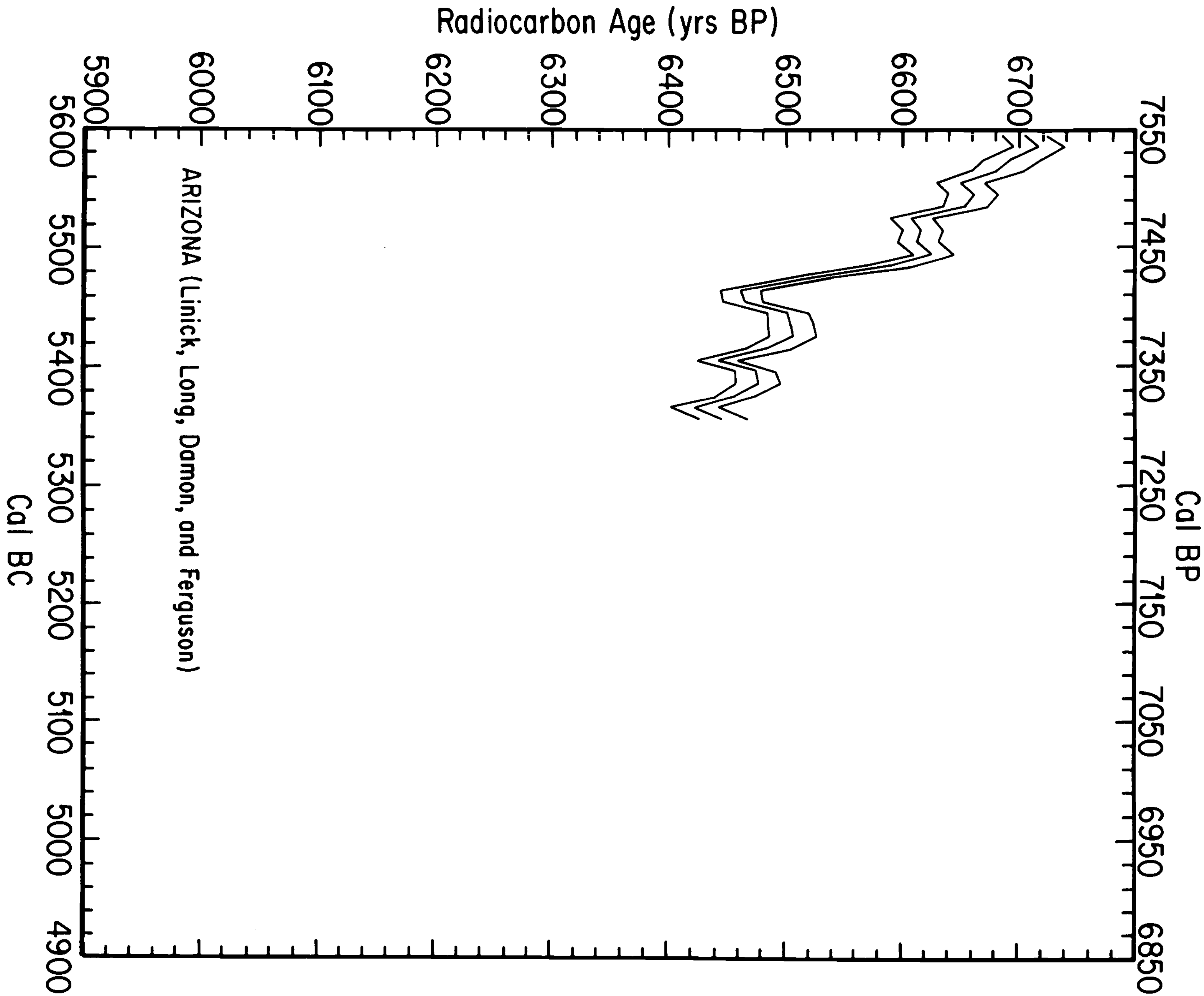
Radiocarbon Age (yrs BP)
5900
6000
6100
6200
6300
6400
6500
6600
6700
Cal BP
7550
7450
7350
7250
7150
7050
6950
6850
Cal BC
5600
5500
5400
5300
5200
5100
5000
4900
ARIZONA (Linick, Long, Damon, and Ferguson)

Fig 4C

TABLE 1
Radiocarbon results for decadal bristlecone pine tree rings, 6554 to 5350 BC

Lab No.	Mid-Point Dendro-Year	$\delta^{13}C$ (‰)	^{14}C Age (yr BP)	$\Delta^{14}C$ (‰)
A-3926	-6549	-19.8	7758 ± 24	64.3 ± 3.2
A-3928	-6529	-20.0	7691 ± 24	70.6 ± 3.1
A-3929	-6519	-20.0	7763 ± 25	59.8 ± 3.2
A-4204	-6519	-20.2	7782 ± 22	57.3 ± 2.9
A-2341	-6514*	-20.4	7704 ± 23	66.9 ± 3.0
A-3930	-6509	-20.4	7720 ± 20	64.1 ± 2.7
A-3796	-6499	-21.8	7729 ± 29	61.7 ± 3.3
A-2342	-6494*	-20.5	7794 ± 31	52.5 ± 4.0
A-3797	-6489	-19.9	7753 ± 23	57.3 ± 3.0
A-3798	-6479	-19.6	7737 ± 23	58.1 ± 3.1
A-3799	-6469	-19.8	7724 ± 25	58.5 ± 3.3
A-2343	-6464*	-20.4	7643 ± 25	68.5 ± 3.3
A-2862	-6459	-20.3	7694 ± 30	61.5 ± 4.0
A-3800	-6449	-19.7	7593 ± 24	73.3 ± 3.2
A-2344	-6444*	-20.4	7602 ± 24	71.4 ± 3.2
A-2863	-6439	-20.2	7615 ± 29	68.5 ± 3.9
A-3801	-6429	-19.1	7557 ± 22	75.5 ± 3.0
A-3995	-6419	-20.0	7586 ± 20	70.3 ± 2.7
A-3883	-6409	-20.0	7510 ± 22	79.2 ± 3.0
A-3884	-6399	-19.8	7547 ± 23	72.9 ± 3.0
A-2521	-6389	-19.8	7592 ± 23	65.6 ± 3.0
A-4205	-6389	-19.6	7578 ± 21	67.8 ± 2.8
A-3885	-6379	-20.0	7496 ± 25	77.2 ± 3.4
A-3886	-6369	-20.4	7463 ± 21	80.3 ± 2.8
A-2525**	-6359	-19.8	7338 ± 27	95.9 ± 3.7
A-3887	-6359	-20.2	7452 ± 24	80.5 ± 3.3
A-2526	-6349	-20.0	7502 ± 22	72.4 ± 3.0
A-2527	-6339	-20.1	7427 ± 24	81.2 ± 3.0
A-2528	-6329	-20.4	7485 ± 27	72.2 ± 3.6
A-2529	-6319	-20.5	7521 ± 27	66.1 ± 3.6
A-2530	-6309	-20.2	7472 ± 27	71.2 ± 3.6

TABLE 1 (continued)

Lab No.	Mid-Point Dendro-Year	$\delta^{13}C$ (‰)	^{14}C Age (yr BP)	$\Delta^{14}C$ (‰)
A-2540	-6299	-20.0	7457 ± 23	72.0 ± 3.1
A-2541	-6289	-20.1	7478 ± 24	67.9 ± 3.2
A-2542	-6279	-19.7	7469 ± 23	67.8 ± 3.1
A-2543**	-6269	-20.4	7563 ± 21	54.1 ± 2.8
A-4028	-6269	-20.7	7485 ± 22	64.4 ± 3.0
A-2544	-6259	-20.4	7507 ± 25	60.2 ± 3.2
A-2556	-6249	-20.2	7441 ± 29	67.6 ± 3.8
A-2557	-6239	-19.9	7461 ± 27	63.7 ± 3.6
A-2558	-6229	-20.6	7428 ± 22	66.9 ± 3.0
A-2559	-6219	-20.4	7404 ± 23	68.6 ± 3.1
A-2560	-6209	-20.5	7348 ± 27	74.9 ± 3.6
A-3214	-6199	-20.3	7425 ± 25	63.3 ± 3.3
A-3215**	-6189	-20.9	7501 ± 23	52.0 ± 3.0
A-3895	-6189	-20.3	7372 ± 24	69.1 ± 3.2
A-3216	-6179	-19.7	7350 ± 26	70.7 ± 3.5
A-3217	-6169	-20.2	7320 ± 25	73.4 ± 3.4
A-3218	-6159	-19.9	7342 ± 26	69.2 ± 3.5
A-3223	-6149	-20.1	7298 ± 26	73.9 ± 3.5
A-3224	-6139	-20.1	7368 ± 25	63.1 ± 3.2
A-3225	-6129	-20.0	7284 ± 25	73.0 ± 3.4
A-3226	-6119	-19.7	7324 ± 26	66.3 ± 3.4
A-3227	-6109	-19.5	7258 ± 23	74.0 ± 3.1
A-3228	-6099	-20.2	7224 ± 20	77.1 ± 2.7
A-3229	-6089	-20.2	7250 ± 24	72.4 ± 3.2
A-3009	-5815	-20.8	6998 ± 25	70.5 ± 3.4
A-2734	-5805	-20.6	6959 ± 22	74.4 ± 3.0
A-2735	-5795	-20.4	6901 ± 27	80.8 ± 3.6
A-2736	-5785	-20.6	6985 ± 26	68.3 ± 3.4
A-2737	-5775	-20.9	6992 ± 26	66.1 ± 3.4
A-2738	-5765	-20.9	6987 ± 21	65.4 ± 2.8
A-2739	-5755	-20.4	6986 ± 22	64.3 ± 2.9
A-2740	-5745	-20.6	7001 ± 24	61.0 ± 3.2

TABLE 1 (continued)

Lab No.	Mid-Point Dendro-Year	$\delta^{13}C$ (‰)	^{14}C Age (yr BP)	$\Delta^{14}C$ (‰)
A-2741	-5735	-20.3	6943 ± 21	67.4 ± 2.8
A-2742	-5725	-20.0	6844 ± 23	79.3 ± 3.2
A-2743	-5715	-20.2	6847 ± 23	77.8 ± 3.2
A-2749	-5705	-20.2	6827 ± 23	79.8 ± 3.1
A-2750	-5695	-20.2	6832 ± 22	77.1 ± 3.0
A-2751	-5685	-19.6	6874 ± 22	70.1 ± 2.9
A-3018	-5675	-20.0	6853 ± 23	71.6 ± 3.1
A-3019	-5665	-20.1	6876 ± 24	67.4 ± 3.2
A-3020	-5655	-19.8	6836 ± 24	71.4 ± 3.2
A-3021	-5645	-19.8	6797 ± 20	75.3 ± 2.7
A-2752	-5635	-20.2	6777 ± 21	76.7 ± 2.8
A-2753	-5625	-20.2	6702 ± 23	85.5 ± 3.1
A-2754	-5615	-19.6	6682 ± 22	86.9 ± 2.9
A-2755	-5605	-18.8	6668 ± 22	87.3 ± 2.9
A-3036	-5595	-19.5	6705 ± 19	81.2 ± 2.5
A-3037	-5585	-20.1	6718 ± 22	78.1 ± 2.9
A-3038	-5575	-20.4	6694 ± 24	80.0 ± 3.2
A-3039	-5565	-21.6	6682 ± 22	80.3 ± 3.0
A-3040	-5555	-20.2	6650 ± 21	83.3 ± 2.8
A-3041	-5545	-19.5	6661 ± 22	80.5 ± 2.9
A-3042	-5535	-20.5	6654 ± 19	80.1 ± 2.6
A-3043	-5525	-20.3	6608 ± 19	85.0 ± 2.5
A-3066	-5515	-20.4	6617 ± 17	82.5 ± 2.3
A-3067	-5505	-20.2	6613 ± 17	81.7 ± 2.3
A-3068	-5495	-20.1	6627 ± 17	78.5 ± 2.3
A-3069	-5485	-20.0	6588 ± 19	82.4 ± 2.5
A-3053	-5475	-20.6	6518 ± 19	90.6 ± 2.6
A-3054	-5465	-20.4	6461 ± 17	97.0 ± 2.3
A-3055	-5455	-19.8	6464 ± 17	95.3 ± 2.3
A-3056	-5445	-20.5	6502 ± 18	88.8 ± 2.5
A-3057	-5435	-20.6	6504 ± 20	87.2 ± 2.7
A-3058	-5425	-20.7	6506 ± 19	85.5 ± 2.5
A-3059	-5415	-20.8	6484 ± 19	87.3 ± 2.6

TABLE 1 (continued)

Lab No.	Mid-Point Dendro-Year	$\delta^{13}C$ (‰)	^{14}C Age (yr BP)	$\Delta^{14}C$ (‰)
A-3060	-5405	-20.7	6442 ± 18	91.6 ± 2.5
A-3072	-5395	-20.5	6475 ± 17	87.3 ± 2.3
A-3073	-5385	-20.6	6477 ± 19	85.6 ± 2.6
A-3074	-5375	-20.2	6457 ± 17	85.7 ± 2.2
A-3075	-5365	-20.1	6421 ± 21	88.9 ± 2.8
A-3076	-5355	-20.2	6447 ± 21	84.4 ± 2.9

* 20-year sample
** ^{14}C data for sample rejected after measurement of second sample from same decade

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RADIOCARBON CALIBRATION DATA FOR THE 6TH TO THE 8TH MILLENNIA BC

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ABSTRACT. ^{14}C calibration curves derived from South German oak tree-ring series are presented. They cover the interval between 4400 and 7200 BC complementing existing data sets and extending them to older periods. The atmospheric ^{14}C level before 6200 BC no longer follows the long-term sinusoidal trend fitted to the bristlecone data. This observation is supported by a tentative match of the Main 9 series.

INTRODUCTION

The Hohenheim oak series Donau 8, Main 6, Donau 6 and Main 4 have been measured by the ^{14}C laboratories of Heidelberg, La Jolla, and Seattle (see eg, Bruns *et al,* 1983; Linick, Suess & Becker, 1985; Stuiver *et al,* 1986). These series are floating but have been linked dendrochronologically in the past three years, resulting in a 3100-year floating series with ^{14}C ages in the interval 5200 to 8200 BP. Recently, this unified series has been matched to bristlecone pine (Linick, Suess & Becker, 1985; Stuiver *et al,* 1986) accurately enough to permit its use as a calibration data base and to permit an assessment of past atmospheric ^{14}C levels.

We report here the ^{14}C data obtained in Heidelberg on this series and compare them with results of other laboratories.

DATA

The tree-ring samples were prepared at the Hohenheim tree-ring laboratory. They were pretreated for ^{14}C dating as follows: samples measured before 1982 (lab numbers lower than 7000) were kept in hot HCl for two hours. Later, the samples were pretreated in the standard AAA sequence. All ^{14}C ages are normalized to oxalic acid, *ie,* all Heidelberg data obtained prior to June, 1982 were recalculated (Kromer, 1984).

The data of the unified series are given in Table 1. The absolute age was obtained using 7230 BC as zero point of the series. This is the best estimate using the matching to the bristlecone series mentioned above and comparing the Heidelberg data ca 6000 BP (Hd-9304 to Hd-9360 of Table 1) to the Irish oak series (Pearson *et al,* 1986).

For calibration purposes, the data are plotted in Figures 1–4 in the standard format. The uncertainty in the dendro-scale due to the matching to bristlecone pine has been estimated to 25 years (Stuiver *et al,* 1986).

The data points are connected by a cubic spline (Reinsch, 1967) using maximum smoothing ($S = N + (2N)^{1/2}$) in Eq (2) of Reinsch (1967). Confidence limits of ±30 yr are indicated. Spline plotting has been suppressed for those periods when data coverage is <1 per 60 yr.

The spacing of the samples is not uniform; at some intervals (eg, 7400 BP, 8150 BP) many samples were measured to identify new trees, filling gaps between the series. After successful dendrochronologic identification, these ^{14}C data were incorporated in the data set.

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ATMOSPHERIC ^{14}C LEVEL

Delta ^{14}C values of the series and an interpolating spline function are shown in Figure 5 (solid curve labeled "Hd"). The data are compared to the measurements in La Jolla (Linick, Suess & Becker, 1985) ("LJ") and Seattle ("S") (Stuiver *et al,* 1986). There is good agreement in the long-term trend in all data sets; on a short time scale (100 yr) differences of up to delta ^{14}C = 15 ‰ do exist.

The unified series discussed so far yields atmospheric ^{14}C levels back to 7200 BC. Thus, it can be checked whether the sinusoidal trend fitted to the bristlecone pine data up to 5400 BC (eg, Neftel, Oeschger & Suess, 1981; Carmi, Sirkes & Magaritz, 1984) is still maintained to older ages. It is obvious from Figure 5 that before 6200 BC the ^{14}C level is consistently higher than what is to be expected by the already declining sinusoidal trend. This observation is supported by a tentative match of the floating series Main 9, which extends from 8200 to 8700 ^{14}C yr BP and thus overlaps in ^{14}C years with the old end of the unified Donau/Main series. From the slope of the respective ends of both series, a minimum zero point of 7750 BC for the Main 9 series is obtained; the delta ^{14}C plots of both series show a smooth transition if 7825 BC is assumed as a zero point. Using this value, delta ^{14}C data of the Main 9 series are shown in Figure 5 (curve labeled "M9").

Evidently, the delta ^{14}C values of the Main 9 series are subject to the final absolute placement of this series but for the present argument it is essential only that the series cannot be shifted by more than 10 ‰ to lower values excluding the sinusoidal trend as a valid representation of the atmospheric ^{14}C level prior to 6200 BC.

It should be noted that the ^{14}C pattern derived from fixing the Main 9 series in the interval given above is fully consistent with the data obtained on the varve series of the Lake of the Clouds (Stuiver, 1970).

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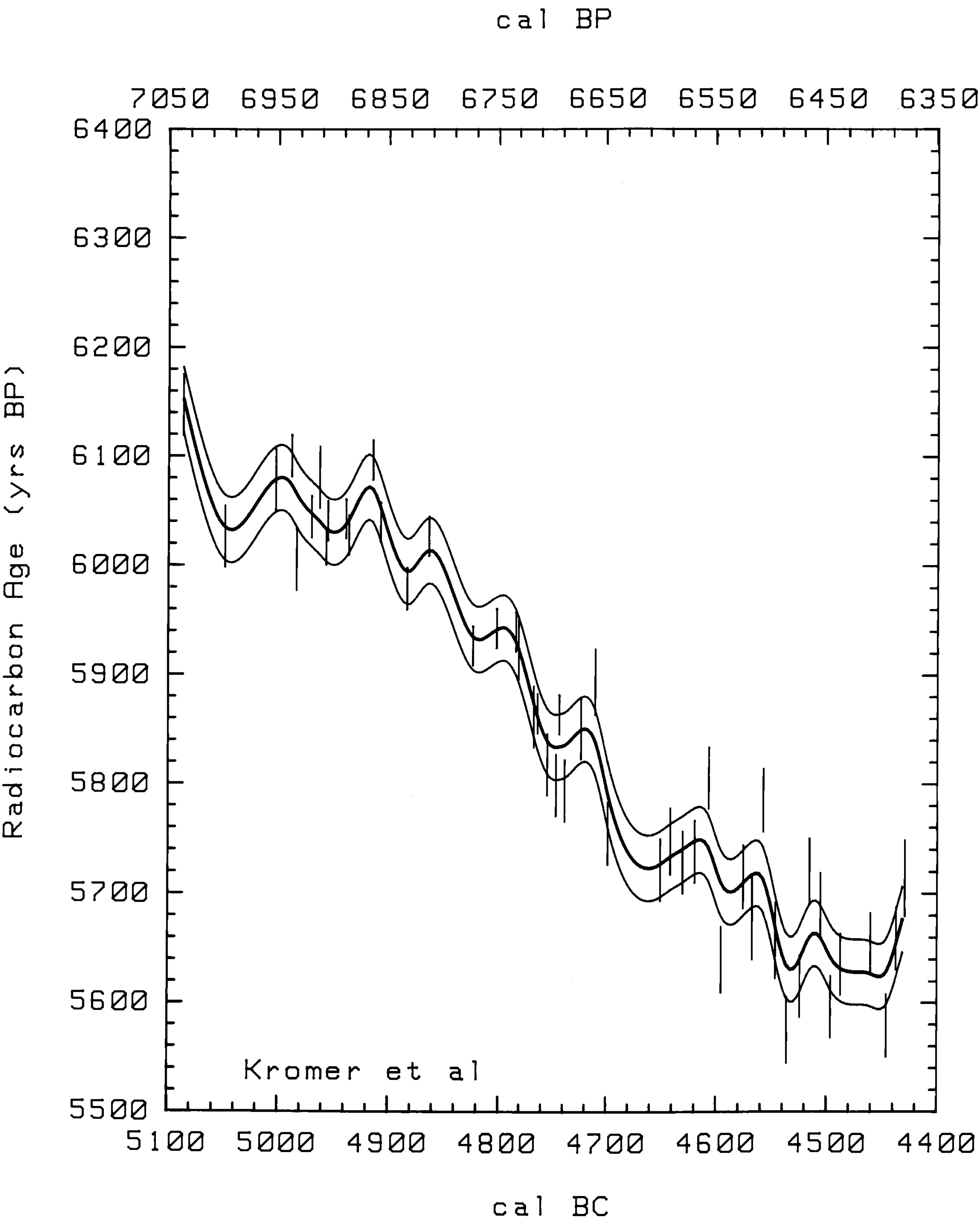
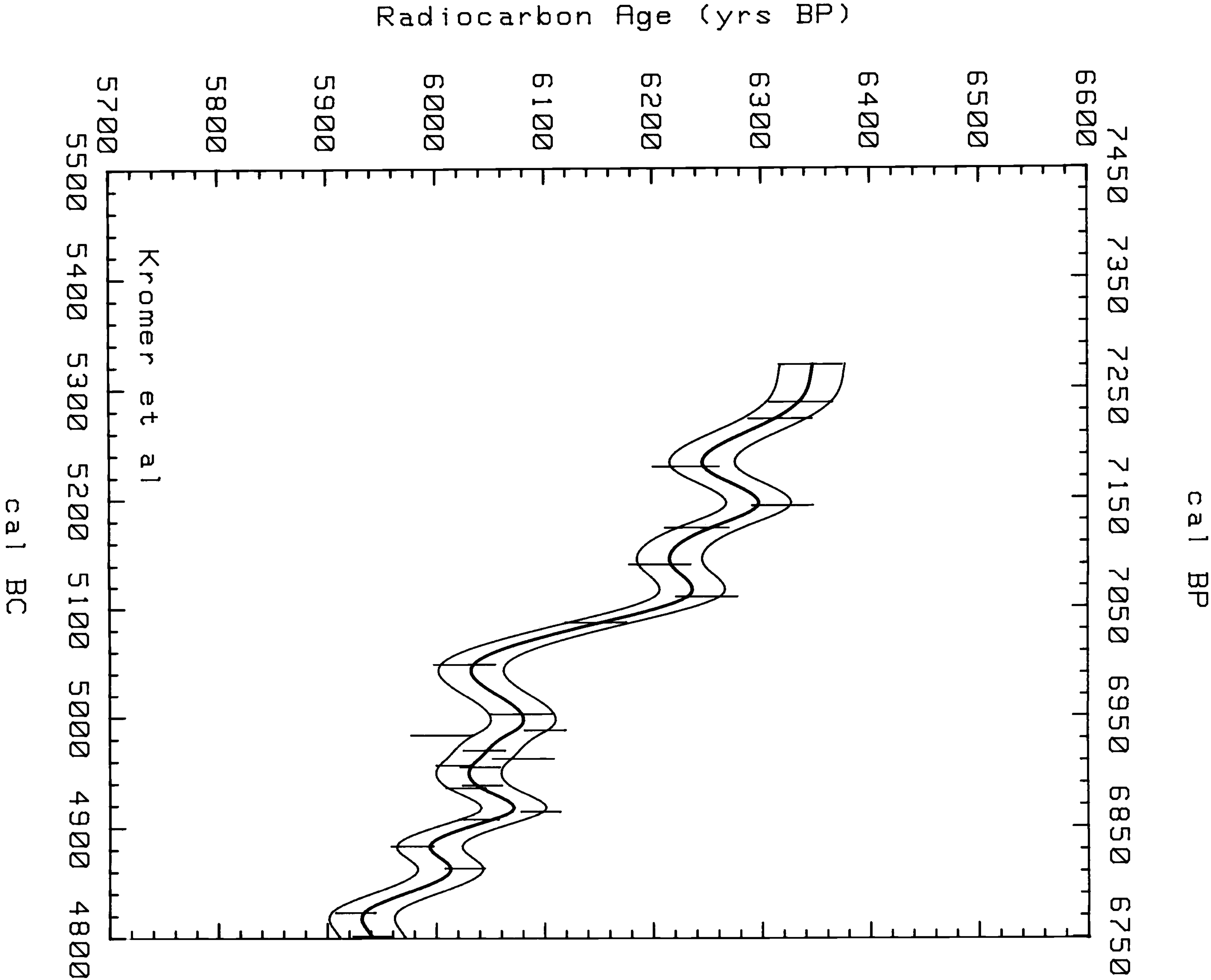
TABLE 1

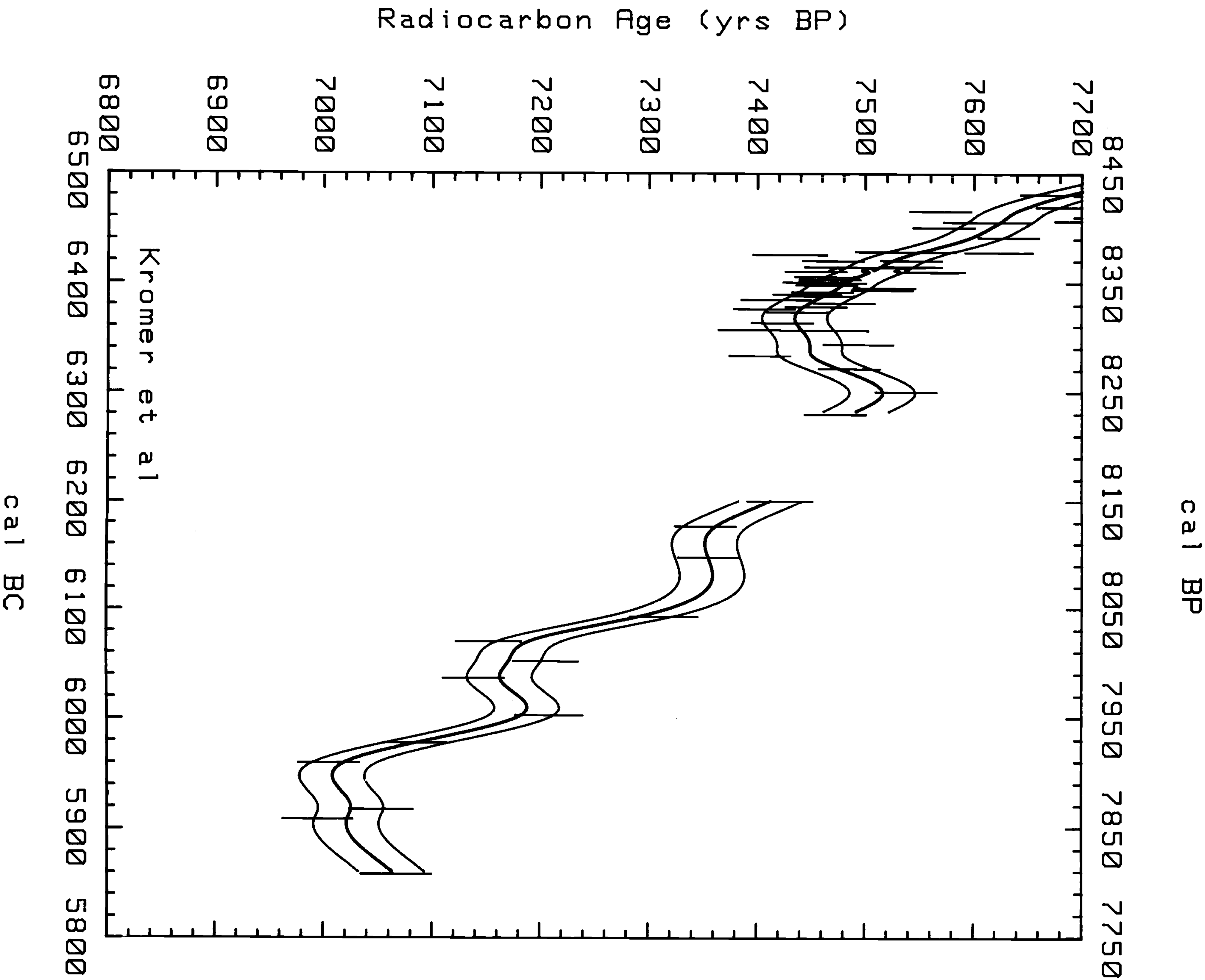
^{14}C data of the unified German oak tree-ring series; dendro-age has been obtained using 7230 BC as zero point of the series

Lab no.	Center ring	No. of rings	^{14}C Age (BP)	$\delta^{13}C$ (‰)	Age (BC) (approx)
Hd - 5028	23	3	8199 +- 41	-25.8	7207
Hd - 8092	37	7	8271 +- 28	-25.9	7194
Hd - 5162	52	4	8212 +- 33	-25.2	7178
Hd - 5263	57	5	8211 +- 35	-24.3	7173
Hd - 5204	64	2	8198 +- 35	-24.0	7166
Hd - 5577	97	5	8141 +- 34	-23.6	7133
Hd - 5529	101	3	8166 +- 35	-24.2	7129
Hd - 5401	123	4	8249 +- 39	-24.2	7107
Hd - 8101	133	5	8263 +- 28	-23.6	7098
Hd - 5733	142	2	8161 +- 29	-25 1	7088
Hd - 6494	143	5	8163 +- 28	-24.8	7087
Hd - 6478	145	3	8158 +- 62	-25.1	7085
Hd - 6408	153	5	8152 +- 28	-26 1	7077
Hd - 6521	156	3	8157 +- 28	-25.8	7074
Hd - 5047	158	2	8081 +- 40	-25.6	7072
Hd - 6484	161	3	8000 +- 28	-25.9	7069
Hd - 6483	166	2	8150 +- 28	-26 0	7064
Hd - 6407	168	2	8166 +- 32	-25.1	7062
Hd - 6449	170	2	8083 +- 28	-26.5	7060
Hd - 5576	172	5	8019 +- 32	-23.9	7058
Hd - 5476	195	3	7913 +- 34	-25.5	7035
Hd - 5523	213	3	7991 +- 28	-25.6	7017
Hd - 5732	227	5	8015 +- 41	-25 8	7003
Hd - 5731	252	5	8019 +- 32	-24.5	6978
Hd - 5522	267	5	8080 +- 36	-24.1	6963
Hd - 5533	292	5	7995 +- 28	-25.1	6938
Hd - 5811	302	2	8041 +- 34	-25.7	6928
Hd - 5439	326	2	7966 +- 28	-25.4	6904
Hd - 5068	334	2	7982 +- 39	-25.0	6896
Hd - 5503	352	2	7923 +- 35	-24.8	6878
Hd - 5502	384	2	7991 +- 32	-24.6	6846
Hd - 5755	398	2	7925 +- 42	-25 3	6832
Hd - 5888	411	3	7974 +- 33	-24.6	6819
Hd - 5885	420	2	7945 +- 28	-24.8	6810
Hd - 5048	437	4	8003 +- 35	-24.7	6793
Hd - 5810	452	5	7867 +- 32	-24.8	6778
Hd - 5027	467	5	7963 +- 31	-25.2	6763
Hd - 5850	482	5	7924 +- 33	-26.3	6748
Hd - 5402	503	1	8001 +- 33	-24 4	6727
Hd - 5744	522	5	7940 +- 32	-25.8	6708
Hd - 5116	547	5	7873 +- 36	-25.7	6683
Hd - 5742	568	2	7882 +- 58	-25.6	6662
Hd - 5743	577	5	7745 +- 34	-25.5	6653
Hd - 5532	613	2	7816 +- 32	-26 1	6617
Hd - 5092	621	2	7807 +- 32	-25.6	6609
Hd - 5754	623	2	7782 +- 28	-25.1	6607
Hd - 5753	645	2	7744 +- 31	-25.4	6585
Hd - 5521	682	5	7737 +- 33	-24.4	6548
Hd - 6321	713	2	7811 +- 32	-24.3	6517
Hd - 5026	737	5	7752 +- 30	-24.8	6493
Hd - 7495	750	1	7671 +- 28	-25.8	6481
Hd - 7496	761	1	7686 +- 28	-26.0	6469
Hd - 7740	765	2	7569 +- 28	-24.9	6465
Hd - 6087	774	2	7707 +- 32	-24.9	6456
Hd - 7647	775	2	7612 +- 40	-25.3	6455
Hd - 7741	780	1	7572 +- 28	-25.1	6450
Hd - 7513	789	1	7632 +- 28	-26.3	6441
Hd - 6213	803	1	7623 +- 31	-25.1	6428
Hd - 7717	802	1	7537 +- 46	-25.7	6428
Hd - 7840	805	1	7430 +- 34	-25.2	6425
Hd - 7704	810	10	7542 +- 28	-25.5	6420
Hd - 7692	811	2	7470 +- 28	-25.2	6420
Hd - 7751	816	2	7542 +- 28	-25.8	6415
Hd - 7703	820	10	7454 +- 28	-26.4	6410
Hd - 6439	816	1	7499 +- 55	-25.6	6414
Hd - 8308	820	2	7563 +- 28	-25.0	6410
Hd - 7686	821	2	7557 +- 28	-25.3	6410
Hd - 7846	825	1	7463 +- 28	-24.6	6405
Hd - 7708	828	5	7467 +- 28	-26.2	6403
Hd - 6212	830	1	7452 +- 28	-25.5	6400
Hd - 7756	831	1	7472 +- 28	-25.2	6400
Hd - 7836	833	3	7464 +- 28	-26 0	6398
Hd - 7687	835	1	7517 +- 28	-25.2	6395
Hd - 7713	837	4	7515 +- 28	-26.1	6393
Hd - 8324	839	2	7460 +- 28	-25.2	6391
Hd - 7688	841	2	7446 +- 31	-25.0	6389
Hd - 7735	843	3	7461 +- 28	-25.9	6388
Hd - 6291	846	5	7417 +- 32	-25 2	6384
Hd - 8325	849	2	7480 +- 28	-24.7	6381
Hd - 7837	853	3	7454 +- 28	-25.8	6378
Hd - 7644	855	4	7406 +- 28	-24.8	6376
Hd - 7707	858	3	7437 +- 28	-25.4	6373
Hd - 7849	868	3	7423 +- 28	-25.5	6363
Hd - 7646	874	2	7410 +- 46	-26.0	6356
Hd - 6292	874	3	7470 +- 32	-24.5	6356
Hd - 6229	887	6	7493 +- 32	-24.2	6343
Hd - 7645	898	5	7402 +- 28	-24.6	6333
Hd - 6227	909	3	7485 +- 28	-24.2	6321
Hd - 6216	930	2	7537 +- 28	-23.8	6300
Hd - 6214	951	3	7472 +- 28	-23.5	6279
Hd - 6228	1030	3	7421 +- 30	-25.7	6200
Hd - 6226	1054	4	7352 +- 28	-23.7	6176
Hd - 6215	1083	3	7355 +- 28	-23.3	6147
Hd - 6284	1138	6	7314 +- 31	-26.0	6092
Hd - 6371	1161	2	7152 +- 30	-26.1	6069
Hd - 6293	1179	3	7205 +- 30	-25.2	6051
Hd - 6372	1194	3	7138 +- 28	-24.5	6036
Hd - 6285	1228	3	7208 +- 31	-25.3	6002
Hd - 6368	1253	3	7085 +- 28	-25.1	5977
Hd - 6277	1271	5	7005 +- 28	-25.0	5959
Hd - 6370	1313	5	7053 +- 29	-27.2	5917
Hd - 6278	1322	6	6995 +- 32	-24.4	5908
Hd - 6279	1372	6	7067 +- 32	-25.2	5858
Hd - 6318	1909	3	6345 +- 29	-25.6	5321
Hd - 6359	1943	5	6336 +- 29	-24.9	5287
Hd - 6301	1958	4	6317 +- 29	-25.3	5272
Hd - 6322	2001	1	6230 +- 30	-23.9	5229
Hd - 6299	2037	6	6319 +- 28	-27.6	5193
Hd - 6367	2057	6	6240 +- 29	-25.4	5173
Hd - 6300	2090	1	6206 +- 28	-25.2	5140
Hd - 6369	2120	1	6249 +- 28	-23.5	5110
Hd - 6298	2144	1	6147 +- 28	-25.5	5086
Hd - 6328	2182	1	6026 +- 28	-23 8	5048
Hd - 6330	2228	2	6078 +- 28	-23.7	5002
Hd - 8498	2243	3	6100 +- 19	-26.4	4988
Hd - 6360	2247	1	6005 +- 28	-24.9	4983
Hd - 8726	2261	2	6044 +- 19	-26.0	4970
Hd - 6375	2268	2	6080 +- 28	-25.1	4962
Hd - 8727	2274	4	6016 +- 16	-25.8	4956
Hd - 9303	2276	3	6040 +- 18	-25.3	4955
Hd - 8737	2292	2	6042 +- 18	-26.4	4938
Hd - 9304	2295	2	6027 +- 18	-24.8	4936
Hd - 8739	2316	2	6096 +- 18	-26.5	4914
Hd - 9314	2323	2	6039 +- 18	-25.5	4907
Hd - 9315	2347	2	5978 +- 19	-25.2	4883
Hd - 9326	2367	2	6026 +- 18	-25.3	4863
Hd - 9327	2407	2	5926 +- 18	-25.2	4823
Hd - 9328	2429	5	5942 +- 18	-25.4	4802
Hd - 9329	2447	2	5939 +- 18	-25.3	4783
Hd - 7389	2450	3	5923 +- 28	-27.1	4781
Hd - 7390	2464	2	5861 +- 28	-25.8	4767
Hd - 9359	2467	2	5864 +- 18	-25.8	4763
Hd - 7391	2476	1	5817 +- 28	-26 4	4754
Hd - 7398	2484	1	5798 +- 28	-27.4	4746
Hd - 9360	2487	2	5863 +- 18	-26.1	4743
Hd - 7400	2492	1	5793 +- 28	-24.8	4738
Hd - 7402	2507	1	5850 +- 28	-24.9	4723
Hd - 7520	2520	1	5893 +- 30	-25.5	4710
Hd - 7653	2532	2	5754 +- 28	-25.4	4698
Hd - 7655	2580	1	5721 +- 28	-26.0	4650
Hd - 7654	2589	1	5747 +- 30	-26.2	4641
Hd - 7656	2600	1	5728 +- 28	-26.0	4630
Hd - 7666	2611	1	5738 +- 28	-23.6	4619
Hd - 7538	2624	1	5805 +- 28	-23 9	4606
Hd - 7667	2635	1	5639 +- 30	-23.7	4595
Hd - 7671	2655	1	5715 +- 29	-24.1	4575
Hd - 7681	2663	1	5677 +- 38	-26 2	4567
Hd - 7515	2673	1	5785 +- 29	-25.6	4557
Hd - 7682	2684	1	5657 +- 35	-24.7	4546
Hd - 7683	2694	1	5575 +- 30	-24.8	4536
Hd - 7706	2706	1	5615 +- 28	-24.1	4524
Hd - 7525	2715	1	5720 +- 30	-24.8	4515
Hd - 7528	2725	1	5690 +- 29	-24.6	4505
Hd - 7714	2734	1	5596 +- 28	-25.0	4496
Hd - 7715	2743	1	5635 +- 28	-25.2	4487
Hd - 7719	2770	1	5654 +- 28	-25.6	4460
Hd - 7729	2784	1	5579 +- 29	-25.0	4446
Hd - 7730	2793	1	5659 +- 28	-25.5	4437
Hd - 7539	2801	1	5714 +- 35	-26.2	4429
Hd - 8404	3043	3	5269 +- 18	-25.6	4188
Hd - 8428	3053	3	5334 +- 16	-25.5	4178
Hd - 8476	3063	3	5336 +- 18	-25.1	4168
Hd - 8477	3073	3	5318 +- 17	-25.3	4158
Hd - 8392	3083	3	5354 +- 17	-25.4	4148
Hd - 8497	3093	3	5368 +- 18	-25.5	4138
Hd - 8371	3103	3	5328 +- 20	-25.3	4128

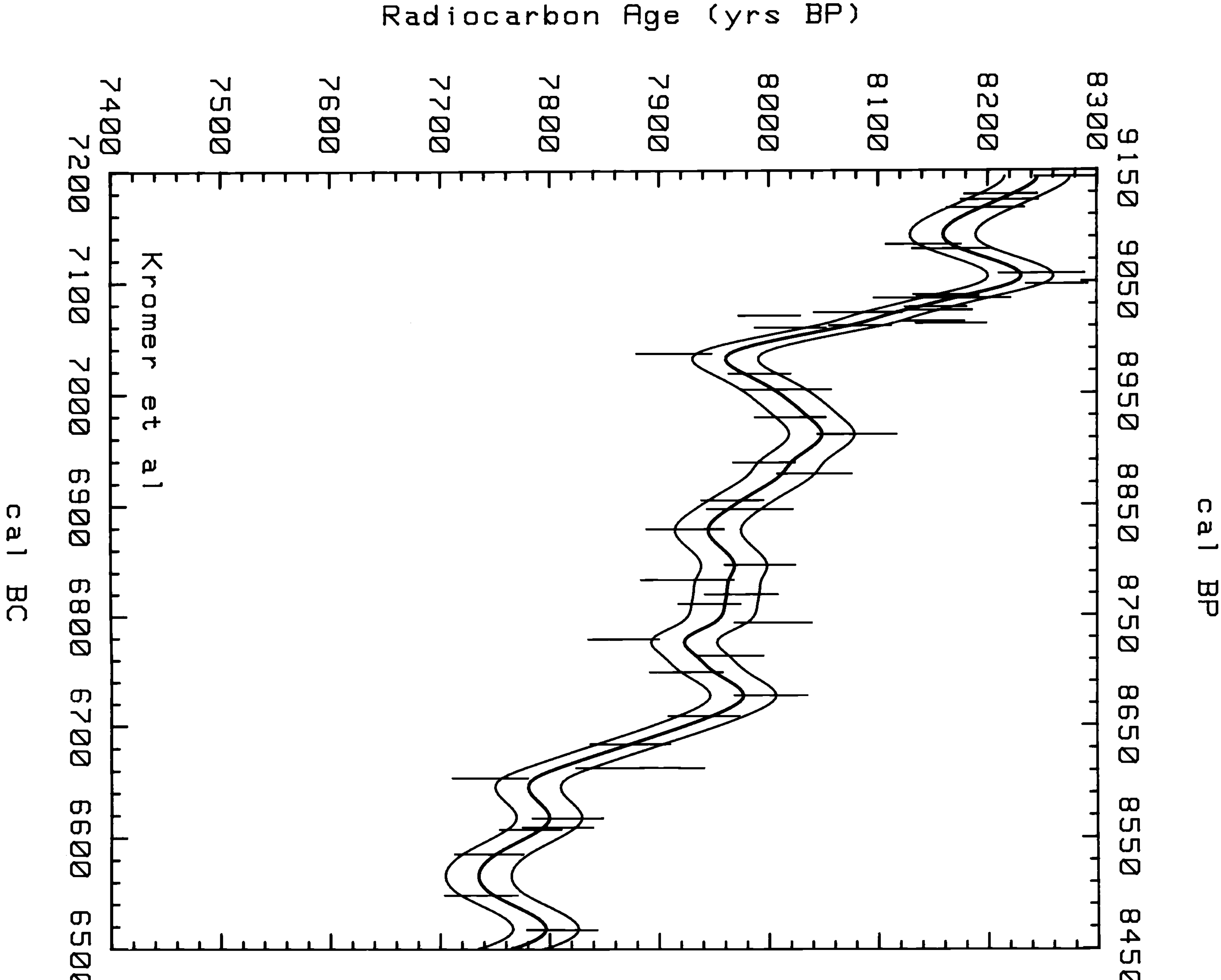


Figs 1–4. ^{14}C age *vs* dendro-age of the unified German oak tree-ring series and spline function through the data. Error band of ±30 yr is indicated. The dendro-scale is considered to be accurate to ±25 yr.


Radiocarbon Age (yrs BP)
5700
5800
5900
6000
6100
6200
6300
6400
6500
6600
cal BP
7450
7350
7250
7150
7050
6950
6850
6750
cal BC
5500
5400
5300
5200
5100
5000
4900
4800
Kromer et al



Radiocarbon Age (yrs BP)
6800
6900
7000
7100
7200
7300
7400
7500
7600
7700
cal BP
8450
8350
8250
8150
8050
7950
7850
7750
cal BC
6500
6400
6300
6200
6100
6000
5900
5800
Kromer et al


Radiocarbon Age (yrs BP)
7400
7500
7600
7700
7800
7900
8000
8100
8200
8300
cal BP
9150
9050
8950
8850
8750
8650
8550
8450
Kromer et al
cal BC
7200
7100
7000
6900
6800
6700
6600
6500

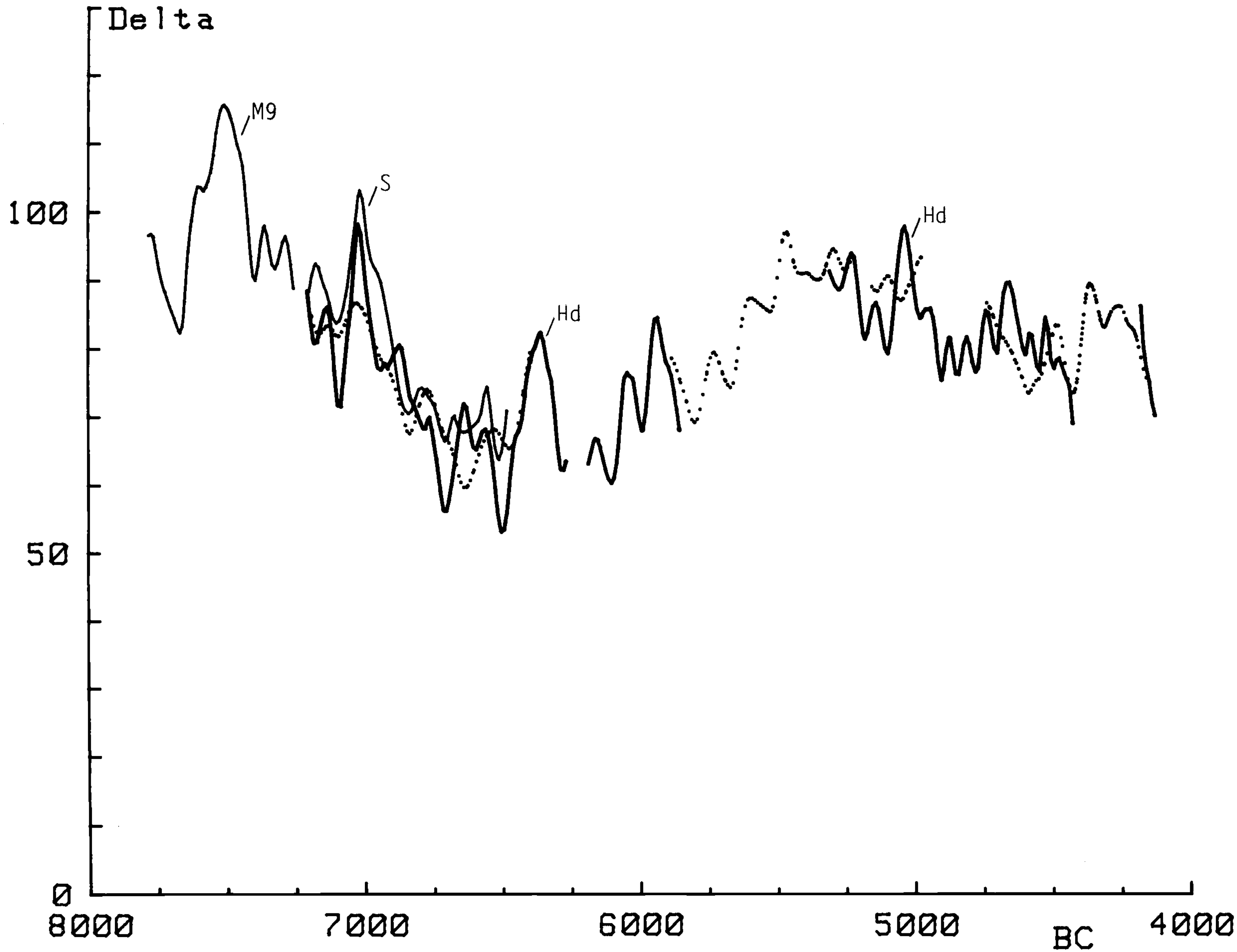


Fig 5. Delta ^{14}C values obtained from the unified German oak series
Solid curve (bold) labeled "Hd" = Heidelberg data (Table 1)
Solid curve labeled "S" = Seattle data (Stuiver *et al*, 1986)
Solid curve labeled "M9" = Heidelberg Main 9 data, delta values approximate (see text)
Dotted curve labeled "LJ" = La Jolla data (Linick, Suess & Becker, 1986)

[RADIOCARBON, VOL 28, NO. 2B, 1986, P 961–967]

EXTENSION OF THE HOLOCENE DENDROCHRONOLOGY BY THE PREBOREAL PINE SERIES, 8800 TO 10,100 BP

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ABSTRACT. Holocene tree-ring chronologies have been established for south-central Europe covering the past 11,000 years. The Hohenheim absolute oak chronology extends to 4089 BC. The ^{14}C-calibrated mid-Holocene floating oak master covers a 3181-year period from ca 4045 to 7225 BC. The earliest well-replicated floating oak master (estimated calendar age 7215 to 7825 BC) extends the European oak dendrochronology back to Boreal times.

Further extension of the Holocene dendrochronology has been achieved by subfossil oak and pine trees from the Rhine, Main, and Danube Rivers. A 774-year floating series of Preboreal pine has been established. ^{14}C ages range (from younger to older end) from 9200 to 9800 BP. Within this series a major atmospheric ^{14}C variation is indicated, resulting in nearly constant ^{14}C ages (9600 BP) over a period of 370 tree-rings.

The European oak and pine tree-ring chronologies cover without major gaps the entire Holocene epoch. Based on the length of the dendro-records, an approximate solar year age of 11,280 years is calculated for the Holocene/Pleistocene boundary.

The Preboreal pine forests along the rivers were replaced by mixed oak forests between 9200 and 8800 BP. By linking the earliest oak masters and the Preboreal pine series, the European dendrochronology can be extended up to the end of Late Glacial times.

THE HOHENHEIM OAK DENDROCHRONOLOGY—PRESENT TO 4089 BC

In 1982 we noticed an offset of 70 years between the tree-ring time scale and the matching of its ^{14}C variations to those of the Bristlecone Pine (Becker, 1983). In cooperation with the Belfast and Cologne Tree-Ring Laboratories, oak chronologies of Northern Ireland, England, and northern and southern Germany have been cross-matched over the first and second millenium BC. After a correction of the Hohenheim series at 500 BC by 71 years, the Hohenheim and the Belfast oak masters evidently cross-date continuously over their critical bridgings of the first millennium BC (Pilcher *et al*, 1984).

The Hohenheim oak master has been used for ^{14}C studies carried out by various laboratories. La Jolla measurements of the period AD 250 to 4000 BC were recently published (Linick, Suess & Becker, 1985). High-precision ^{14}C measurements for the period 1 to 2000 BC have been established by Minze Stuiver of Seattle (Stuiver *et al*, 1986). John Vogel of Pretoria has carried out ^{14}C analyses of Hohenheim oak samples of the third millennium BC (Vogel *et al*, 1986). For the fourth millennium BC, the Groningen Laboratory has measured the ^{14}C variation of the Hohenheim Neolithic oak master (de Jong, 1981; de Jong, Becker & Mook, 1986).

In addition to its use for ^{14}C calibration, the Hohenheim oak master provides a solid base for dendro-dates of south-central European prehistory. In cooperation with the Tree-Ring Laboratories at Hemmenhofen (A Billamboz), Neuchatel (H Egger & P Gassmann), Moudon (A & Chr Orcel) and Zurich (U Ruoff & coworkers) more than 130 prehistoric oak dwelling settlements have been dendro-dated (Becker *et al*, 1985; Billamboz & Becker, 1985). The dendro-dated sites are located on lake shores and mires of eastern France, western and northern Swiss lakes, Lake Bodensee, and southwest Germany.

According to the dendro-dates, these dwelling settlements were constructed during Neolithic and Bronze Age times, beginning in the 38th and ending in the 9th century BC (Table 1). They confirm earlier ^{14}C calibrations of Neolithic dwelling settlements (Ferguson, Huber & Suess, 1966), which have been questioned by archaeologists for some time.

THE MID-HOLOCENE FLOATING HOHENHEIM OAK MASTER : 4045–7225 BC

Since 1982 the earlier floating mid-Holocene oak series, Donau 8, Main 6/13, and Main 4/11 (Becker, 1983) have been linked together to yield a continuous 3181-year floating series. According to the ^{14}C calibration of this sequence by the La Jolla Laboratory, the series covers the period 4035 to 7215 BC (Linick, Suess & Becker, 1985). Recent measurements of Seattle and Heidelberg confirm this calibration (Stuiver *et al*, 1986; Kromer *et al*, 1986), which results in an extension beyond the Bristlecone Pine sequence of an additional 500 years.

The Hohenheim mid-Holocene oak master consists of 266 individual oaks from the Main River, and is replicated by 72 additional oaks from the Danube and Rhine Rivers over 2307 years of the Main chronology.

EARLY HOLOCENE OAK CHRONOLOGIES : 7800 TO 9000 BC

An Early Holocene dendrochronologic extension was achieved by collecting subfossil oaks from the Early Boreal period. The oldest well-replicated floating oak master (Main 9) dates before the calibrated mid-Holocene floating master mentioned above. A comparison of the ^{14}C ages of the end of the Main 9 series with the beginning of the floating calibrated master yields a calendar age of the series of 7215 to 7825 BC (Kromer *et al*, 1986).

The Main 9 series marks the end of well-replicated oak chronologies, but some subfossil oaks are still older then the Main 9 series. According to conventional ^{14}ages, these earliest Holocene oaks started to grow in the Rhine valley at 9200 BP, in the Danube at 8890 BP, Main and Mosel valleys at 8860 BP, and the Mosel valley at 8800 BP. The Early Holocene Danube, Mosel, and Main/Regnitz series are replicated by 3 to 8 cross-dated individuals (Fig 1).

PREBOREAL PINE CHRONOLOGIES : 8900 TO 10,150 BP

We have sampled 128 pine trees (*Pinus sylvestris*) deposited in fluvial gravels along the Rhine and Danube Rivers. ^{14}C dates show that the earliest pine stands must have already developed during the Bölling and Alleröd Interstadials. Most of the sampled trees date from the Preboreal period. Three floating Preboreal masters were established. The largest series (B–C) consists of 55 samples resulting in a 774-year tree-ring record.

The ^{14}C ages of the series A and B are shown in Figure 2. There is evidence for a substantial ^{14}C variation between 9800 and 9500 BP indicated by a sharp transition between 9750 and 9900 BP measured in series A and a flat region between 9650 and 9550 BP in series B–C corresponding to 350 solar years (Table 2).

A similar decrease in ^{14}C age relative to solar years was observed in peat bog sediments of the Wachseldorn site in Switzerland (Oeschger *et al*, 1980). However, comparing these data with our measurements on pine tree rings, the Wachseldorn sequence appears to be shifted by 250 years to older ages.

The last Preboreal floating pine series (D, Fig 1) covers the period of ca 8900 to 9100 BP. From this sequence the linkage between the Early Holocene pine and oak chronologies can be expected.

ABSOLUTE AGE ESTIMATE OF THE HOLOCENE/PLEISTOCENE BOUNDARY

The successful construction of a 774-year pine master and the establishment of replicated pine and oak series in the gap between this master and the Main 9 oak master encourages further extensions of the dendrochronology and its ^{14}C calibration back to the Pleistocene/Holocene boundary. The earliest Holocene pine series (A) consists of a floating 194-year sequence, which covers by 5 cross-matched trees the period of ca 9800 to 10,000 BP. Also, three individual pines reach back to 10,150 BP.

If we assign these earliest Holocene pine trees to the transition from Younger Dryas to Preboreal we can derive a lower limit for the calendar age of the Holocene/Pleistocene boundary:

The three large Holocene oak masters together with the Preboreal pine master B–C span a period of 10,600 dendro-years. We estimate the time span between the beginning of the oak master Main 9 and the end of the Preboreal pine master B–C to be equal to the difference in ^{14}C years (400 yr), and estimate an additional 300-year interval between the Preboreal pine master and the period covered by the oldest Preboreal pine samples mentioned above. With these estimates, the Holocene period spans 11,280 dendro-years. It should be noted that the uncertainty in this estimate is biased to an even larger age in dendro-years as lower real ages of the floating chronologies (*ie,* smaller gaps) would require larger overlaps of the already existing dendro-series, which should be detectable dendrochronologically.

Using this calculation and the ^{14}C age of the oldest Preboreal pine sample (10,150 BP), we calculate $\Delta\ ^{14}C$ at the Pleistocene/Holocene boundary to be +110‰. Judging from the already existing tree-ring series covering the two remaining gaps in the Hohenheim dendrochronology, this value cannot be lower than 90‰. Thus, the atmospheric ^{14}C level appears to have been already at its high level at the beginning of the Holocene (Table 3).

PALEOCLIMATIC EVIDENCE AS SEEN IN THE PREBOREAL PINE SERIES

The radiometric data provide good evidence that the Preboreal pine forests along the valleys of the Rhine and Danube Rivers must have been replaced by immigrating oaks between 9200 and 8900 BP. The transition from Preboreal pine-birch forests to hazel-oak and mixed oak forests is well known from various central European lowland pollen profiles. However, considering the dates of the subfossil tree remnants given above, this transition must have occurred very rapidly, eg, probably during a single generation of trees. Comparing the latest pine dates and the earliest oak dates from various valley regions in south-central Europe, it seems that during the spreading of a deciduous forest community by the re-immigrating oaks, a dense forest canopy must have developed quickly. Within these mixed pine-oak alluvial forests the pine, a light-demanding tree species, very probably could no longer regenerate and therefore became displaced within a very short time period.

Holocene valley oak tree-ring patterns of the past 9000 years show substantial variations of tree growth, which can be related to natural changes and man-made disturbances of the paleohydrology of the rivers (Becker, 1982). However, drastic climatic variations are not obvious from this study of Holocene oak remnants. The subfossil Preboreal pines seem to provide much better information for past environmental conditions that controlled tree growth. Many of the pine cross-sections have remarkable growth depressions often with partly or completely missing rings. Some of the missing rings can only be detected after cross-matching a large number of individuals. For example, within one of the Preboreal pines, 12 partly missing rings were detected over an extreme 40-year growth depression. After cross-matching the curve with the Preboreal master, an additional 3 totally missing rings were found.

The subfossil pine trunks often have injuries, which later are overgrown with the uninjured parts of the stem. Other damages are deep vertical splits formed repeatedly, because the tree could close them only by developing bark, which sometimes reaches close to the center of the stem. Forest fires can be excluded as a causal factor, because charcoal should then have been preserved as well as the, indeed well-preserved, timber and bark.

Two explanations are possible for the damage to the Preboreal pines: 1) considering the fluvial dynamics of their environment, floods with drifting ice blocks could have damaged the pines after the melting of frozen rivers. Such features were recently described from living pines on the Oulanka River in northeast Finland (Koutaniemi, 1984); 2) the large vertical splits probably result from repeated splitting of frozen stems during severe winter frost periods. Forest damage of that kind can be observed within contemporary lowlands of the Rhine-Main-Danube region only on very sensitive tree species such as ash. However, they do not occur in this region on pines, which are able to tolerate extreme winters.

If the damage to the subfossil trees would indeed have been caused by flooding with floating ice blocks and by frost splitting, then it can be concluded that remarkably low winter temperatures existed in south German lowlands during Preboreal times.

SUBFOSSIL PINES FROM THE ALLERÖD AND BÖLLING INTERSTADIALS

A first floating pine master has been linked together for the Alleröd period (ALL 1, Fig 3). This series consists of 3 individual trees, which span a total number of 335 years. ^{14}C dates indicate a growth period from ca 11,800 to 11,465 BP. Two additional samples date from ca 11,300 to 11,000 BP. These samples provide a chance for the construction of a larger Alleröd sequence. A single pine was collected from the Isar River, dating from the Bölling Interstadial at ca 12,180 to 12,000 BP.

It should be stressed that among the hitherto sampled fluvial pines, not a single tree remnant was found from the Older and Younger Dryas Stadials. This lack of evidence seems to indicate that the Bölling and Alleröd pine stands became extinct during the climatic deteriorations of the following Stadials.

ACKNOWLEDGMENTS

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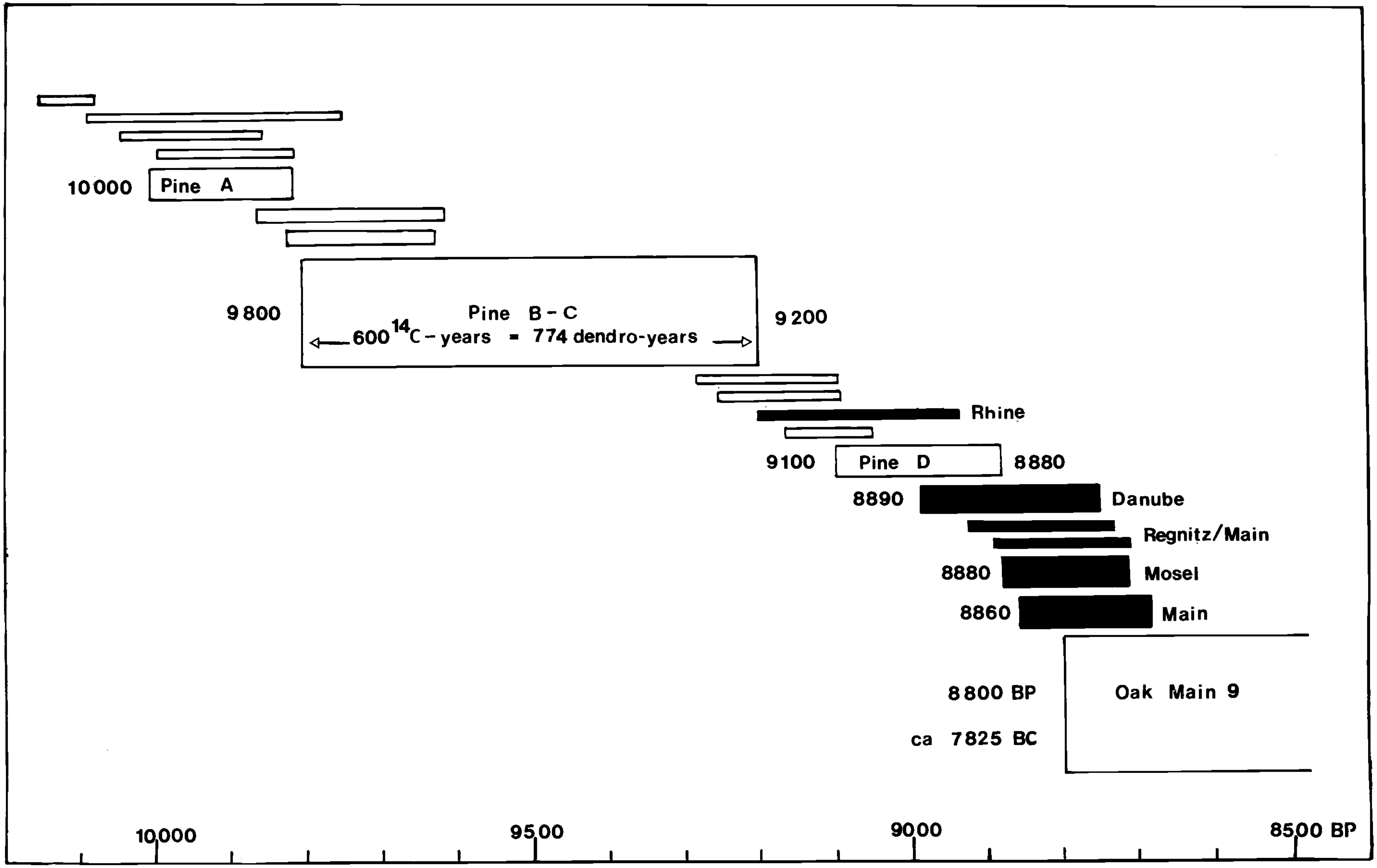

Fig 1. Present stage of Early Holocene European oak and pine tree-ring chronologies. Small blocks represent individual trees; medium-sized blocks, series replicated by 3 to 8 individuals; large blocks, well-replicated masters. White blocks = Scotch pine, black blocks = oak.

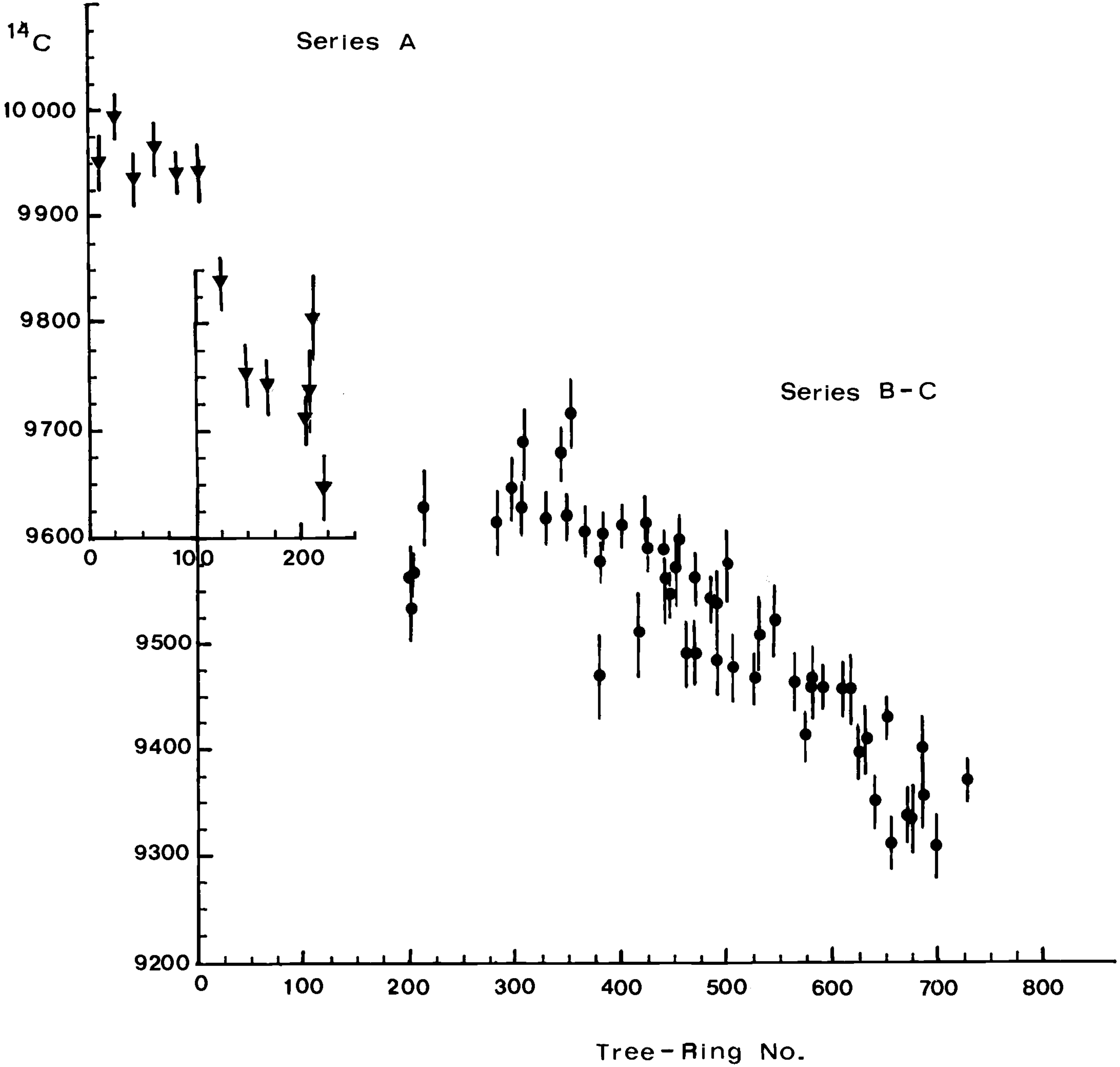

Fig 2. ^{14}C ages *vs* ring numbers of the Preboreal pine series A and B–C. Both series are floating, therefore, the transition from A to B–C is not yet fixed dendrochronologically.

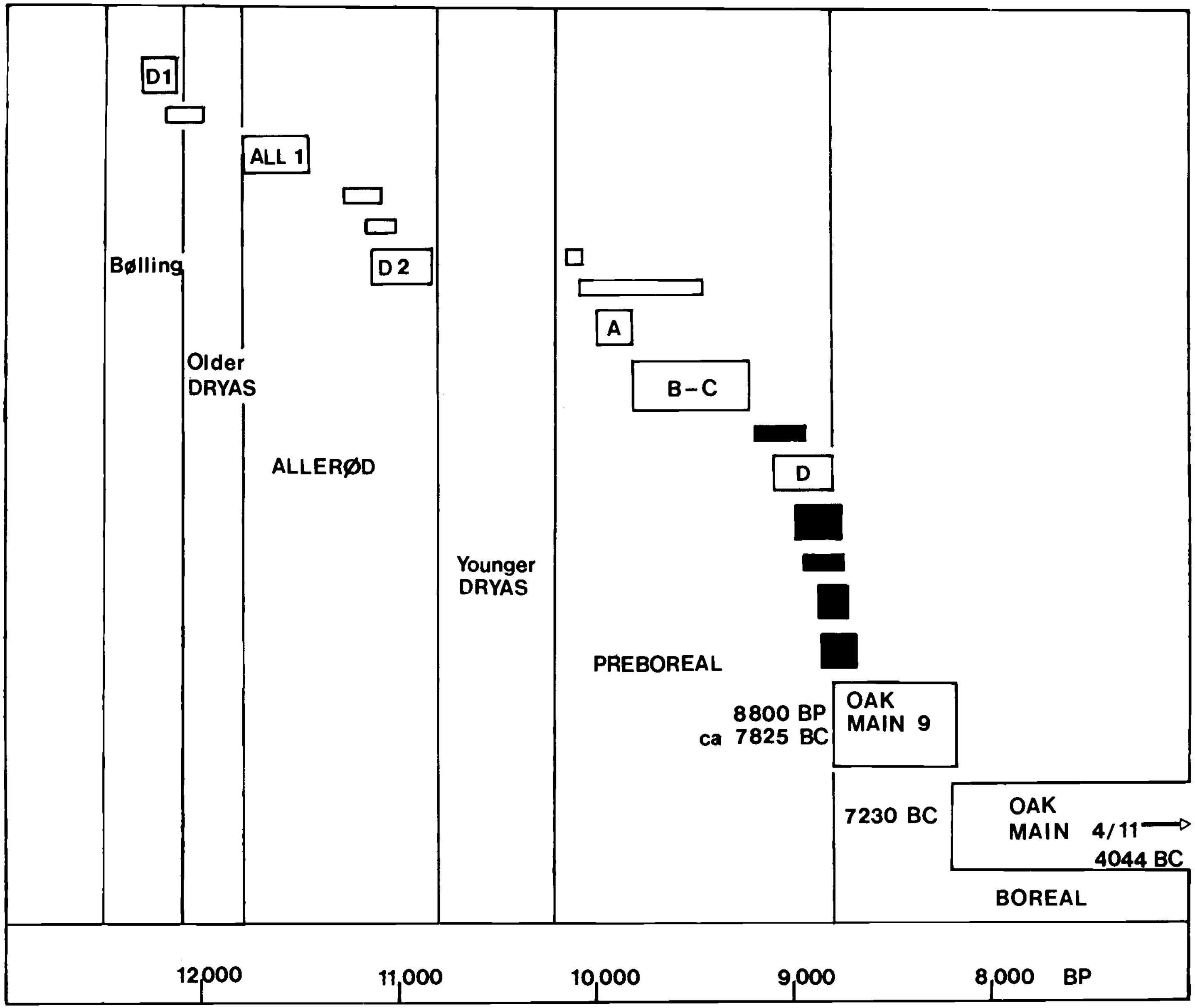

Fig 3. Late Glacial pine and Early Holocene pine-oak dendrochronologies. Black blocks = oak; series D1 and D2 are from Dättnau/Switzerland (Kaiser, 1975).

TABLE 1

Dendro-dates of Neolithic and Bronze Age dwelling sites of eastern France, Switzerland, and southwest Germany, derived by the Tree-Ring Laboratories of Hemmenhofen, Neuchatel, Moudon, and Zurich by cross-dating with the Hohenheim oak master

Region	Dendro-dated cultures					
SW Germany	Late Neolithic 3850–3650 BC	(7)	End of Late Neolithic 3590–3510	(2)	End of Late Neolithic 3330–3260 BC	(3)
W Switzerland E France	Classic Cortaillod 3860–3680 BC	(8)	Late Cortaillod 3630–3550 BC	(5)	Horgen 3290–2980 BC	(11)
N Switzerland	Pfyn and 3820 to		Cortaillod 3530 BC	(16)	Horgen 3240–2870 BC	(6)
SW Germany	End. Neolithic 3080–2670 BC	(4)			Early Bronze Age 1760–1500 BC	(2)
W Switzerland & E France	Lüscherz 2800–2700 BC	(12)	Saone-Rhone civilization 2630–2420 BC	(7)	Early Bronze Age 1650–1610 BC	(1)
N Switzerland	Corded Ware ceramics 2760–2690 BC	(7)	Late Corded Ware ceramics 2600–2460 BC	(3)	Middle Bronze Age 1660–1500 BC	(3)
SW Germany	Late Bronze Age 1060–850 BC	(2)				
W Switzerland & E France	Final Bronze Age 1080–850 BC	(28)				
N Switzerland	Late Bronze Age 1100–910 BC	(11)				

The dendro-dates (approximated to decennia) specify series of cutting dates, beginning with the earliest and ending with the last dwelling site of a culture within the region. Dendro-dates and their associations with prehistoric cultures, as well as archaeologic terms, according to the contributions of A Billamboz, H Egger and P Gassmann, A and C Orcel, and U Ruoff *in* Becker *et al* (1985). The numbers in parentheses are the numbers of the dated sites. In most cases each site contains several dendro-dated structures.

TABLE 2

Radiocarbon measurements of tree rings of the 774-year Preboreal Hohenheim pine chronology. The data are listed from the oldest to the youngest ring of the floating series.

HD-no.	Tree-ring no.	^{14}C age (BP)	HD-no.	Tree-ring no.	^{14}C age (BP)
−9423	*102–107	9684 ± 40	−7536	*461–466	9486 ± 40
−9424	*106–111	9850 ± 40	−7601	*467–476	9488 ± 40
−9427	*107–117	9781 ± 40	−8889	471–474	9559 ± 25
−8657	*117–127	9647 ± 31	−8690	486–489	9540 ± 20
−8752	*197–207	9560 ± 31	−7573	*489–494	9535 ± 40
−8656	200–206	9532 ± 30	−7917	*490–496	9481 ± 40
−9428	*201–209	9564 ± 22	−8910	501–504	9572 ± 34
−8753	*211–222	9628 ± 35	−8911	506–509	9474 ± 34
−9449	*284–286	9612 ± 31	−7915	*527–530	9466 ± 40
−9466	*293–306	9644 ± 29	−8904	531–534	9506 ± 34
−9280	*308–312	9687 ± 32	−8905	546–549	9520 ± 34
−9065	304–312	9627 ± 24	−8977	561–569	9462 ± 25
−9075	329–332	9616 ± 26	−9026	574–577	9410 ± 20
−9076	344–347	9676 ± 26	−8957	581–584	9463 ± 34
−9087	349–352	9618 ± 22	−8978	581–584	9458 ± 24
−8806	351–360	9712 ± 31	−9007	589–592	9456 ± 20
−8826	366–369	9603 ± 23	−9064	609–612	9454 ± 27
−7623	*377–385	9468 ± 40	−8970	616–619	9455 ± 34
−8835	381–384	9576 ± 20	−9154	624–627	9394 ± 26
−8836	396–399	9601 ± 20	−8971	631–634	9405 ± 34
−8867	401–404	9609 ± 20	−9160	639–642	9348 ± 25
−7572	*413–423	9507 ± 40	−8989	651–654	9428 ± 20
−8795	*421–429	9611 ± 25	−9161	654–657	9309 ± 25
−8868	426–429	9587 ± 20	−9191	669–672	9336 ± 26
−8876	*441–443	9585 ± 40	−8792	*671–679	9331 ± 40
−7566	*441–446	9559 ± 43	−9192	684–687	9354 ± 32
−7608	*446–450	9545 ± 23	−9154	681–689	9398 ± 32
−8758	*449–459	9568 ± 35	−9199	694–702	9307 ± 30
−8877	456–459	9595 ± 20	−7705	*727–730	9368 ± 40
−8658	*461–467	9488 ± 40			

* Indicates ^{14}C dates of tree samples, which were later cross-matched with the master. All other samples were prepared from tree rings of the master for calibration.

TABLE 3

Calculation of the solar-year age of the transition from Younger Dryas to Preboreal times based on Holocene tree-ring records

Dendrochronology	Absolute age of the sequence		Tree rings
Absolute oak master	AD 1985–4089 BC	Dendro-dated	6074
Mid-Holocene oak	4045 BC–7230 BC	Calibrated	3181
Boreal oak Main 9	7215 BC–7825 BC	Calibrated	609
	zeropoint 8800 BP	Conventional BP	
Earliest oak series	8700 BP–9200 BP	Conventional BP	400
Preboreal pine B–C	9200 BP–9800 BP	Conventional BP	774
Oldest pine series	9800 BP–10,150 BP	Conventional BP	300
Tree-ring record of replicated masters			*10,580
Tree-ring record of Early Holocene oaks			400
Tree-ring record of earliest pine trees			300
Total sum of Holocene tree-ring records, dendro-years			11,280
^{14}C age of the earliest Holocene pine, conventional BP			10,150

* Existing overlaps between the series are substracted.

[RADIOCARBON, VOL 28, NO. 2B, 1986, P 969–979]

RADIOCARBON AGE CALIBRATION BACK TO 13,300 YEARS BP AND THE ^{14}C AGE MATCHING OF THE GERMAN OAK AND US BRISTLECONE PINE CHRONOLOGIES

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INTRODUCTION

With the recent establishment of an unbroken West European tree-ring sequence spanning the past 7272 years (Pilcher *et al,* 1984) the calibration of the ^{14}C time scale was advanced considerably. It is now possible to use this chronology as an independent cross-check on the 8681-year US Bristlecone Pine series (Ferguson & Graybill, 1983). There also are opportunities for ^{14}C matching (wiggle matching) between the older portion of the Bristlecone Pine series and floating (not tied to the present) parts of the South German Oak sequence. Linick, Suess and Becker (1985) used this approach in matching the earliest part of the Bristlecone Pine series with the Donau 6 Main 4/11 (Becker, 1983) series and thus established a D6M4/11 "zero" point (tree-ring no. 1) of 7215 BC.

We report here 49 high-precision measurements of the D6M4/11 series (Table 1). Fifteen Bristlecone Pine samples with dendrochronologically determined ages (6480–6470, 6370–6350, and 5805–5685 BC) also were measured (Table 2). ^{14}C age matching of the new results confirms the D6M4/11 ring 1 age of 7215 BC within a few decades.

Having anchored the available 750 years of the D6M4/11 series to the calendric scale in this manner results in the ^{14}C age calibration curve (from 6470 to 7200 yr BC) given in Figures 3 and 4. A comparison of the D6M4/11 results with the Lake of Clouds varve series (Stuiver, 1970, 1971) proves the reliability of this varve sequence for ^{14}C age calibration. This leads, in combination with adjusted Swedish varve dates, to tentative age calibration results back to 13,300 cal BP (Fig 7).

TECHNIQUE AND INTERCALIBRATION

Cellulose was prepared from all wood samples. The analytical procedures involving sample preparation and CO_2 gas counting were discussed previously (Stuiver, Robinson & Yang, 1979; Stuiver & Quay, 1980, 1981). Standard deviations, as well as off-sets, need to be considered for an assessment of the reliability of the calibration curve.

Standard Deviation

The reported standard deviation σ_c in a ^{14}C age determination is traditionally calculated from the Poisson statistics of the accumulated sample and standard counts. This procedure can only underestimate the statistical error in the laboratory determinations because other factors (ao sample purity and counting voltage variability) also play a role. To account for the additional variance σ_a^2 an error multiplier K can be used for well-defined cases (Stuiver, 1982; International Study Group, 1982). The use of K values, however is not a simple matter because K depends on counting time and sample age.

The following relationship applies:

$$K\sigma_c = \sqrt{\sigma_c^2 + \sigma_a^2} \tag{1}$$

or

$$K = \sqrt{1 + \left(\frac{\sigma_a}{\sigma_c}\right)^2} \tag{2}$$

Standard errors σ_c for Seattle 4-day-counts are ca 17 years for ^{14}C ages in the 2000–4000 yr range. An analysis of reproducibility of duplicate runs leads to an upper limit for K of 1.5 to 1.6 (Stuiver & Pearson, 1986). Substitution of K = 1.5 in equation (1) yields a σ_a of 19 years, or

$$K = \sqrt{1 + \left(\frac{19}{\sigma_c}\right)^2} \tag{3}$$

The dependence of K on counting time or age is illustrated by the following examples:

1) Counting the sample twice as long reduces σ_c by a factor of 1.4. Here the K value (Eq 3) is 1.9.

2) Having an older sample with half the ^{14}C activity increases σ_c by an approximate factor of 1.4. The K value for samples this old is nearly 1.3.

Clearly, K values can be used only within the confines of defined counting conditions.

The errors in the ^{14}C ages listed in this paper are all based on counting statistics alone. According to Eq 3, the error "multiplier" for samples of the age range given (and for 4-day counts) would be 1.3.

Off-sets

The variance σ_a^2 accounts for the degree of reproducibility of the measurements made within a single laboratory. It does not account for systematic errors. Such errors may reflect a simple off-set (caused, eg, by a wrong activity level of the standard), or they may reflect age-dependent anomalies (eg, if the "dead" time in counting, which depends on sample activity, would be important and uncorrected for).

The ^{14}C timescale calibration requires independent determination of the ^{14}C activities by two or more laboratories. The magnitude of the off-sets between different laboratories can be estimated from the differences in measured ^{14}C ages of duplicate samples.

A comparison of 214 sample pairs of wood of identical age, but of different geographic regions gave an age difference of 0.6 yr between Belfast

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and Seattle (Stuiver & Pearson, 1986). These 214 samples were all <4500 yr old.

The Seattle laboratory also participated in the Glasgow international calibration project (International Study Group, 1982). The six measured samples, with approximate age of 5000 ^{14}C yr BP, differed from the group average by 17 yr (average of three estimates), with the Seattle ages being older.

A comparison of data with three other laboratories of samples in the 7000–8000 yr BP range yields somewhat larger differences. The ^{14}C ages of 19 samples of the German Oak chronology (Table 1) differ 29 ± 10 yr from their La Jolla counterparts which are wood samples with mid-point ages up to 3.5 yr different from the Seattle set (Linick, Suess & Becker, 1985). Six sample pairs (Table 3) yield an age difference of 27 ± 12 between the Seattle and Heidelberg laboratories. The largest difference is between Seattle and Tucson, where the ^{14}C ages of 13 Bristlecone Pine sample pairs (5805–5685 BC, Table 2 & Linick *et al*, 1986) differ by 52 ± 8 yr. For the latter three comparisons, the Seattle ^{14}C ages are on average all on the younger side.

The standard deviations in the off-sets are based on counting statistics of the laboratory results alone. The application of K values of ca 1.5 to the results of all laboratories involved would bring the off-sets, with the exception of Tucson-Seattle, within 2 σ of the quoted error.

The differences in age determinations of different laboratories need further investigation, and the user of calibration curves should realize that off-sets of a couple of decades are possible when calibration curves of a single laboratory are used. These small differences are, of course, relatively unimportant for the preliminary calibration back to 13,300 yr BP.

^{14}C MATCHING OF THE BRISTLECONE PINE AND DONAU 6 MAINE 4/11 SERIES

The German Oak ^{14}C ages of the 750-yr section of the floating D6M4/11 chronology are listed in Table 1 and plotted in Figure 1 to the left. Also plotted in the same graph are the ^{14}C ages of two Bristlecone Pine samples. The ring numbers of the 6480–6470 and 6370–6350 BC Bristlecone Pine samples on the D6M4/11 scale were obtained by ^{14}C matching. The matching is imprecise for two samples, and the resulting zero point (year 1) fixing of the D6M4/11 series at 7190 BC may be off by a few decades. There is also good agreement of the above Bristlecone Pine ^{14}C ages with Heidelberg and La Jolla (Linick, Suess & Becker, 1985) results on the D6M4/11 series (Fig 1, right side). This confirms the ca 7190 BC start of the German Oak sequence.

The ^{14}C ages of the two Bristlecone Pine samples also agree with Bristlecone Pine dates obtained previously at La Jolla (Bruns *et al*, 1983). Seattle and La Jolla results are compared with each other on the left side of Figure 2. To the right is a comparison of the absolutely dated Seattle Bristlecone Pine dates (Table 2) of the 5805–5685 BC interval and the La Jolla D6M4/11 results calibrated on a 7215 BC zero point (Linick, Suess & Becker, 1985). The unweighted averages of the data sets would have been equal if the D6M4/11 series had started at 7234 BC.

The above analysis of Bristlecone Pine and German Oak dates gives a zero point ^{14}C age determination of the D6M4/11 series in the 7190–7234 year BC range. The new results are entirely compatible with the 7215 BC determination of Linick *et al* (1986), and this date for the start of the D6M4/11 has therefore been adapted for the calculations of the Δ^{14}C values given in Table 1. Similarly, adoption of the 7215 BC start gives the Figures 3 and 4 ^{14}C age calibration curves. The sudden departure from a rather smooth ^{14}C age trend at 7014 BC is based on a single age determination. Independent confirmation is needed before too much significance is attached to this anomaly.

The uncertainty in the starting date of the D6M4/11 chronology caused by ^{14}C age matching may add a systematic uncertainty of a few decades to the standard deviations already given in the graphs.

THE LAKE OF THE CLOUDS VARVE CHRONOLOGY

The ^{14}C matching of the Oak and Bristlecone Pine series makes it possible to compare tree-ring-derived Δ^{14}C values (back to 7215 BC) with varve-derived Δ^{14}C values from Lake of the Clouds sediment back to 10,200 yr BP (Stuiver, 1970, 1971). The Seattle measurements of the D6M4/11 series (with 7215 BC calibration), and the Lake of the Clouds Δ^{14}C data are in good agreement for the 8400–9200 yr BP interval (Fig 5). The more extensive varve data set also agrees with the La Jolla results of the Donau series (Linick, Suess & Becker, 1985) (averaged over centuries in Fig 6, 6000–9200 yr BP interval). Clearly, the Lake of the Clouds varve series has been shown to be a reliable indicator of atmospheric Δ^{14}C change.

The older portion of the Lake of the Clouds varve chronology can be ^{14}C matched with floating varve chronologies in a similar manner as tree rings. A suitable candidate is the Swedish varve chronology. The younger portion of this chronology, as used by Tauber (1970), was derived from varves studied at a single site (Fromm, 1971). This part of the chronology appears less reliable than the older part of the sequence where the chronology has been derived from several closely overlapping varve deposits. For the purposes of extending the Lake of the Clouds chronology, we considered the Swedish varve segment with Tauber's (1970) ^{14}C ages between 8600 and 12,350 yr BP to be "floating," and matched the older part of the Lake of the Clouds chronology with the younger part of the floating Swedish segment. This yields the varve-derived Δ^{14}C values back to 13,300 yr BP given in Figure 6.

The ^{14}C matching of the Lake of the Clouds ^{14}C ages with the corresponding ones of the Swedish chronology points towards a shortage in the Swedish varve count. The off-set was previously estimated at 800 varves (Stuiver, 1970), and is 1000 varves when the two oldest ^{14}C ages of the Lake of the Clouds chronology are matched. A part of the discrepancy has been solved by a re-evaluation of the varved sediment in the Ångermanälven valley which resulted in an additional 365 varves (Cato, 1985). An anomaly of 400 to 600 varves may still exist near 10,000 cal BP.

The anomaly appears smaller for the revised Swedish chronology near 10,700 BP. The end of the Younger Dryas has a revised date of 10,700 ± 50 varves (Stromberg, 1985), which is in good agreement with the annual ice layer count of the same event of 10,720 ± 75 yr (Hammer *et al*, 1986).

The ^{14}C age of the end of the Younger Dryas was estimated at 10,000 ± 75 yr by Hammer, Clausen and Tauber (1986). According to our ^{14}C matching with the Lake of the Clouds chronology, and using Tauber's (1970) evaluation of Swedish ^{14}C dates, the corresponding cal BP date is 10,970 ± 110 yr (the standard deviation is based on the fact that 1) the age conversion does not take into account the century type ^{14}C oscillations, and 2) the standard deviation in the ^{14}C age is 75 yr).

The three methods, varve counting, ice stratigraphy, and a mixture of ^{14}C matching and varve counting lead to a cal BP age for the end of the Younger Dryas of, respectively, 10,700 ± 50, 10,720 ± 75, and 10,970 ± 110 yr. It is possible that the matching method overestimates the cal BP age by a few hundred years, which would correspond for the pre-10,500 cal BP interval to a reduction in $\Delta^{14}C$ values of 3% (Fig 6) and a reduction in age anomalies of ca 250 yr (Fig 7).

A final evaluation awaits a more precise assessment of the ^{14}C ages and varve counts of the first 2000 years of the Swedish chronology. The Figure 7 calibration curve is only approximate in the pre-10,500 cal BP portion where errors of a few hundred years certainly are a possibility.

TIME-SCALE CALIBRATION BEYOND 10,000 YEARS BP

Following the reasoning given in the previous section, the age calibration based on tree rings (averaged over centuries) and Lake of the Clouds varves can be extended to 13,300 cal BP using the earlier portion of the Swedish varve chronology. The Figure 7 data prior to 10,500 BP are based on ^{14}C matching with the Swedish varve chronology.

The older part of the Figure 7 calibration curve, where conventional ^{14}C ages appear at least 1000 yr too young, may need future adjustment when other chronologies become available. As discussed in the previous section, the pre-10,500 cal BP age anomalies may be over-estimated in Figure 7 by a few hundred years. It also should be noted that at 10,000 yr BP the first 300 years of the age anomaly are due to the use of the "short" 5568-yr half-life for a conventional ^{14}C date. The Figure 7 data set, of course, also neglects the details of the century type oscillations. An excellent approximation of the Figure 7 data is $X = 1.05R + 470$, where X is the cal BP age and R the ^{14}C age BP.

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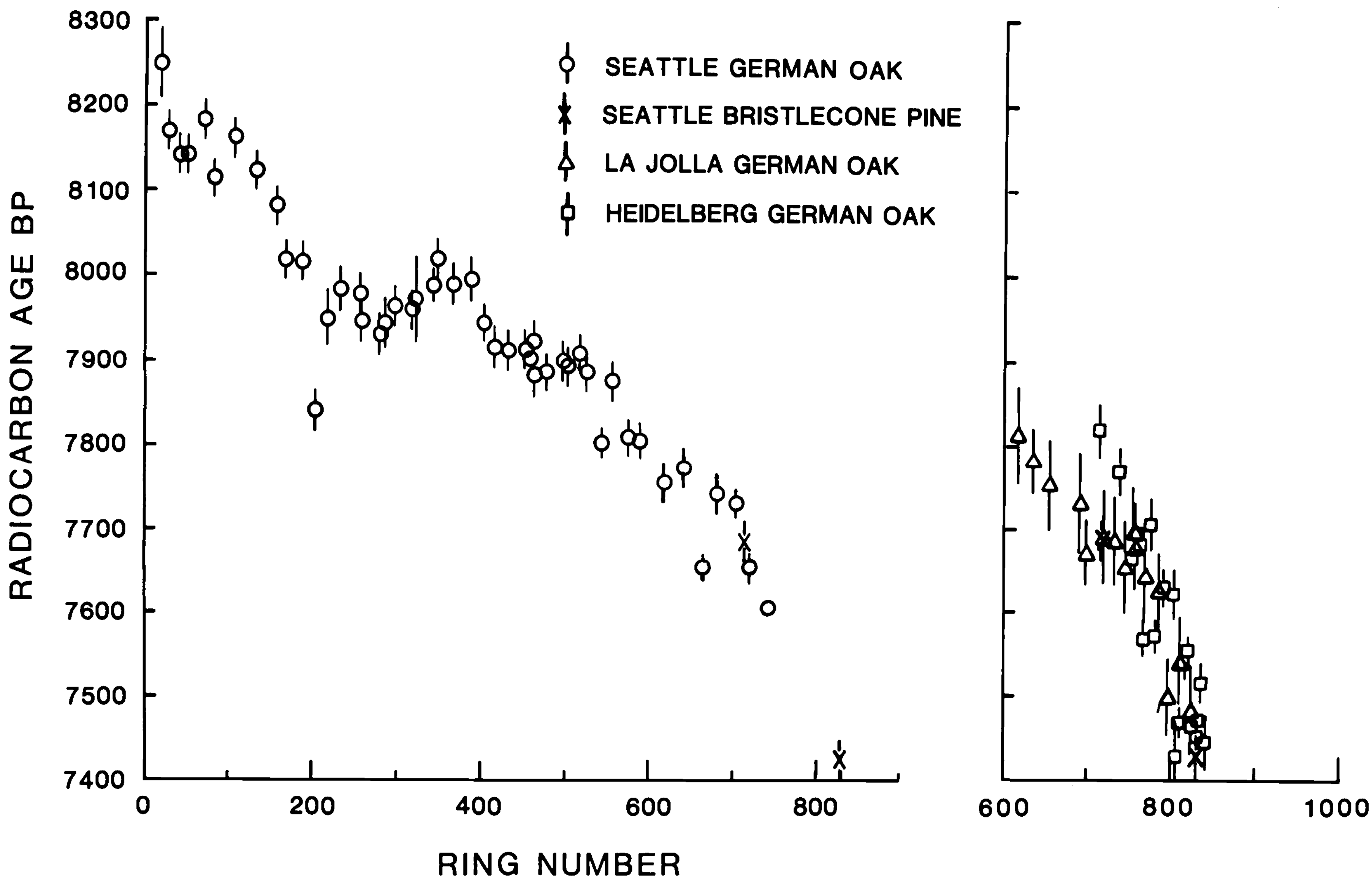


Fig 1. *Left:* ^{14}C ages, with standard deviations derived from counting statistics only, *vs* ring number of the D6M4/11 German Oak series. The two Bristlecone Pine data points assume an age of 7190 yr BC for ring number 1. *Right:* Heidelberg, La Jolla, and Seattle ^{14}C ages *vs* ring number of the D6M4/11 series.

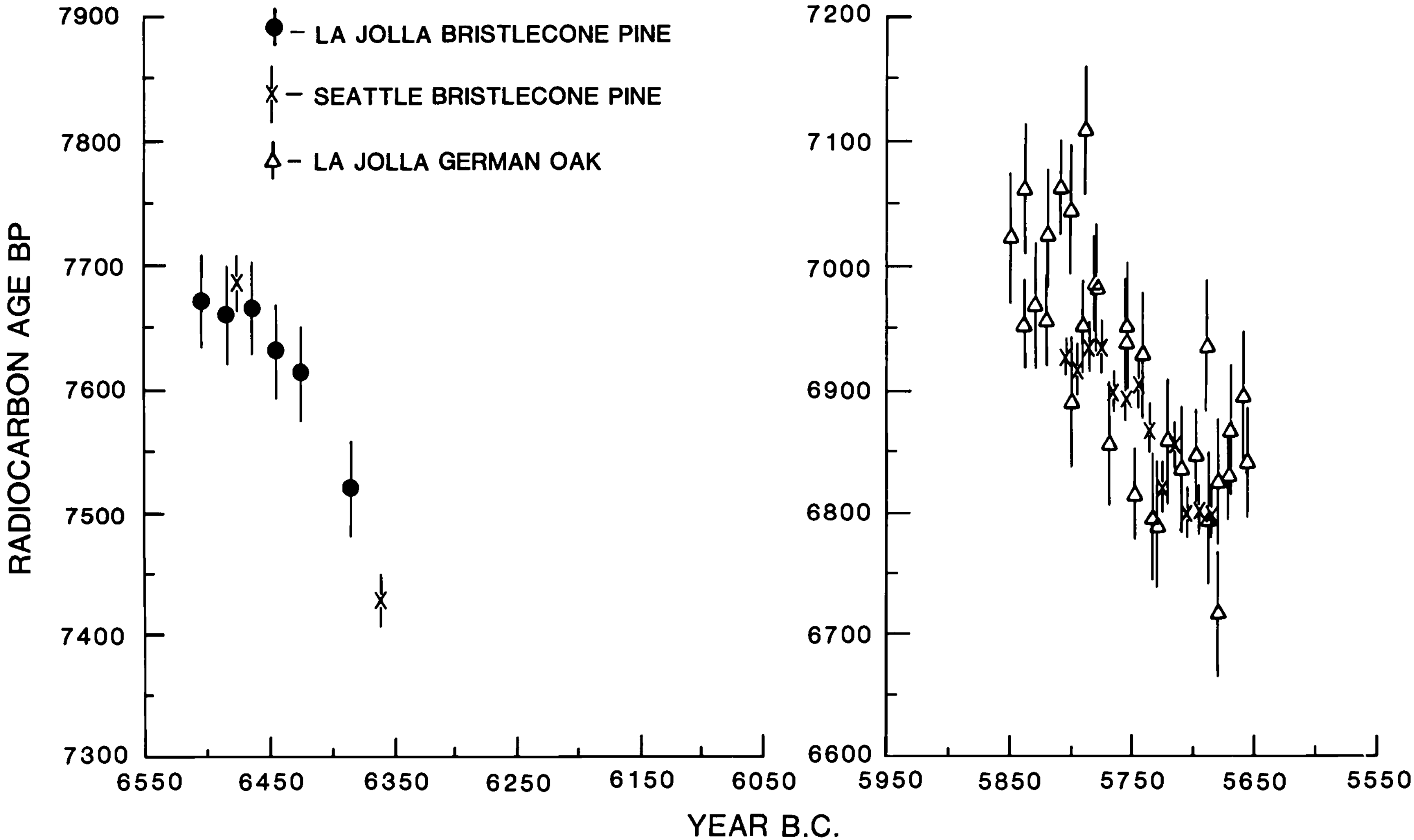
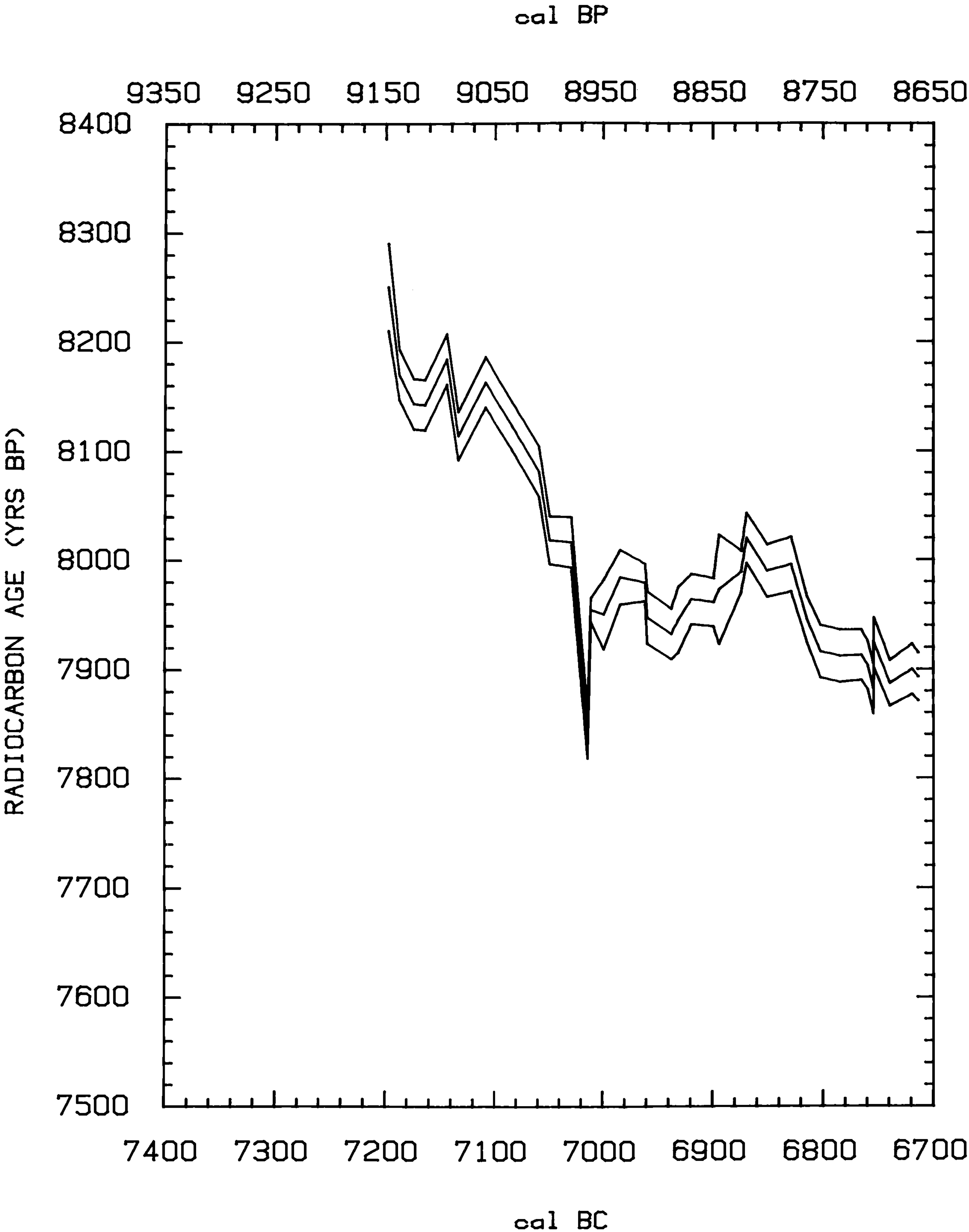
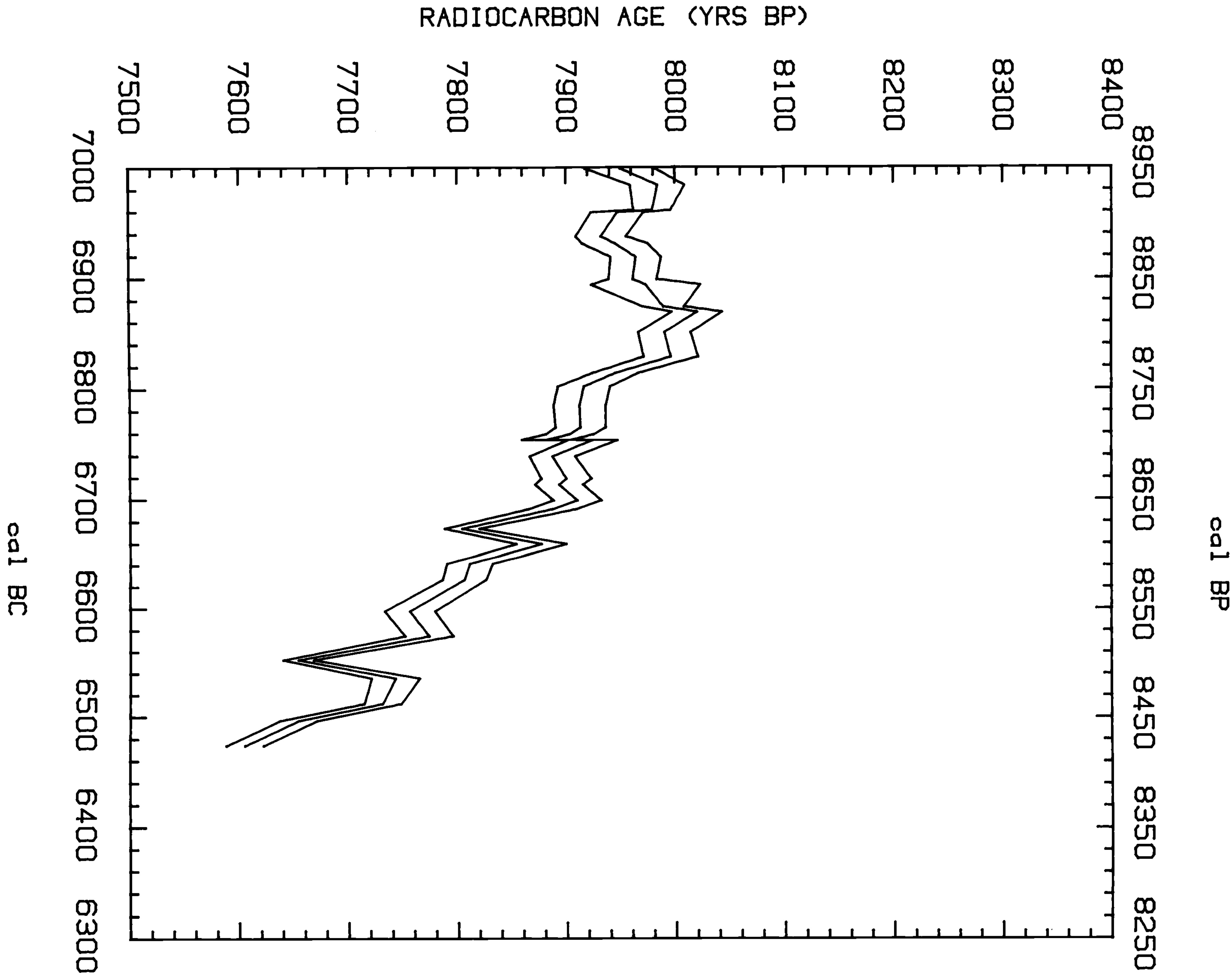


Fig 2. *Left:* La Jolla and Seattle Bristlecone Pine ^{14}C ages. *Right:* Seattle Bristlecone Pine ^{14}C ages compared to La Jolla ages of the German Oak chronology (with ring 1 of the D6M4/11 series at 7215 yr BC). Vertical bars denote 1σ in the measurement.



Figs 3, 4. ^{14}C time-scale calibration derived from the German Oak chronology (with ring 1 of the D6M4/11 series at 7215 yr BC). The width of the calibration curve is based on standard deviations derived from counting statistics only (see text).


RADIOCARBON AGE (YRS BP)
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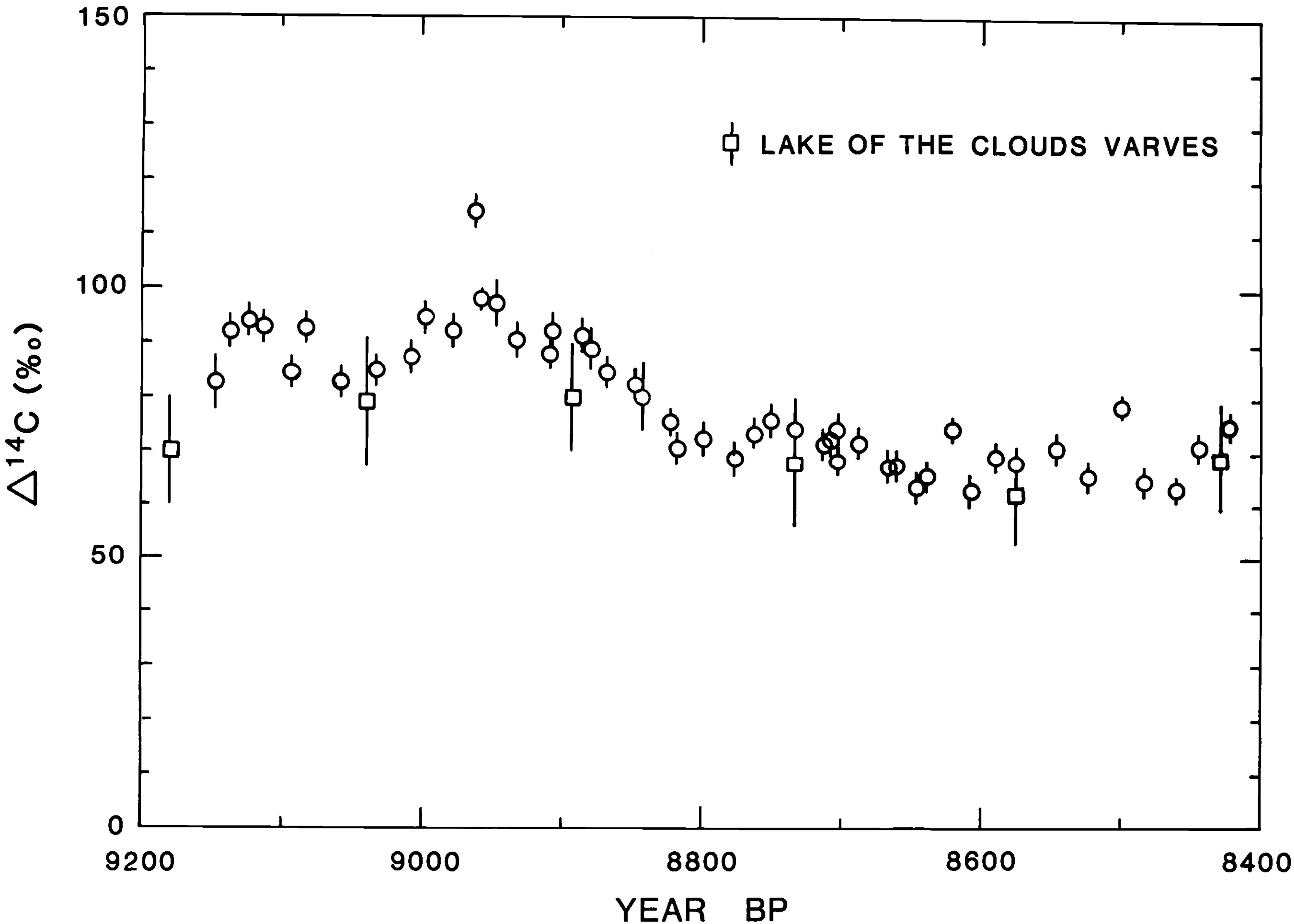

Fig 5. A comparison of $\Delta^{14}C$ values derived from Lake of the Clouds varves and South German Oak tree-ring samples. ^{14}C age errors are 1σ, based on counting statistics only.

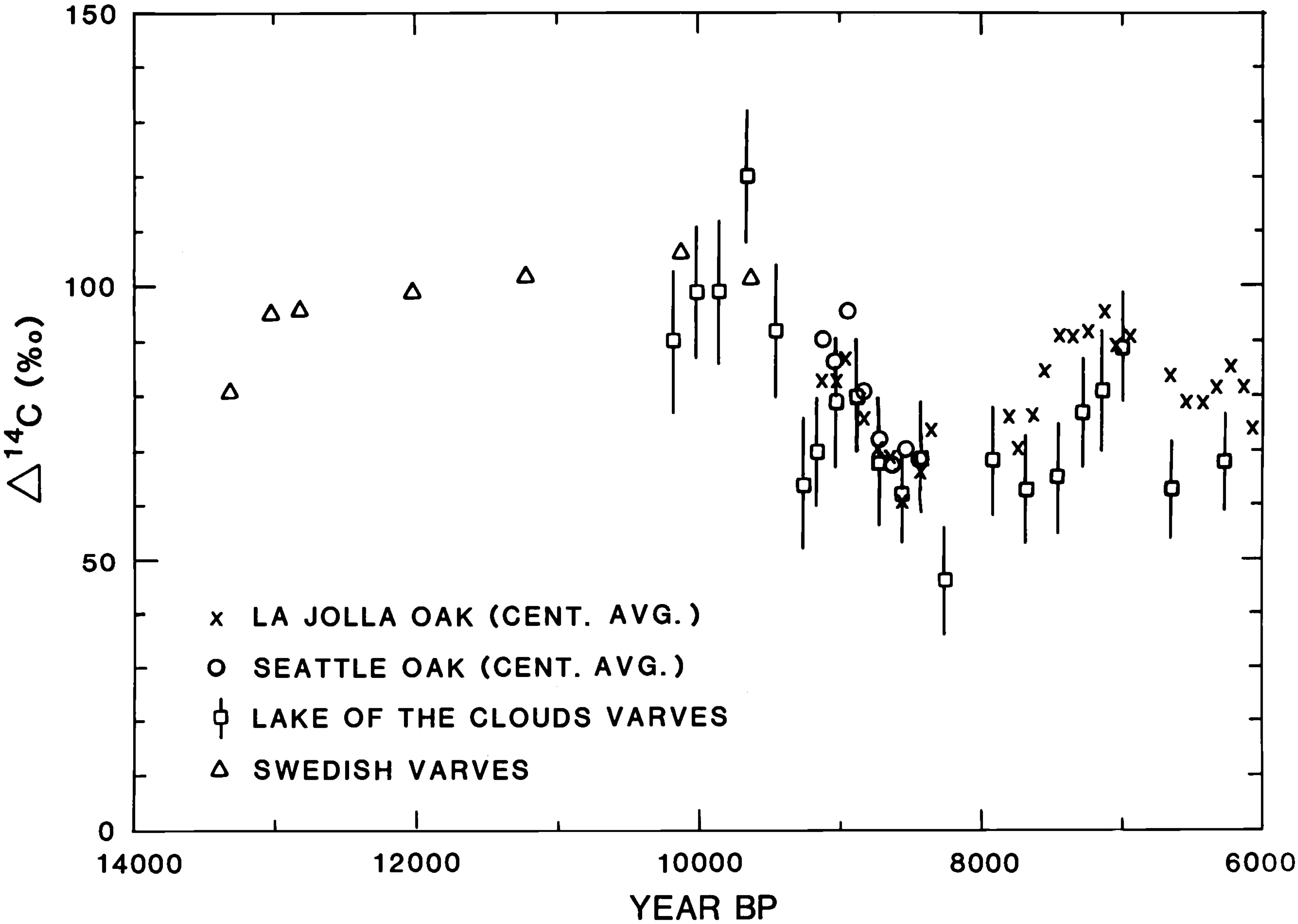

Fig 6. Century-averaged $\Delta^{14}C$ values derived from La Jolla (Linick, Suess & Becker, 1985) and Seattle measurements of the South German Oak chronology (with ring 1 of D6M4/11 at 7215 BC). Also given are $\Delta^{14}C$ values derived from the Lake of the Clouds (Stuiver, 1970, 1971) and Swedish (Tauber, 1970) varve chronology. The standard error in the century averages is a few per mil or less.

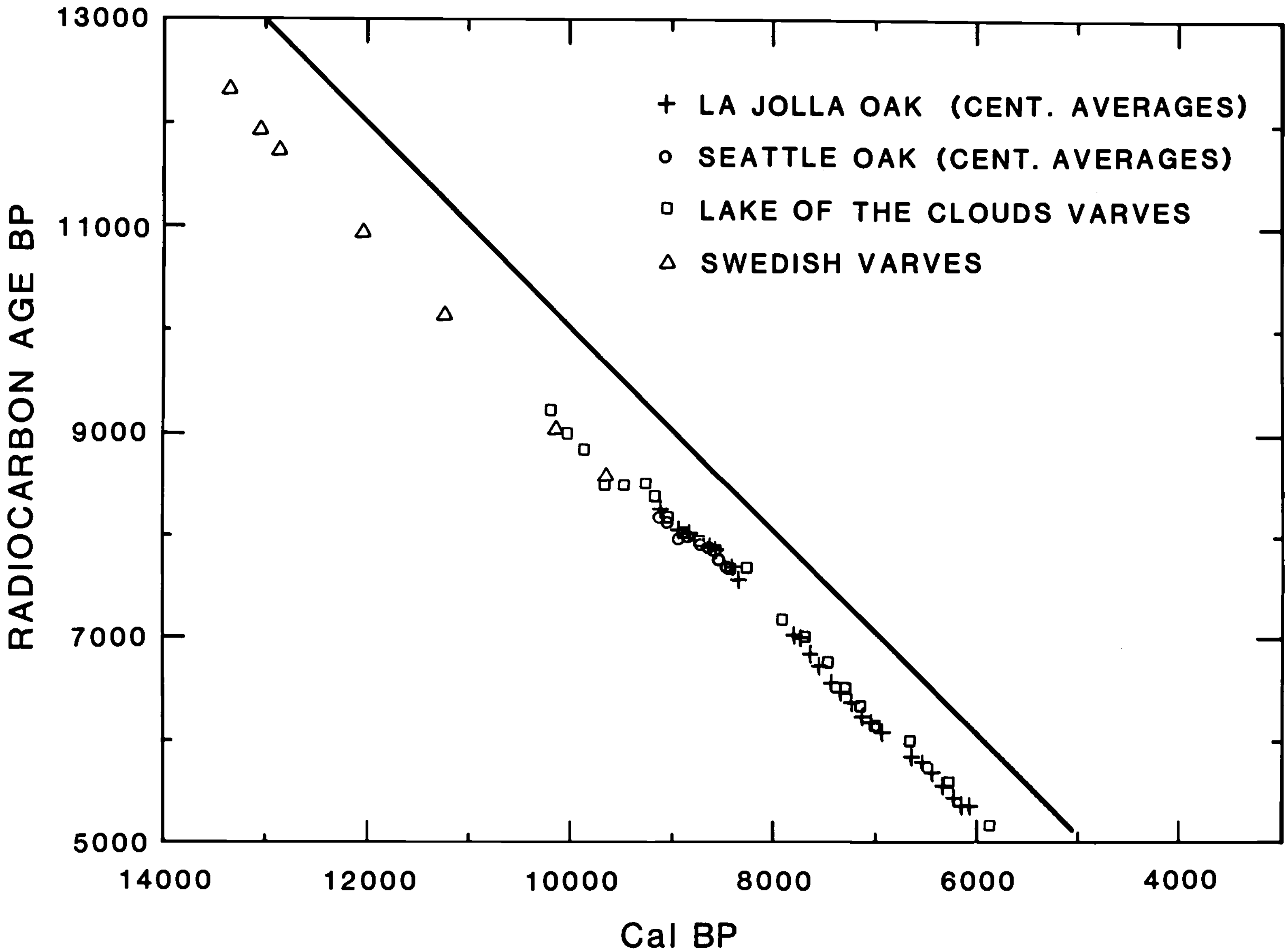

Fig 7. Century-averaged ^{14}C ages of the South German Oak chronology. The Lake of the Clouds and Swedish varve chronology data were derived from the ^{14}C ages of single samples.

TABLE 1
Becker's D6M4/11 series with ring 1 matched at 7215 BC
Standard deviations are based on counting statistics only.

Ring no.	Year BC	Year BP	No. of rings	Radiocarbon age	$\Delta^{14}C$	QL* no.
18.5	7197.5	9146.5	2	8250 ± 40	+82.8 ± 5.0	10000
28.5	7187.5	9136.5	4	8170 ± 23	+92.3 ± 2.9	10001
42.0	7174	9123	5	8143 ± 23	+94.2 ± 2.9	10002
52.0	7164	9113	5	8142 ± 23	+93.0 ± 2.9	10003
72.0	7144	9093	5	8184 ± 23	+84.6 ± 2.9	10005
82.5	7133.5	9082.5	6	8114 ± 22	+92.8 ± 2.7	10006
107.0	7109	9058	5	8163 ± 23	+82.9 ± 2.9	10007
132.0	7084	9033	5	8123 ± 22	+85.0 ± 2.7	10008
157.0	7059	9008	5	8081 ± 23	+87.4 ± 2.9	10009
167.0	7049	8998	5	8018 ± 22	+94.6 ± 2.7	10010
187.0	7029	8978	5	8016 ± 23	+92.3 ± 2.9	10011
202.0	7014	8963	5	7841 ± 23	+114.3 ± 2.9	10012
205.0	7011	8960	11	7954 ± 11	+98.3 ± 1.4	10013
217.0	6999	8948	5	7950 ± 32	+97.3 ± 4.0	10014
232.0	6984	8933	5	7984 ± 25	+90.7 ± 3.1	10015
255.0	6961	8910	11	7979 ± 17	+88.3 ± 2.1	10016
257.0	6959	8908	5	7947 ± 24	+92.4 ± 3.0	10017
278.5	6937.5	8886.5	6	7932 ± 23	+91.6 ± 2.9	10018
285.0	6931	8880	11	7945 ± 30	+89.0 ± 3.7	10019
297.0	6919	8868	5	7964 ± 23	+84.8 ± 2.9	10020
317.0	6899	8848	5	7961 ± 22	+82.6 ± 2.7	10021
322.0	6894	8843	5	7973 ± 50	+80.3 ± 6.2	10022
342.0	6874	8823	5	7989 ± 19	+75.6 ± 2.4	10023
347.0	6869	8818	5	8020 ± 23	+70.8 ± 2.9	10024
365.5	6850.5	8799.5	4	7990 ± 24	+72.4 ± 3.0	10025
387.5	6828.5	8777.5	4	7996 ± 25	+68.8 ± 3.1	10026
402.0	6814	8763	5	7945 ± 21	+73.7 ± 2.6	10027
414.0	6802	8751	3	7916 ± 24	+76.0 ± 3.0	10028
431.0	6785	8734	3	7912 ± 24	+74.3 ± 3.0	10029
451.0	6765	8714	3	7913 ± 23	+71.6 ± 2.9	10030
457.0	6759	8708	5	7903 ± 22	+72.1 ± 2.7	10031
462.0	6754	8703	5	7882 ± 23	+74.3 ± 2.9	10032
462.5	6753.5	8702.5	6	7924 ± 23	+68.6 ± 2.9	10033
477.0	6739	8688	5	7887 ± 21	+71.7 ± 2.6	10034
497.0	6719	8668	5	7900 ± 23	+67.4 ± 2.9	10035
502.5	6713.5	8662.5	6	7893 ± 22	+67.6 ± 2.7	10036
517.0	6699	8648	5	7910 ± 22	+63.5 ± 2.7	10037
525.0	6691	8640	11	7887 ± 22	+65.5 ± 2.7	10038
542.5	6673.5	8622.5	6	7804 ± 16	+74.3 ± 2.0	10039
556.5	6659.5	8608.5	6	7877 ± 23	+62.7 ± 2.9	10040
574.5	6641.5	8590.5	10	7811 ± 21	+69.2 ± 2.6	10041
589.5	6626.5	8575.5	10	7806 ± 20	+67.9 ± 2.5	10042
618.5	6597.5	8546.5	4	7756 ± 23	+70.8 ± 2.9	10043
641.5	6574.5	8523.5	6	7774 ± 22	+65.5 ± 2.7	10044
663.5	6552.5	8501.5	8	7654 ± 14	+78.6 ± 1.7	10045
680.5	6535.5	8484.5	8	7743 ± 22	+64.5 ± 2.7	10046
704.0	6512	8461	5	7731 ± 17	+63.1 ± 2.1	10047
719.5	6496.5	8445.5	4	7654 ± 17	+71.3 ± 2.1	10048
742.0	6474	8423	5	7605 ± 17	+75.0 ± 2.1	10049

*Quaternary Isotope Lab (Seattle)

TABLE 2
Ferguson's Bristlecone Pine series
Standard deviations are based on counting statistics only.

Year BC	Year BP	No. of rings	Radiocarbon age	$\Delta^{14}C$	QL no.
6475	8424	10	7686 ± 23	+64.2 ± 3.1	10064
6360	8309	20	7427 ± 22	+84.1 ± 3.0	10063
5805	7754	10	6926 ± 14	+78.9 ± 2.0	10062
5795	7744	10	6915 ± 21	+79.2 ± 2.9	10061
5785	7734	10	6935 ± 20	+75.2 ± 2.7	10060
5775	7724	10	6934 ± 22	+74.0 ± 3.0	10059
5765	7714	10	6897 ± 16	+77.6 ± 2.2	10058
5755	7704	10	6893 ± 17	+76.9 ± 2.4	10057
5745	7694	10	6904 ± 20	+74.1 ± 2.7	10056
5735	7684	10	6867 ± 20	+77.7 ± 2.8	10055
5725	7674	10	6820 ± 20	+82.7 ± 2.7	10054
5715	7664	10	6853 ± 20	+77.0 ± 2.8	10053
5705	7654	10	6799 ± 20	+82.9 ± 2.7	10052
5695	7644	10	6802 ± 20	+81.2 ± 2.7	10051
5685	7634	10	6799 ± 20	+80.3 ± 2.7	10050

TABLE 3
Seattle and Heidelberg measurements of duplicate samples of Becker D6M4/11 wood. Standard deviations are based on counting statistics only.

Ring no.	Heidelberg Radiocarbon age BP	Seattle Radiocarbon age BP	Difference
556.5	7884 ± 22	7887 ± 22	-3 ± 31
502.5	7925 ± 22	7893 ± 22	32 ± 31
562.5	7959 ± 22	7924 ± 23	35 ± 32
285	7996 ± 20	7945 ± 30	51 ± 36
255	7960 ± 22	7979 ± 17	-19 ± 28
205	8010 ± 20	7954 ± 11	56 ± 23

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RADIOCARBON AGE CALIBRATION OF MARINE SAMPLES BACK TO 9000 CAL YR BP

MINZE STUIVER*, G W PEARSON**, and TOM BRAZIUNAS*

INTRODUCTION

Calibration curves spanning several millennia are now available in this special issue of *RADIOCARBON.* These curves, nearly all derived from the ^{14}C age determinations of wood samples, are to be used for the age conversion of samples that were formed through use of atmospheric CO_2. When samples are formed in reservoirs (eg, lakes and oceans) that differ in specific ^{14}C content from the atmosphere, an age adjustment is needed because a conventional ^{14}C age, although taking into account ^{14}C (and ^{13}C) fractionation, does not correct for the difference in specific ^{14}C activity (Stuiver & Polach, 1977). The ^{14}C ages of samples grown in these environments are too old, and a reservoir age correction has to be applied. This phenomenon has been referred to as the reservoir effect (Stuiver & Polach, 1977).

The reservoir age, or apparent age, R(t) is here defined as the difference between conventional ^{14}C ages of samples grown contemporaneously in the atmosphere and the other carbon reservoir. R(t) is not constant (t = cal age) because the difference in reservoir and atmosphere ^{14}C specific activity is liable to change with changes in reservoir parameters (such as size of the carbon pool, input and output fluxes and exchange with the atmosphere) and atmospheric $\Delta^{14}C$ values. However, due to the lack of detailed information, a variable reservoir age correction usually cannot be applied, and the user of ^{14}C ages then resorts to the assumption of a constant reservoir age correction R* (*ie*, the reservoir ^{14}C specific activity is assumed to parallel atmospheric ^{14}C specific activity at all times). The reservoir age correction R* is obtained from the conventional ^{14}C age of reservoir samples of either historically known age, or of inferred known age (such as the uppermost portion of lake sediment). This approach is, of course, only a first order approximation. However, even though the resulting reservoir corrected ^{14}C age is not the ultimate in accuracy, the corrected ^{14}C age should be closer to the ^{14}C age of a contemporaneous wood sample than the uncorrected one.

The recent introduction of the dating of mg C samples through AMS (accelerator mass spectrometry) allows for an improved determination of variable reservoir ages R(t) in lakes because it is now possible to measure, at different depths, the age differences between 1) those plant macrofossils that were originally utilizing atmospheric $^{14}CO_2$, 2) lake carbonate, and 3) gyttja. The first study of this kind has been made for the sediments of a small closed basin of the Lobsingsee, Switzerland (Andrée *et al*, 1986b). Here the problem of reservoir age corrections can be avoided entirely if a sufficient number of macrofossils formed directly from atmospheric CO_2 can be found.

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For small carbon reservoirs where the exchange rate with the atmosphere is dominant (eg, a shallow 10ha lake) the change in specific ^{14}C content may well parallel the observed change in atmospheric ^{14}C content. For other reservoirs, however, appreciable differences are possible. For instance, the top 75m of the ocean (well mixed due to wave action, etc) attenuates atmospheric decadal $\Delta^{14}C$ changes strongly due to its inertia in responding to atmospheric forcing, and the deep ocean lags appreciably in its response to long-term atmospheric ^{14}C change. The idea of a constant reservoir age correction R* is not tenable in this case.

The reservoir age of marine shells has been determined in the past from the conventional ^{14}C age of shells of known historic age (year AD X), after correcting for fossil fuel CO_2-induced ^{14}C age change in the mixed layer of the ocean (Mangerud & Gulliksen, 1975; Robinson & Thompson, 1981). This fossil fuel corrected ^{14}C age is then compared with the age of the sample, *ie*, 1950 − X, and the difference is the reservoir or apparent age. This procedure assumes constant atmospheric ^{14}C level, where calendar years and ^{14}C years are interchangeable. Thus, the reservoir age in this instance is the fossil fuel corrected shell ^{14}C age minus the ^{14}C age of a sample formed from atmospheric CO_2 in AD X.

Olsson (1980), in addition, discusses the ^{14}C ages of samples formed from atmospheric CO_2 of the 19th century, and compares these with the conventional shell ^{14}C ages. The difference again is the apparent or reservoir age. But, as noted by Olsson, "in this discussion, it has been tacitly assumed that the aim is to arrive at a reservoir effect that is not affected by short-term fluctuations of radiocarbon in the atmosphere."

Two avenues of age calibration are possible for a sample formed in a fluctuating ^{14}C environment. One is to derive the variable reservoir age R(t) in conventional ^{14}C years, apply this correction to obtain a reservoir corrected ^{14}C age, and then use the calibration curves valid for samples formed directly from atmospheric CO_2. The other is to produce a separate calibration curve that includes the variability in reservoir ages. Such a curve gives the conventional ^{14}C age minus a ΔR number (explained later on) *vs* the cal BP (cal AD/BC) age. We here follow the latter approach for marine samples.

A box-diffusion model as described by Oeschger *et al* (1975) was used to simulate global carbon exchange. We attribute the observed atmospheric $\Delta^{14}C$ variability of the last 9000 yr to solar (heliomagnetic) and geomagnetic modulation of the cosmic ray flux (Stuiver & Quay, 1980; Sternberg & Damon, 1983), and consider model parameter change induced by oceanic (climate) change to be negligible over this time interval (Andrée *et al*, 1986a). The observed atmospheric $\Delta^{14}C$ record is used to calculate the ^{14}C content of the mixed layer (top 75m) of the model ocean, and the model mixed layer ^{14}C ages are plotted *vs* cal AD/BC (cal BP) ages. The calibration curves are different from those given elsewhere in this issue because the ^{14}C ages are not directly measured but calculated from the atmospheric record through carbon reservoir modeling. The curves therefore not only reflect the original measuring uncertainty in the wood $\Delta^{14}C$ values that constitute the model input, but also uncertainties in model parameters.

THE GLOBAL CARBON MODEL

The atmospheric $\Delta^{14}C$ data used as input for the model span the AD 1950–7746 BC interval. A composite data set (Fig 1) was derived by combining the data of Stuiver and Pearson (1986) for the AD 1950–500 BC interval, of Pearson and Stuiver (1986) for 500–2490 BC, of Pearson *et al* (1986) for 2500–5210 BC, of Linick, Suess and Becker (1985) for 5219–5346 BC and 5818–5882 BC, of Stuiver *et al* (1986) for 5685–5815 BC, 6475–6552 BC, and 6574–7198 BC, of Kromer *et al* (1986) for 5908–6200 BC, 6279–6469 BC, and 7206–7746 BC, and of Linick *et al* (1986) for 5355–5675 BC and 6205–6275 BC. The Figure 1 data represent average $\Delta^{14}C$ values of 20-yr samples back to 5220 BC, and of a mixture of intervals (single yr to up to 20 yr) prior to that.

Detailed atmospheric $\Delta^{14}C$ on a decadal scale is given in Figure 2 for the last 4500 yr (Stuiver & Becker, 1986).

For the carbon reservoir modeling, we constructed a curve with bi-decadal coverage for the entire AD 1950–7740 BC interval. The initial equilibrium conditions of the model were set at an atmospheric $\Delta^{14}C$ value of +90‰ (Stuiver *et al*, 1986). An important parameter of the box-diffusion model (see also Stuiver & Quay, 1981) is the atmospheric CO_2 concentration which is fixed at 280ppm (Neftel *et al*, 1985; Stuiver, Burk & Quay, 1984). Oceanic C concentration is set at 2.31moles/m^3 (Takahashi, Broecker & Bainbridge, 1981). The biosphere is set at a constant 1900 Gigatons C (Olson, Pfuderer & Chan, 1978). The biosphere is divided into two reservoirs with residence times of 2.7 yr and 80 yr (Emanuel *et al*, 1984). The reservoir with fast turnover contains 10.6% of the total biomass, the other 89.4% (Emanuel *et al*, 1984). Gas exchange rate F is set at 19moles/m^{2}yr in order to yield a nearly 50‰ $\Delta^{14}C$ difference between the atmosphere and mixed layer in the year 1830 (the last bi-decadal midpoint without fossil fuel CO_2 influence). To generate a 40‰ difference between the atmospheric and mixed layer $\Delta^{14}C$, F has to be adjusted to 24moles/m^{2}yr.

A vertical diffusion coefficient K_z of 1.26cm^2/sec yields a deep ocean $\Delta^{14}C$ value of −190‰ in 1850, in agreement with GEOSECS measurements (Stuiver, Quay & Östlund, 1983).

MODEL RESULTS

The model input is the post-7750 BC atmospheric $\Delta^{14}C$ record, of which the post-7200 BC portion is given in the top curve of Figure 3. The $\Delta^{14}C$ values of the 550 yr preceding 7200 BC (Fig 1) were used for a proper startup of the model.

Model-derived mixed layer $\Delta^{14}C$ values (F = 19moles/m^{2}yr, K = 1.26cm^2/sec, to yield a mixed layer $\Delta^{14}C$ = −49.7‰ (R = 409 yr) at AD 1830) are given in the middle curve. Relative to the atmosphere, there is a substantial attenuation of the higher $\Delta^{14}C$ frequencies in the mixed layer. For the deep ocean (bottom curve) only a long-term trend remains.

To determine the sensitivity of the model results to the choice of F and K_z, we also generated mixed layer $\Delta^{14}C$ values with model parameters set at F = 24moles/m^{2}yr,K_z = 1.26cm^2/sec, to yield a mixed layer $\Delta^{14}C$ = −40.4‰ (R = 331 yr) at AD 1830. The difference between the F = 19 and F = 24moles/m^2 yr model outputs of mixed layer $\Delta^{14}C$ values and ^{14}C ages are given in Figure 4. Evidently the calibration curve is relatively insensitive to F because the model-calculated mixed layer ages, after normalization on the same baseline, differ by up to 16 ^{14}C years.

Eddy diffusivity is faster in the upper portion of the ocean than in the lower part (Stuiver, 1980). We compared the model-generated mixed layer ^{14}C ages for K_z values of 1.26cm^2/sec and 2.2cm^2/sec, with R set at 409 yr in AD 1830 in both cases. The faster diffusivity was accompanied by an increased exchange coefficient F of 20moles/m^{2}yr. The resulting model outputs of mixed layer ^{14}C ages differed by a fraction of a decade for the long term (millennia), as well as the shorter term (century) type oscillations. Thus, the fine structure of the model mixed layer curves is not sensitive to assumed K_z values.

Figure 5 gives the conventional ^{14}C ages of the atmosphere, mixed layer of the ocean, and the deep ocean. The differences in basic features of the atmospheric and marine calibration curves are caused by the strong attenuation in the oceans of the higher frequency $\Delta^{14}C$ perturbation. This leads to the variable R(t). With the traditional method of correcting marine ^{14}C ages one would deduct a fixed reservoir age R* (derived for one year only) from the Figure 5 results and use it for all ages. Two examples of this approach are given in Figures 6 and 7 where fixed reservoir ages of 409 yr and 1684 yr are deducted from, respectively, the mixed layer and deep ocean ^{14}C ages. The deducted reservoir ages are those calculated for the year 1830. Whereas the fixed reservoir age concept indeed gives calibration curves resembling the atmospheric one for the 4300–5000 BC interval (Fig 6), appreciable differences are found for the 200–900 BC interval (Fig 7). This is due partially to the perturbation in atmospheric $\Delta^{14}C$ between 400 and 750 BC which results in the horizontal portion of the Figure 7 atmospheric calibration curve. This perturbation is much smaller in the mixed layer, and absent in the deep ocean (Fig 7). Similarly, the lag in deep ocean response to the long-term post 5000 BC atmospheric $\Delta^{14}C$ decline results in the lower curve offset in Figure 7.

Atmospheric $\Delta^{14}C$ changes in our model are caused by production rate changes. The atmospheric $\Delta^{14}C$ changes in turn influence the oceans. A reverse scenario in which changes in ocean circulation lead to atmospheric $\Delta^{14}C$ changes is contradicted by the work of Andrée *et al* (1986a) on the ^{14}C age differences of the mixed layer and the deep ocean. These age differences were derived from the ^{14}C ages of planktonic and benthic marine organisms in two sediment cores of the South China Sea (Fig 8). As discussed by Andrée *et al* (1986a), a drastic post 6000 BP speed-up in ocean circulation is needed if the oceans would be the primary cause of the long-term change (Fig 1) in atmospheric $\Delta^{14}C$ values. For this scenario a much lower rate of ocean mixing is needed in the early Holocene which would generate ^{14}C age differences twice as large as currently found between mixed layer and deep ocean (Andrée *et al,* 1986a). As this is not the case (Fig 8), our first order assumption of constant reservoir parameters is justified. It should be noted, however, that even with a fixed mode of ocean circulation, changes of up to 200 yr are possible in the mixed layer-deep sea Holocene ^{14}C age differences (Fig 8).

The variable reservoir ages R(t) of the mixed layer and deep ocean deduced from Figure 5 are given in Figure 9A. The atmospheric $\Delta^{14}C$ lowering associated with fossil fuel combustion decreases the reservoir age of the mixed layer and deep ocean by about, respectively, 100 yr and 170 yr between AD 1850 and 1950 (Fig 9B).

RADIOCARBON AGE CALIBRATION AND ΔR DETERMINATION

The question arises how a user provided with a conventional ^{14}C age of a sample from a certain part of the ocean should use the calibration curves that are calculated for the world oceans. After proper correction for isotope fractionation (Stuiver & Polach, 1977), the conventional ^{14}C ages of marine shells are generally too old. The age anomaly (reservoir age) is 200 to 400 yr for the mixed layer of the world oceans, but may be larger in areas of upwelling (up to 1300 yr, Stuiver & Braziunas, 1985).

Our calibration curves depict the relationship between cal AD/BC (cal BP) ages and *conventional* (Stuiver & Polach, 1977) ^{14}C ages. Those ^{14}C ages are corrected for isotope fractionation, but not for any reservoir deficiency. The model mixed layer and deep ocean reservoir ages average, respectively, 373 yr and 1554 yr over the last 9000 yr. These averages result from our choice of specific model parameters and do not reflect local variations in the ocean reservoir ages.

To accommodate local effects, the model ocean can be matched with regional parts of the world ocean by assuming a parallel $\Delta^{14}C$ response, *ie,* we assume as a first approximation identical time-dependent response of the regional and world ocean to atmospheric forcing. Further refinement would be possible if each region could be modeled separately. However, we have to work at present with the above approximation.

The reader of the previous sections will have noticed the time-dependent character of the reservoir age R(t) of the mixed layer of the ocean. The reservoir age, or the conventional ^{14}C age difference between samples formed contemporaneously in the mixed layer and the atmosphere, is time-dependent because the oceanic $\Delta^{14}C$ response to atmospheric $\Delta^{14}C$ forcing differs from the atmospheric signal. However, an approximately parallel response to atmospheric forcing of a regional part of the ocean and the world ocean results in a constant difference (ΔR) in reservoir age of the two. Thus, although reservoir ages are time-dependent, ΔR, as a first approximation, is not.

The difference ΔR in reservoir age of the regional part of the ocean from which the users sample is derived, and the reservoir age of our model ocean, is determined through the use of Figure 10A. The user needs information on reservoir ages, *ie,* a ^{14}C age P should be available for a historic (year AD X) sample collected from the same reservoir from which his/her sample is derived. The user has to derive from Fig 10A the model mixed layer (or deep ocean) ^{14}C age Q for year AD X. The correction factor to be used for the sample ^{14}C age in the calibration Figures 11 and 12 is then $\Delta R = P - Q$.

In case the user lacks information on ^{14}C ages of historic samples he/she can assume the sample comes from an environment similar to the model world ocean. The Figure 11 and 12 calibration curves (with $\Delta R = 0$) can then be used directly.

Our calculations neglect hemispheric reservoir differences that cause ^{14}C ages of atmospheric samples of the Southern Hemisphere to be ca 30 years older than those of the Northern Hemisphere. Hemispheric differences will be taken into account in a model currently being developed by one of us (T Braziunas).

Suggested ΔR values for various oceanic regions are plotted in Figure 10B. These weighted mean ΔR values were derived from ^{14}C ages listed in Table 1, which also gives the sample groupings from which the average ΔR values were derived. Except for a few instances, Table 1 contains only shell sample dates.

The standard deviations given with ΔR in Table 1 were derived from the errors reported with the ^{14}C ages. The ^{14}C age groupings also can be viewed as a data set from which the standard deviation ("scatter" sigma) in the unweighted mean can be calculated. These "scatter" sigmas in the unweighted mean are given in Table 1.

The largest of each set of sigmas was used for the ± value plotted in Figure 10B. In view of the much debated under-reporting of ^{14}C age errors, it was gratifying to see that the scatter sigma was, on average, only 1.1 times the ^{14}C age sigma. From this we conclude 1) the additional uncertainty in ΔR introduced by non-uniform ^{14}C content of the regional ocean reservoirs is small, and 2) the age errors given for the Table 1 shell samples are realistic estimates of the measurement precision.

The uncertainty in the age conversion process depends on the extent to which a particular sample's environment resembles the average model world ocean, and on the degree to which the model simulates the reality. It is not possible to give these uncertainties as standard deviations, and the calibration curves therefore lack an uncertainty band.

When converting a conventional ^{14}C age into cal AD/BC (or cal BP) age, the standard deviation in the sample age determination σ_s should be taken into account. There will be an additional error in either the determined or the assumed reservoir age difference ΔR. As noted, $\Delta R = P - Q$ where P is the conventional ^{14}C age of an historic sample, and Q the model-calculated conventional ^{14}C age of a sample of the same historic age. The ΔR error (σ_R) depends on the error in P, as well as Q. We do not have a standard error for the model-calculated Q value. Only a lower limit can be given for σ_R by substituting the error in the ^{14}C age determination P. This error is listed in Table 1 as a "minimum estimate" for σ_R.

The σ_R should be combined with σ_s according to $\sigma_{total} = \sqrt{\sigma_s^2 + \sigma_R^2}$. The

(^{14}C age − ΔR) ± σ_{total}, after conversion, determines a minimum range in calibrated ages.

Marine and "atmospheric" samples with identical ^{14}C ages and standard deviations will differ in calibrated age, as well as in the range in calibrated ages. The cal range will usually be larger for the marine sample due to the incorporation of the standard deviation σ_R in the reservoir age difference ΔR. The issue of multiple intercepts, however, is much less important for marine samples because the calibration curves (Figs 11, 12) are much less wiggley than the corresponding atmospheric ones (eg, Stuiver & Pearson, 1986).

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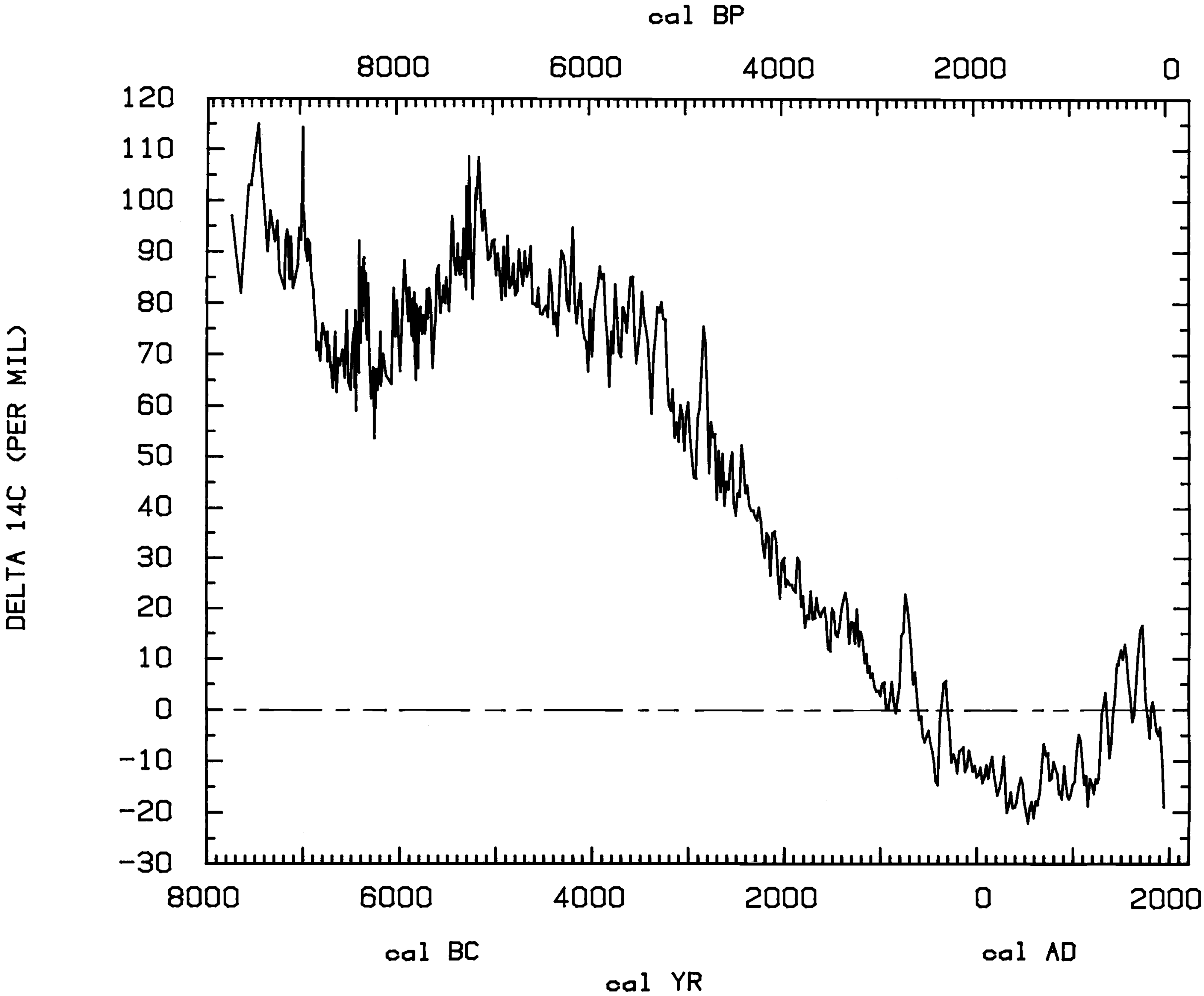


Fig 1. Atmospheric $\Delta^{14}C$ *vs* age. Compiled from data sources given in the text.

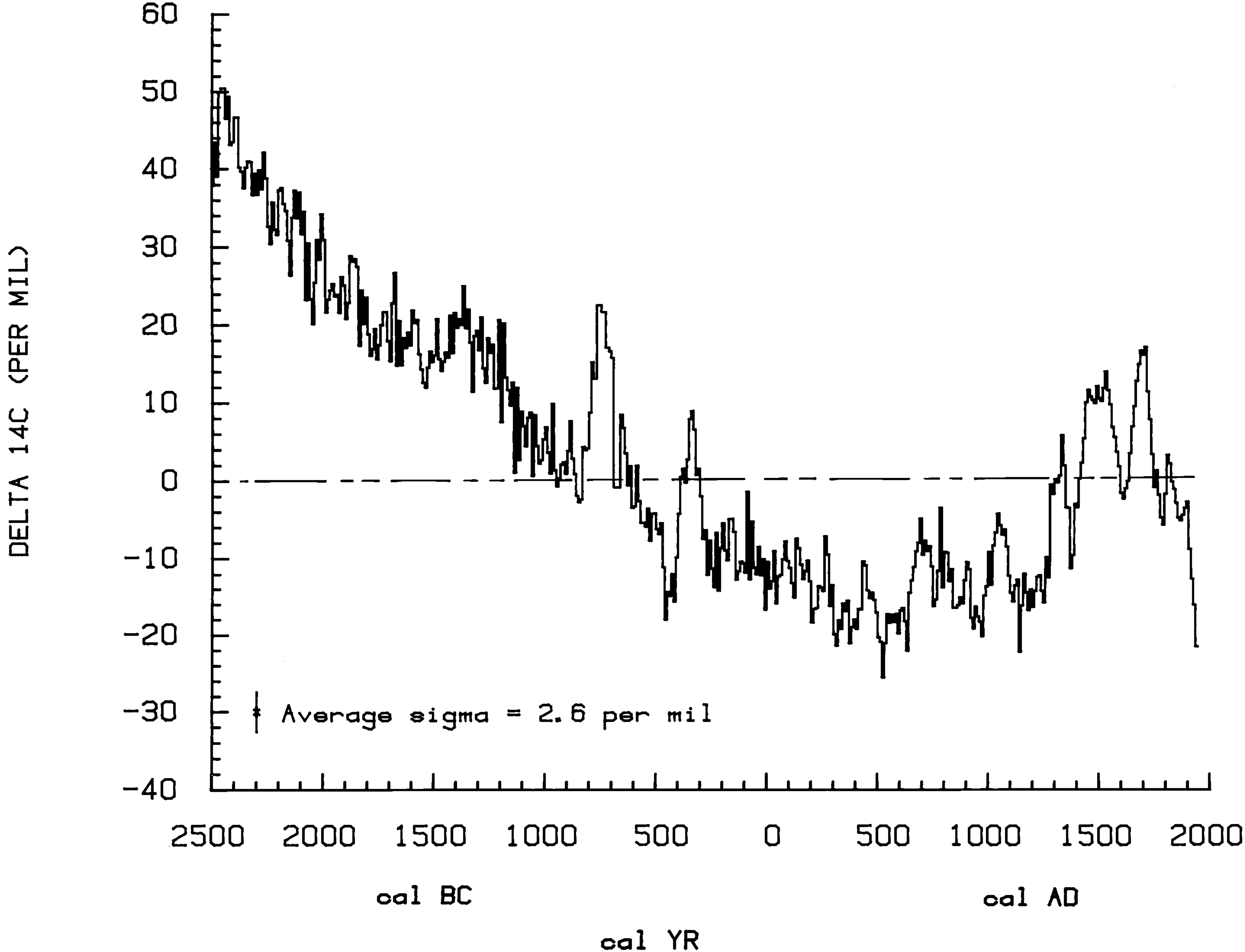


Fig 2. Atmospheric $\Delta^{14}C$ of the past 4½ millennia for each decade (Stuiver & Becker, 1986). The average standard deviation of the decadal measurements is 2.6‰.

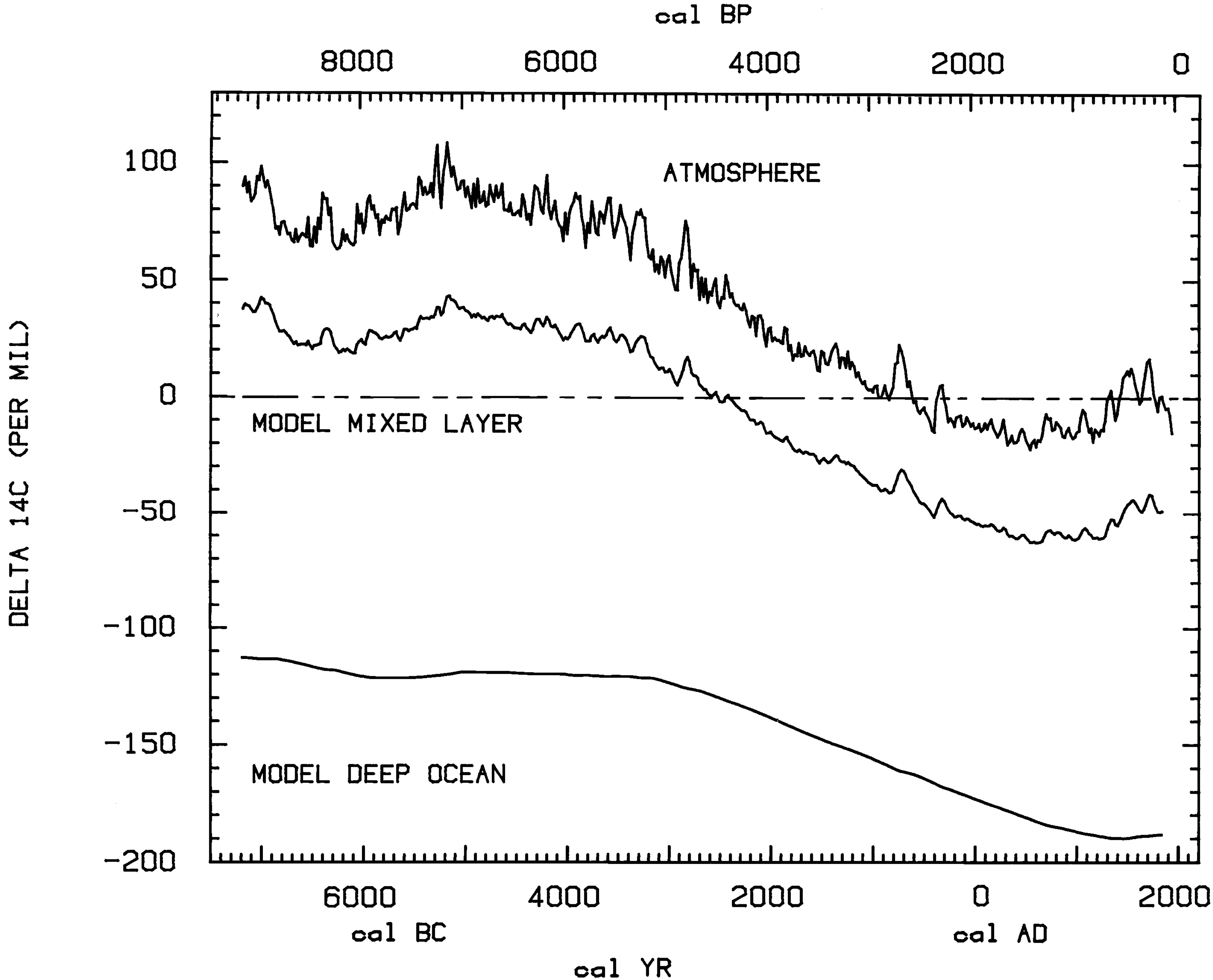


Fig 3. Atmospheric $\Delta^{14}C$ (bi-decadal values) as used for the model calculations and calculated mixed layer and deep ocean $\Delta^{14}C$ values.

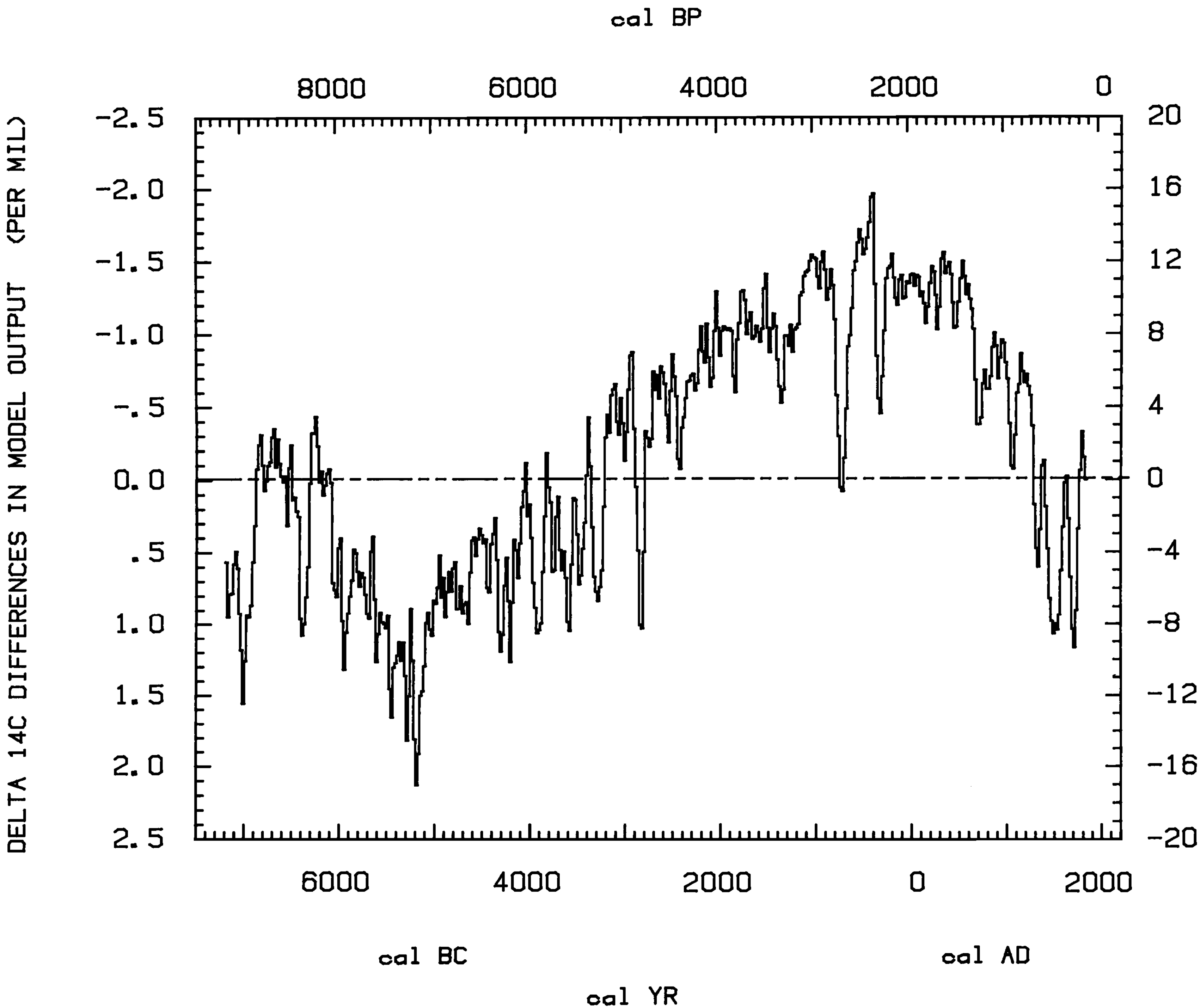


Fig 4. The calculated $\Delta^{14}C$ and ^{14}C age differences of the mixed layer for model oceans with mixed layer reservoir deficiencies R set at either 409 yr or 331 yr. The offset of 80 yr in baseline has been neglected because it will be compensated for by an 80-yr change in ΔR (defined later on).

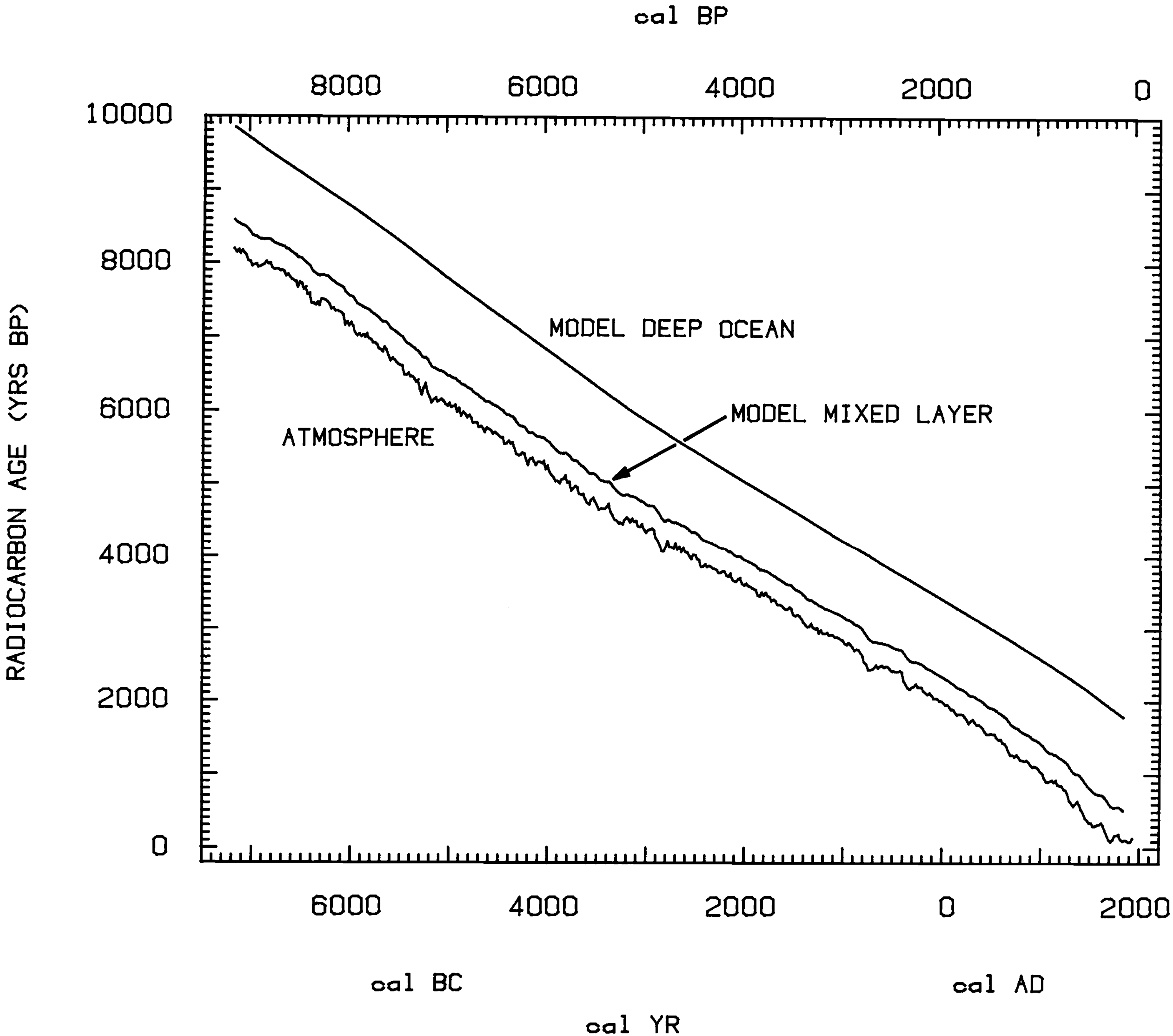


Fig 5. ^{14}C ages of the atmosphere (bi-decadal values) and calculated conventional ^{14}C ages of the mixed layer and deep ocean.

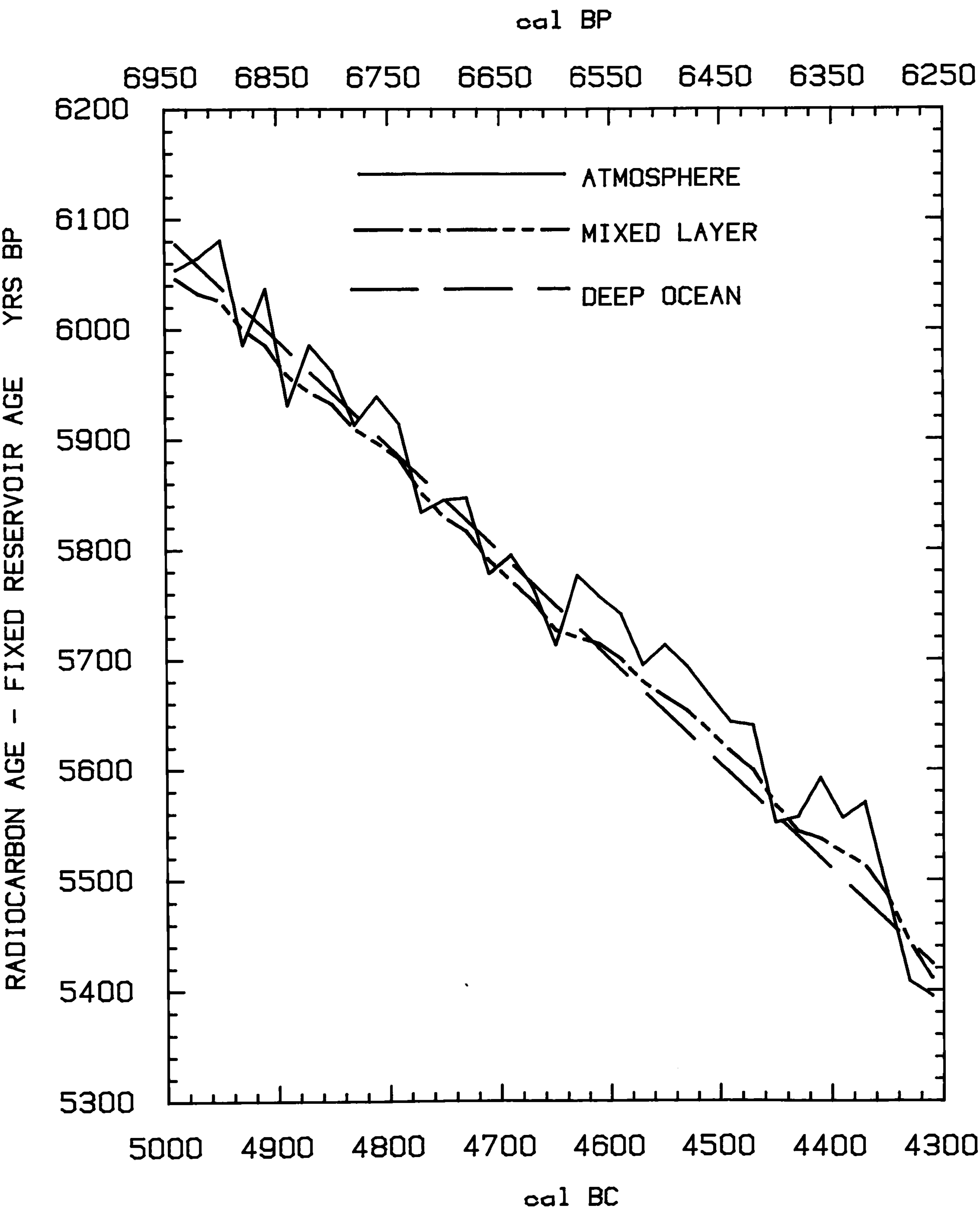


Fig 6. ^{14}C ages of "atmospheric" samples compared to reservoir corrected mixed layer and deep ocean ^{14}C ages for the 4300–5000 BC interval. The fixed reservoir correction was 409 yr and 1684 yr for, respectively, the mixed layer and the deep ocean.

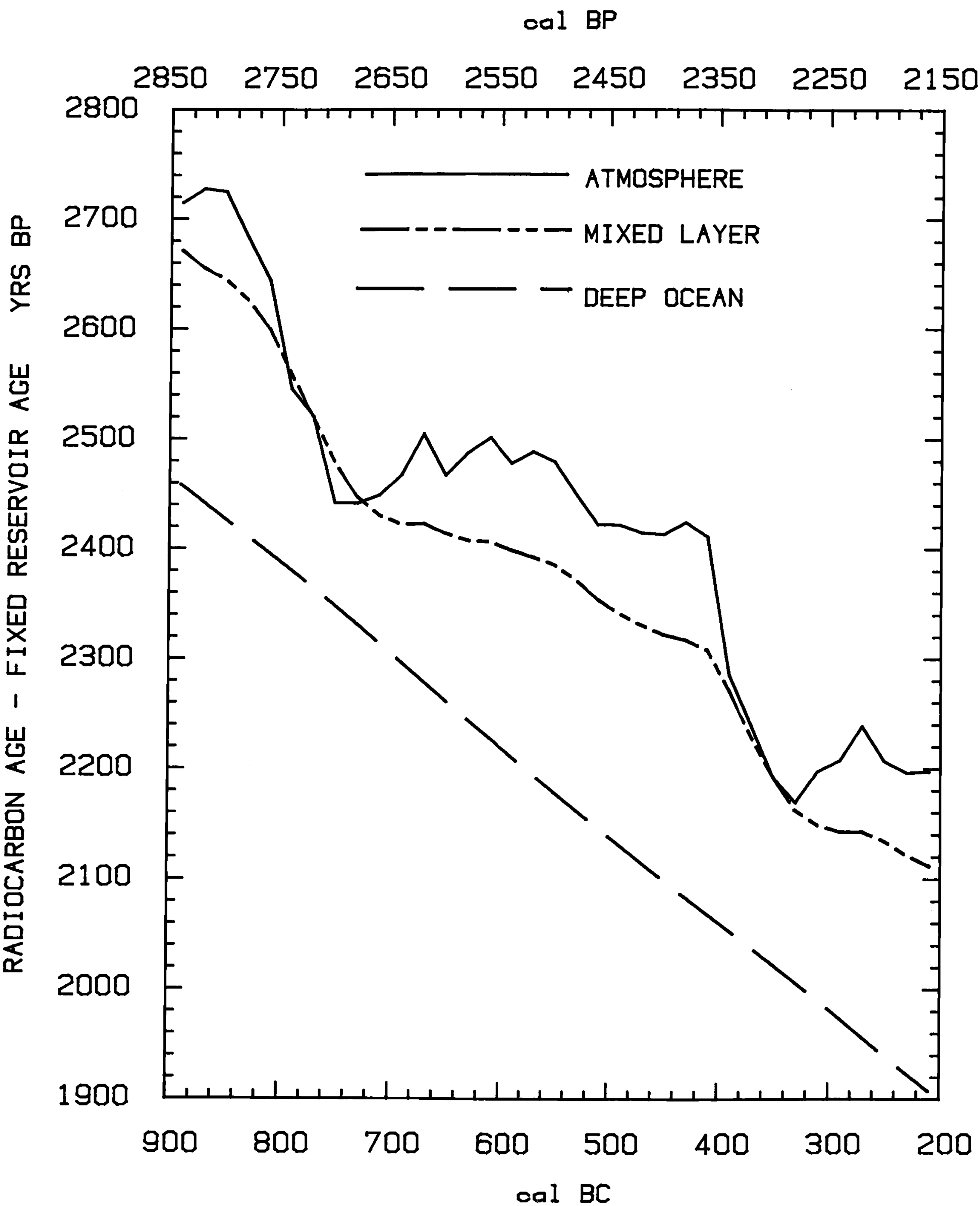


Fig 7. Similar to Figure 6 for the years 200–900 BC.

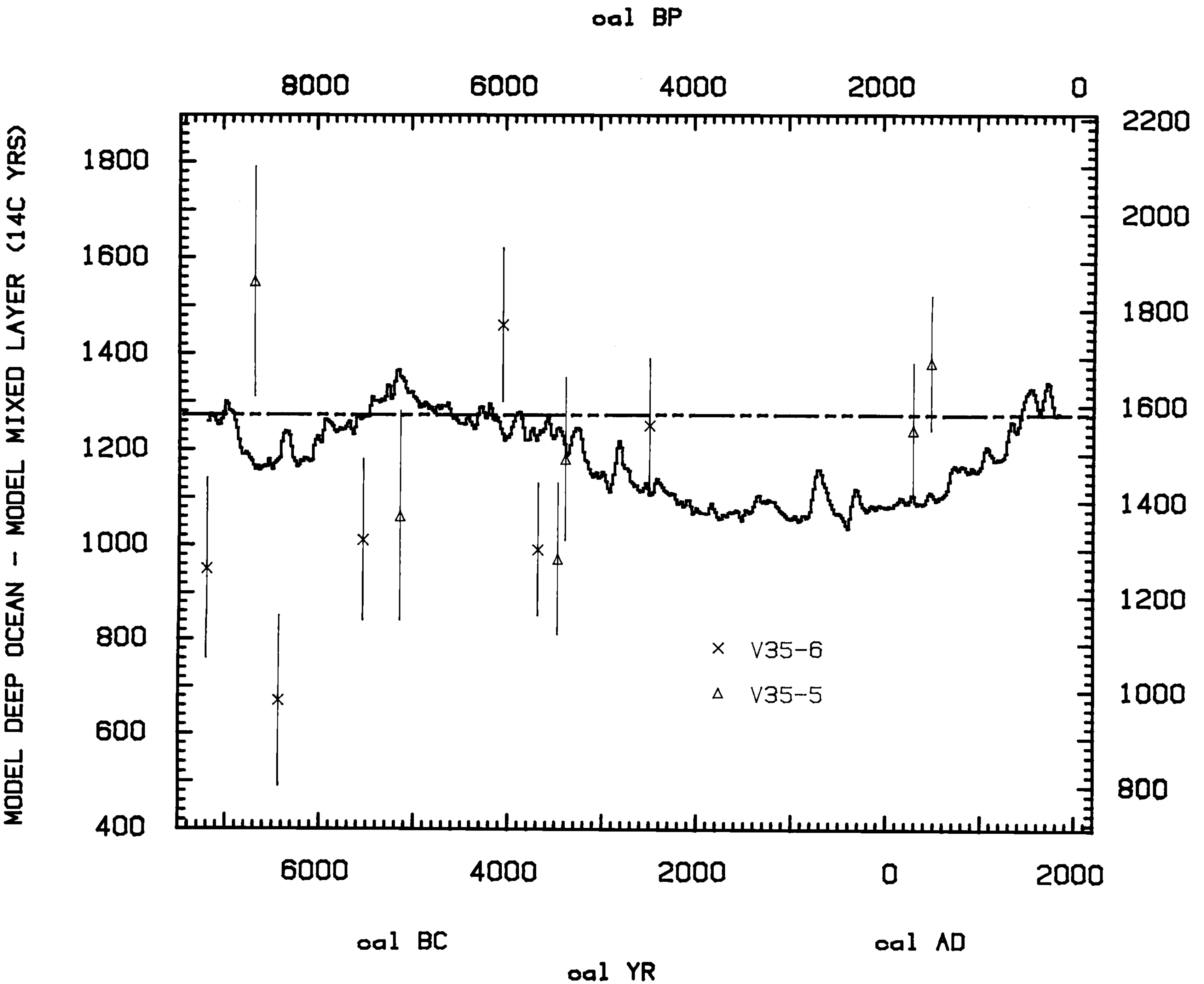


Fig 8. The calculated deep ocean-mixed layer ^{14}C age differences compared to benthic-planktonic differences measured by Andrée *et al* (1986a) for the South China Sea. The deep water in the China Sea is more ^{14}C-deficient than our model ocean, causing a shift between the ^{14}C time scales of 1585 (latest pre-anthropogenic age difference in Andrée *et al*) minus 1275 ^{14}C years (model AD 1830 value), both indicated by the dotted line.

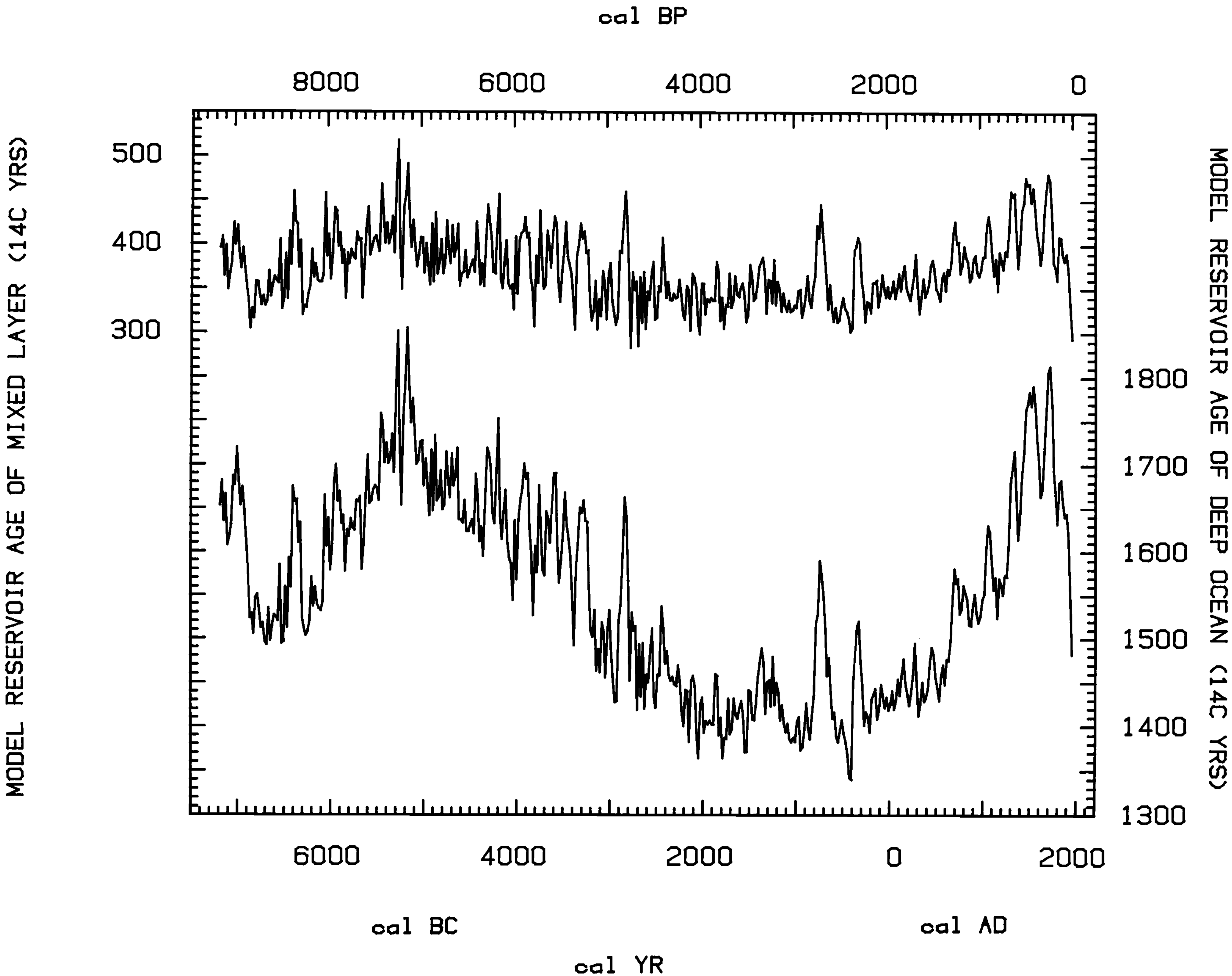


Fig 9. The changing pattern of model-calculated reservoir ages R(t) of the mixed layer (top curve) and the deep ocean (bottom curve).

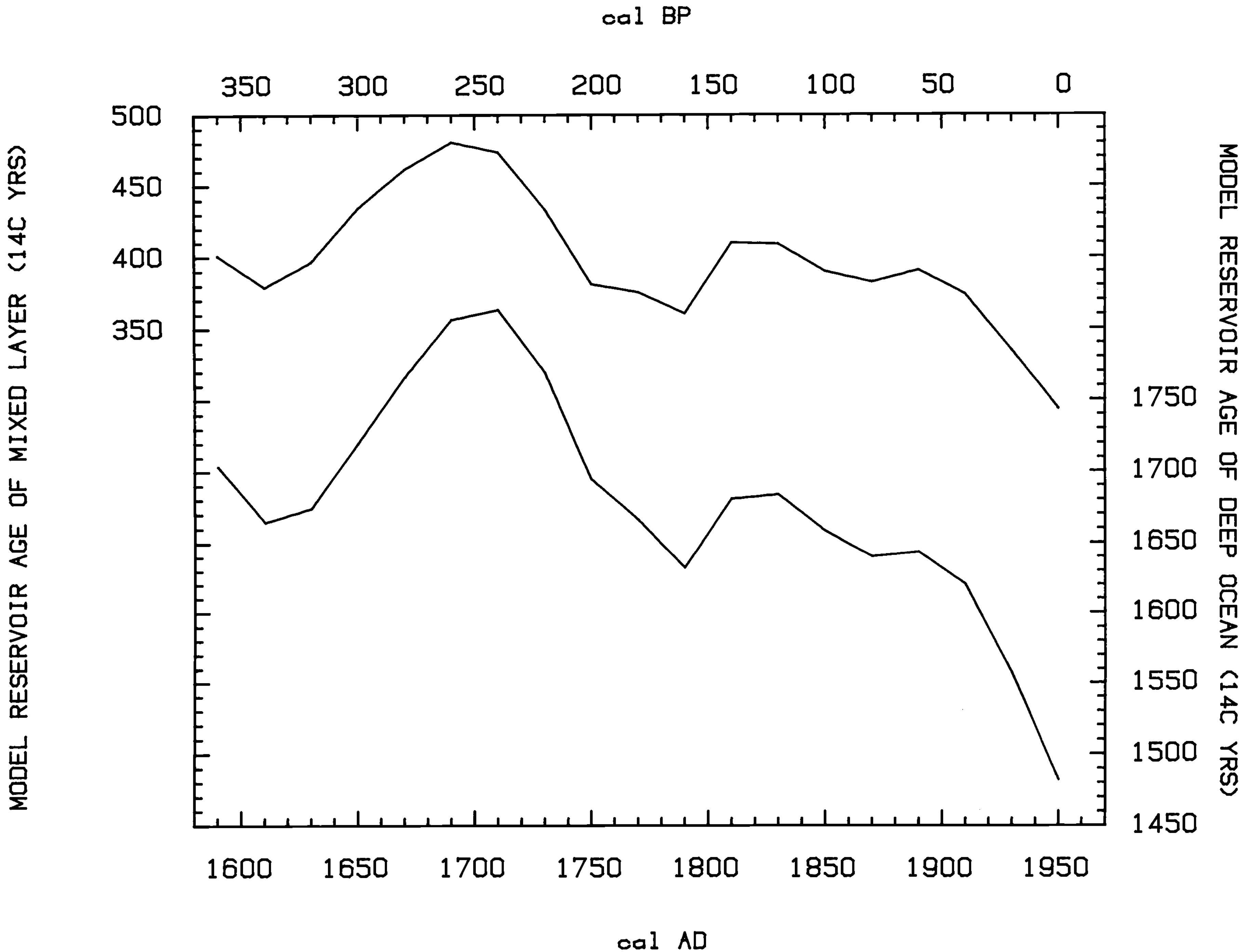


Fig 9B. Model calculated reservoir age for the mixed layer of the ocean (upper curve) and the deep ocean (lower curve).

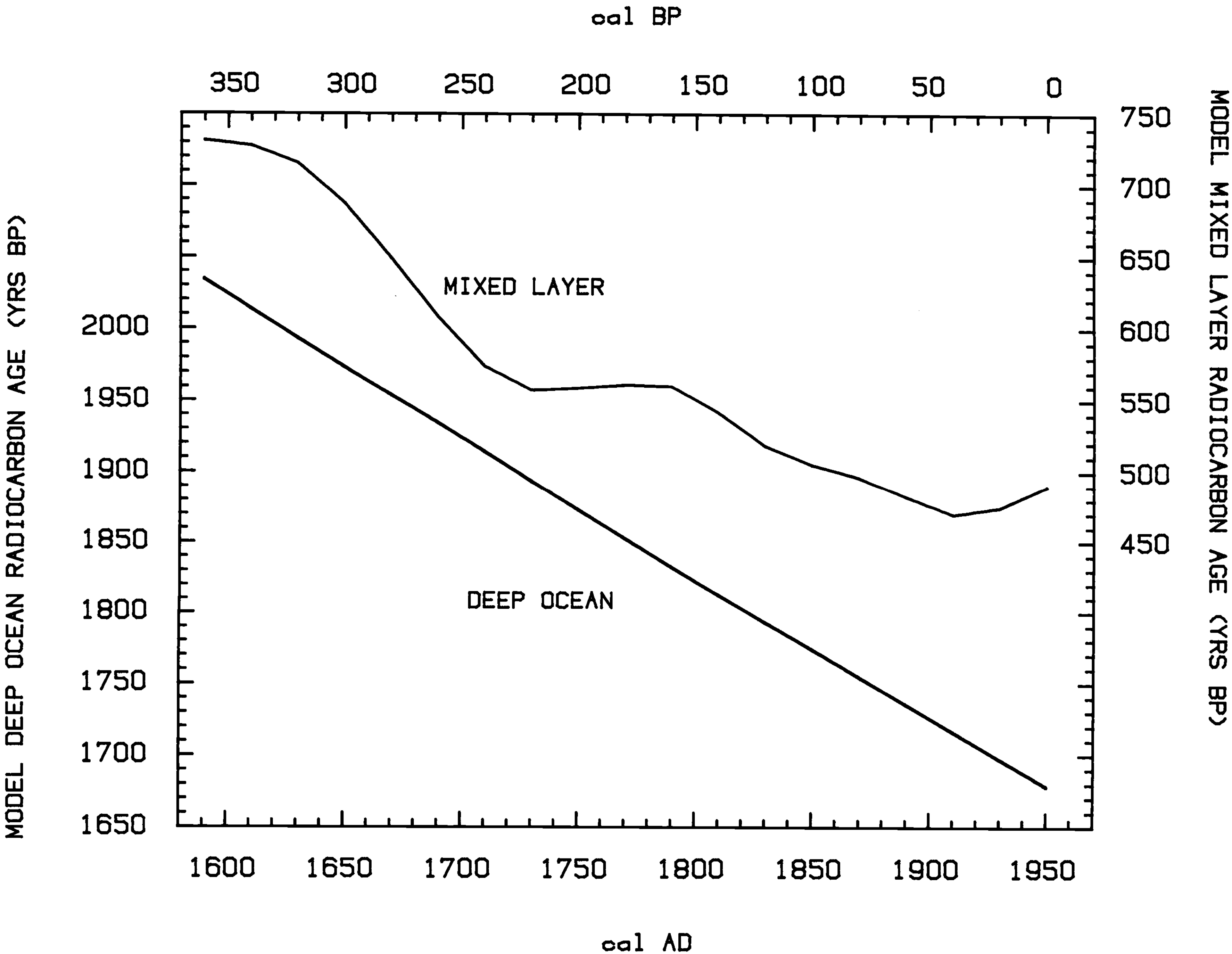


Fig 10A. Model-calculated conventional ^{14}C ages of the mixed layer and deep ocean for the AD 1600–1950 interval.

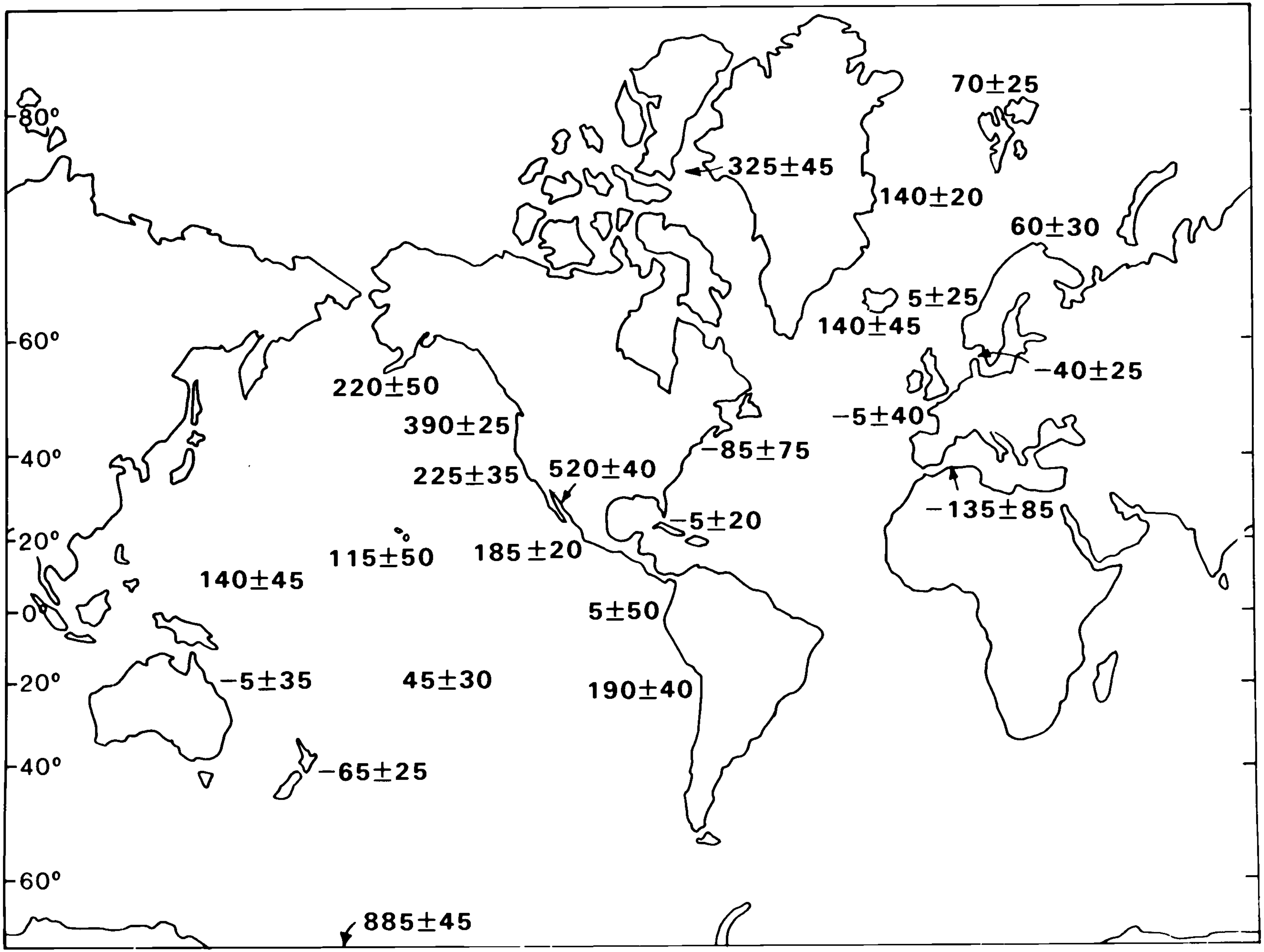


Fig 10B. Coastal region ΔR values in ^{14}C yr as derived mostly from shell dates. The ± values are minimum standard deviations based on the scatter of the data, or the measurement precision, whichever is larger (see Table 1 for details).

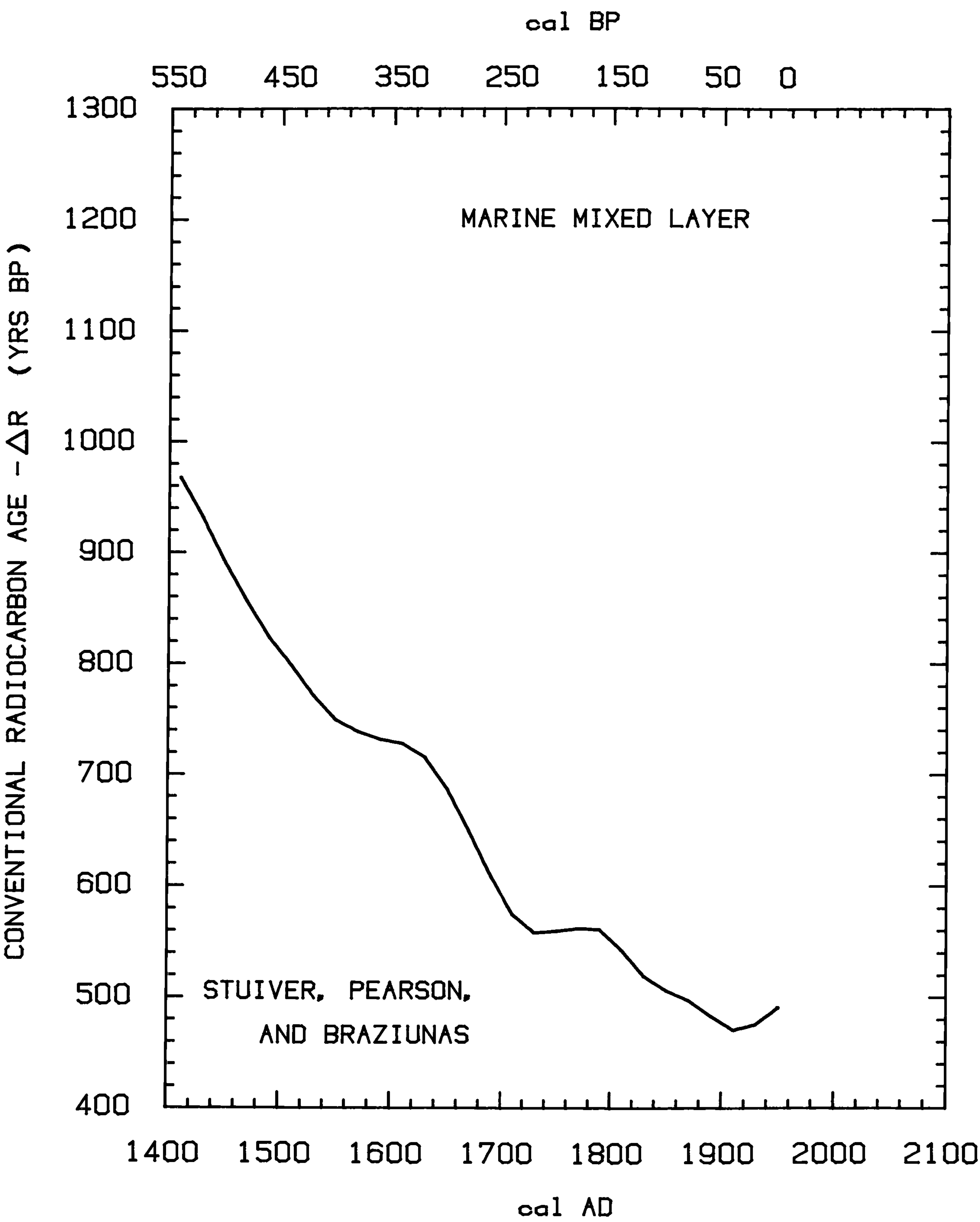


Fig 11. Mixed layer conventional ^{14}C ages *vs* cal AD/BC (cal BP) ages. The value to be substituted for ΔR is discussed in the text.

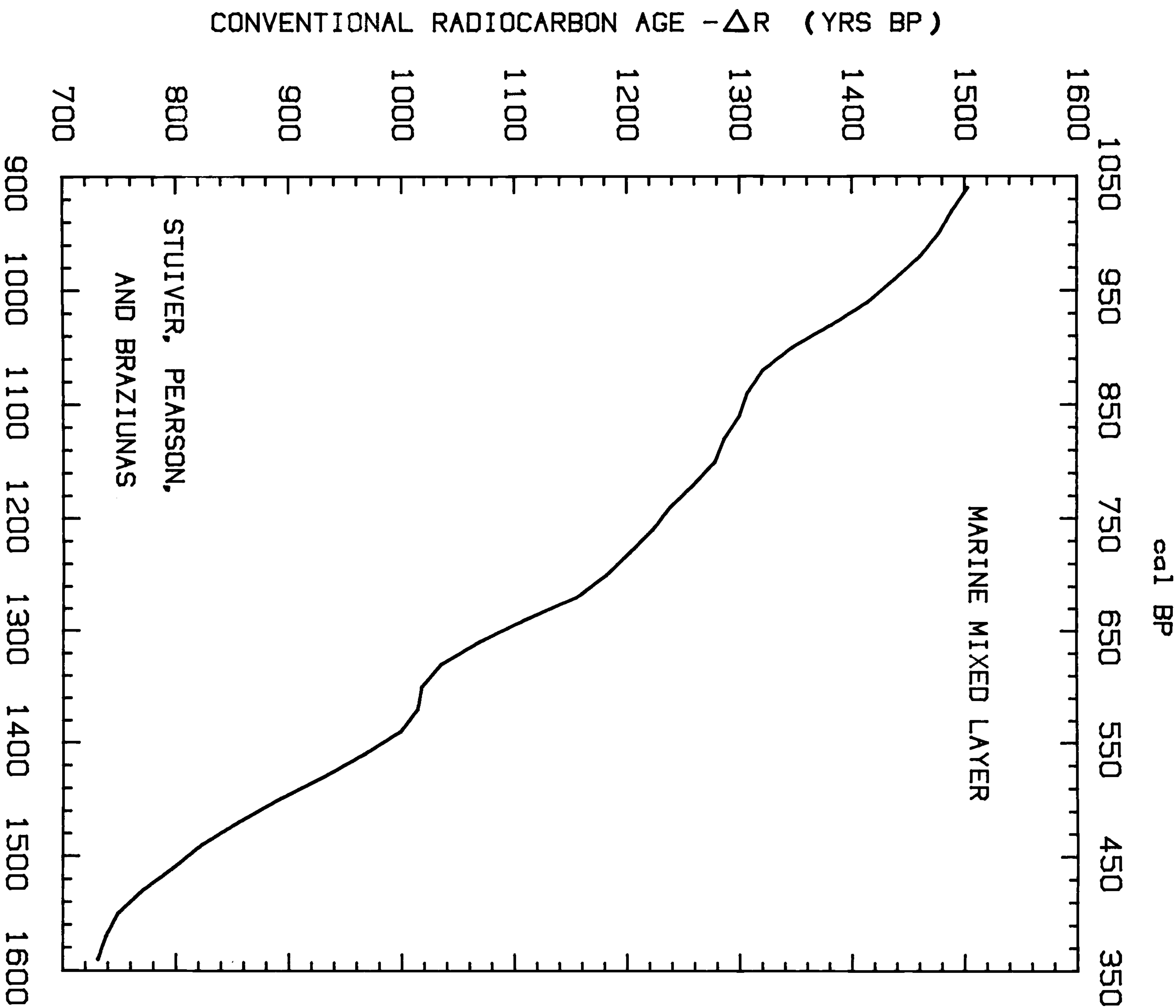
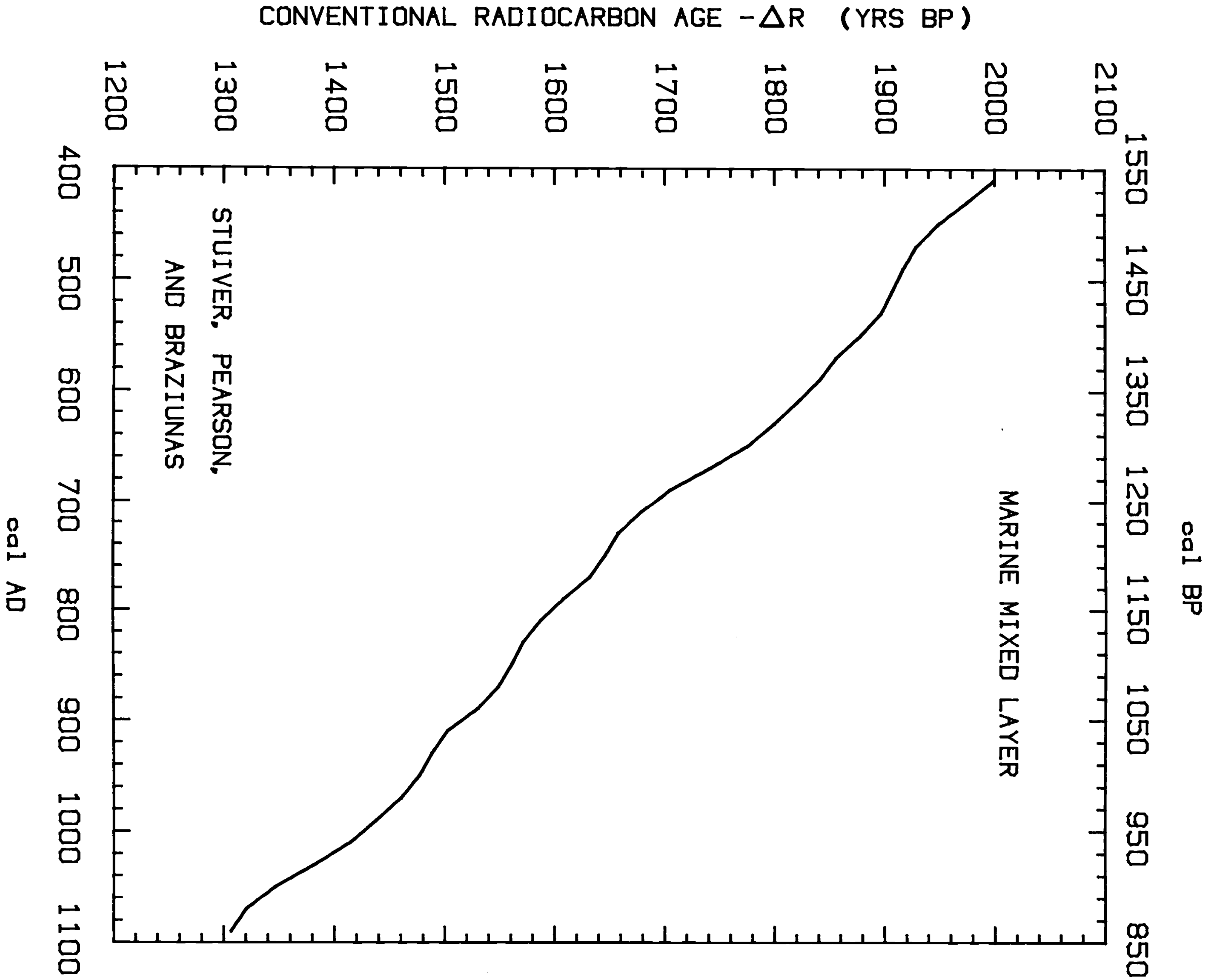

CONVENTIONAL RADIOCARBON AGE −ΔR (YRS BP)
700
800
900
1000
1100
1200
1300
1400
1500
1600
cal BP
1050
950
850
750
650
550
450
350
MARINE MIXED LAYER
STUIVER, PEARSON, AND BRAZIUNAS
cal AD
900
1000
1100
1200
1300
1400
1500
1600

Fig 11B



CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
cal BP
1550
1450
1350
1250
1150
1050
950
850
cal AD
400
500
600
700
800
900
1000
1100
MARINE MIXED LAYER
STUIVER, PEARSON,
AND BRAZIUNAS

Fig 11C

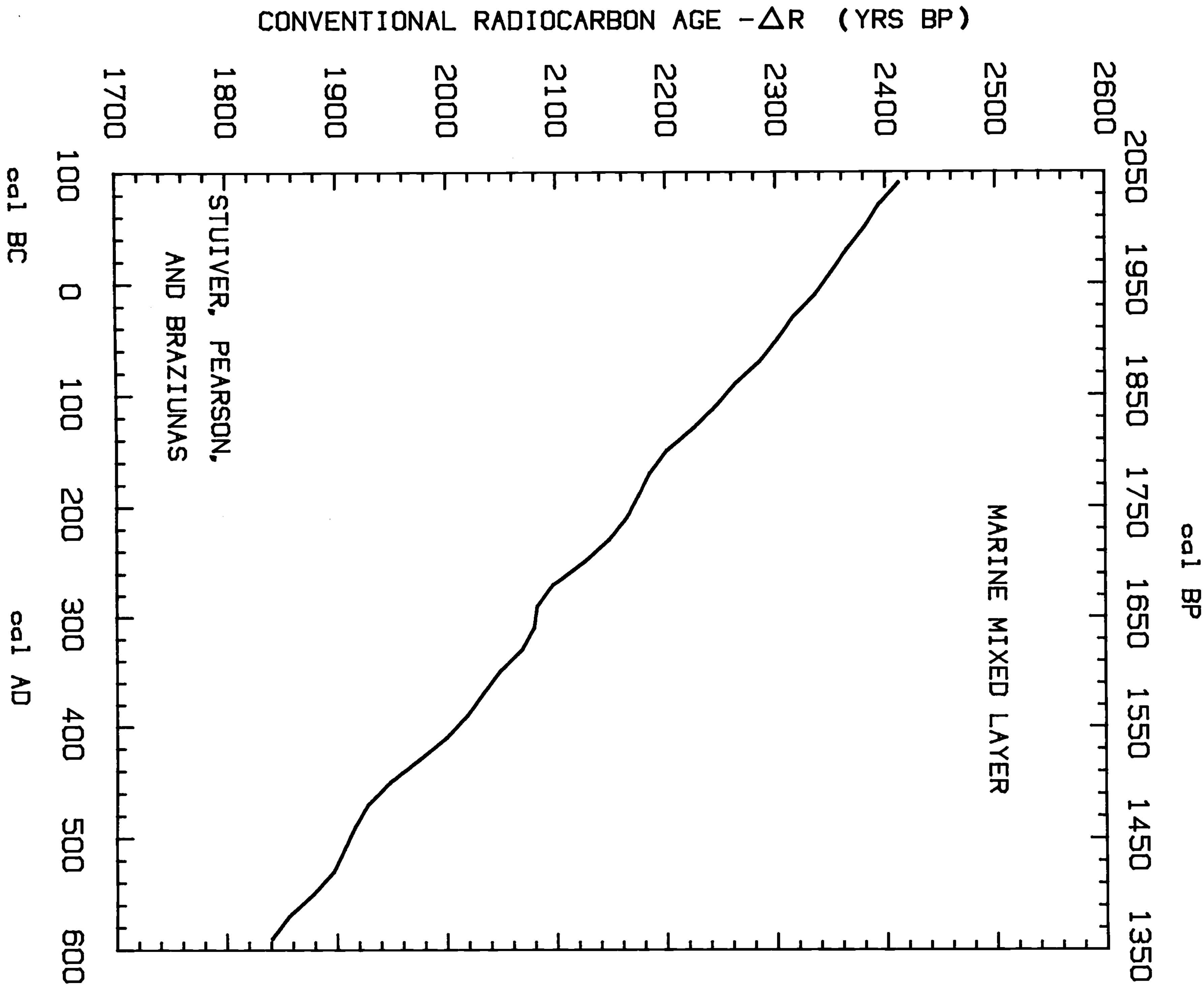
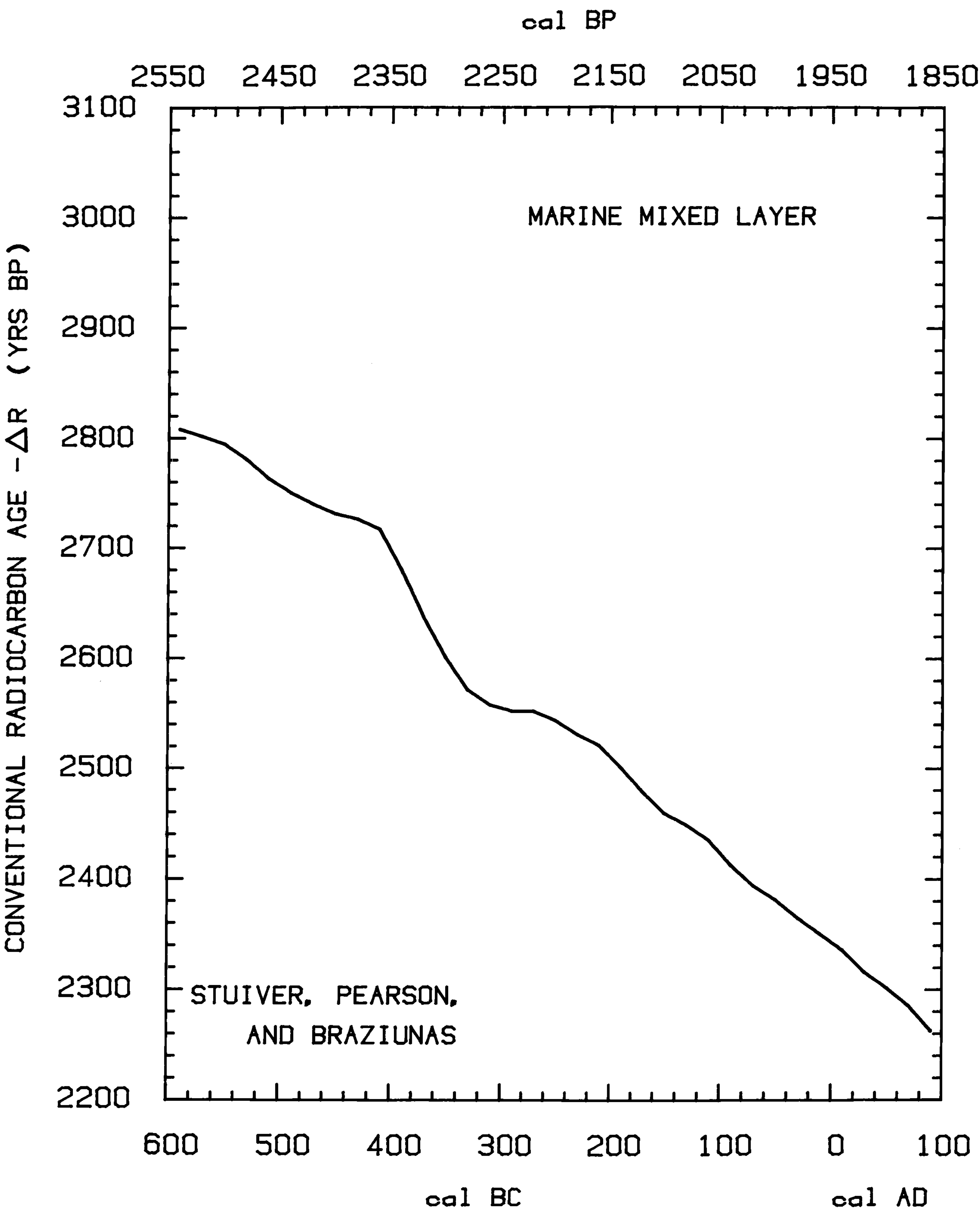

CONVENTIONAL RADIOCARBON AGE −ΔR (YRS BP)
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
cal BP
2050
1950
1850
1750
1650
1550
1450
1350
cal BC
cal AD
100
0
100
200
300
400
500
600
STUIVER, PEARSON,
AND BRAZIUNAS
MARINE MIXED LAYER

Fig 11D


cal BP
2550
2450
2350
2250
2150
2050
1950
1850
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
MARINE MIXED LAYER
STUIVER, PEARSON,
AND BRAZIUNAS
600
500
400
300
200
100
0
100
cal BC
cal AD
Fig 11E

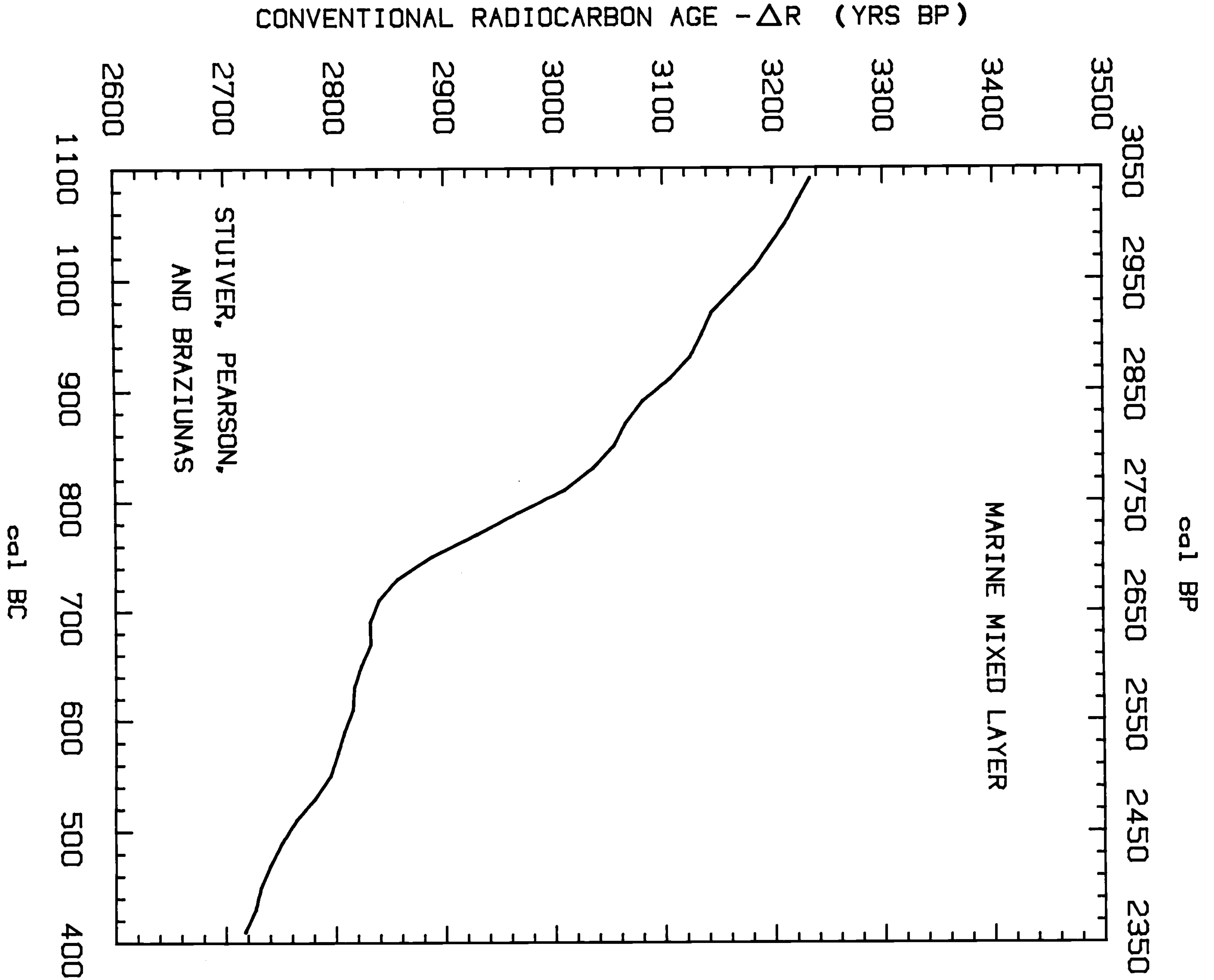

CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
cal BP
3050
2950
2850
2750
2650
2550
2450
2350
cal BC
1100
1000
900
800
700
600
500
400
STUIVER, PEARSON, AND BRAZIUNAS
MARINE MIXED LAYER

Fig 11F

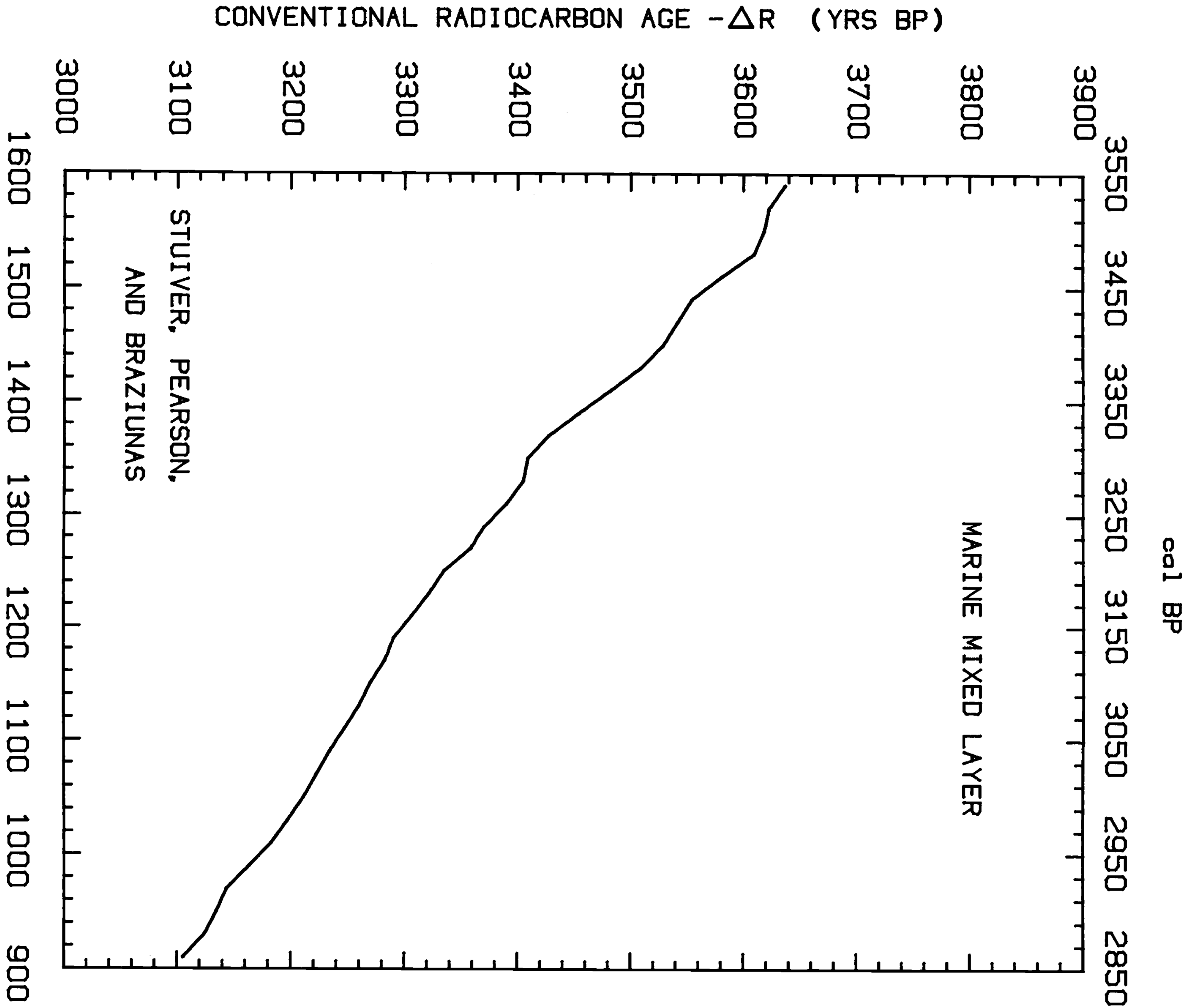

CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
3000 3100 3200 3300 3400 3500 3600 3700 3800 3900
cal BP
3550 3450 3350 3250 3150 3050 2950 2850
MARINE MIXED LAYER
STUIVER, PEARSON,
AND BRAZIUNAS
1600 1500 1400 1300 1200 1100 1000 900
cal BC

Fig 11G

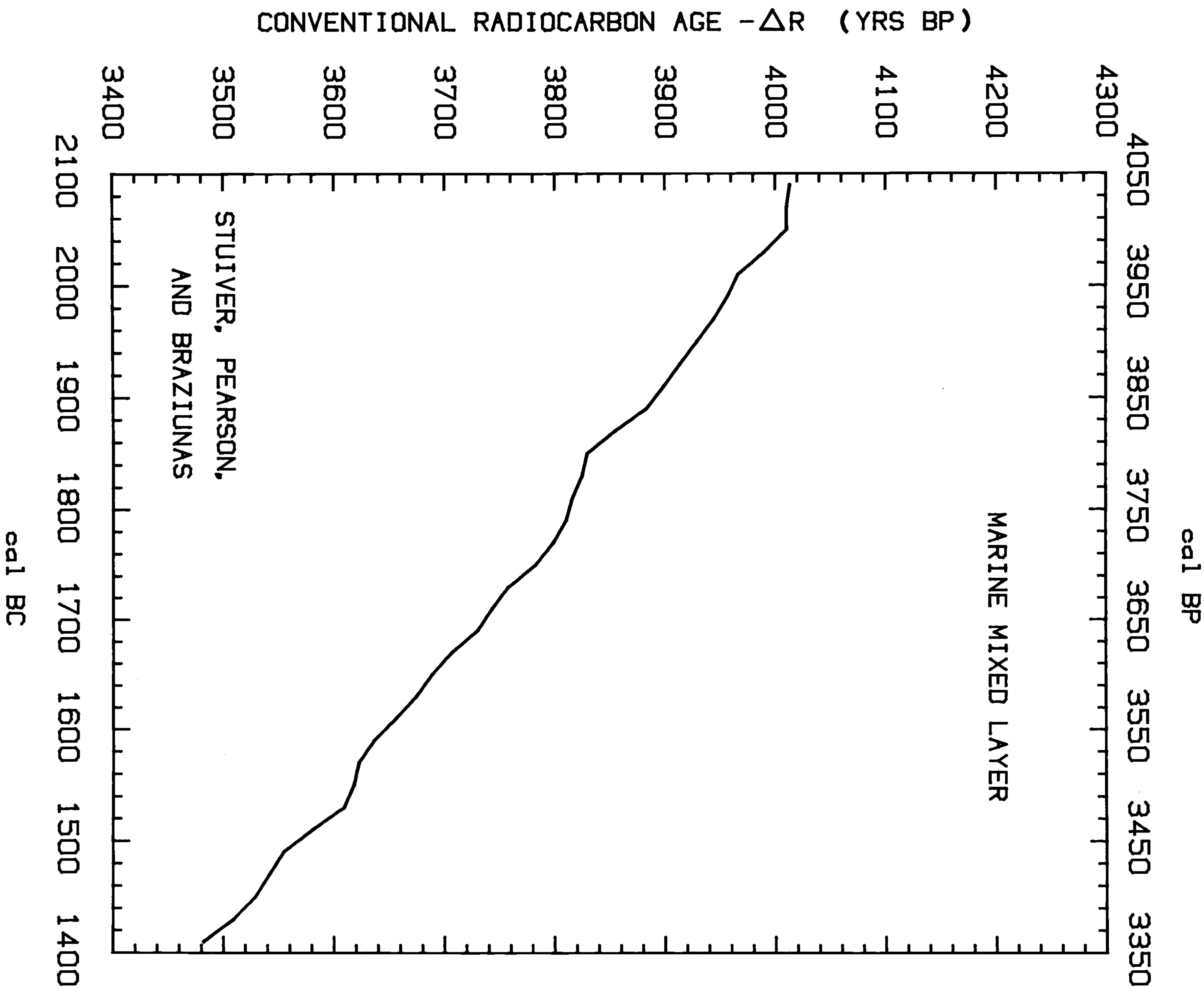

CONVENTIONAL RADIOCARBON AGE −ΔR (YRS BP)
3400
3500
3600
3700
3800
3900
4000
4100
4200
4300
cal BP
4050
3950
3850
3750
3650
3550
3450
3350
cal BC
2100
2000
1900
1800
1700
1600
1500
1400
MARINE MIXED LAYER
STUIVER, PEARSON, AND BRAZIUNAS

Fig 11H

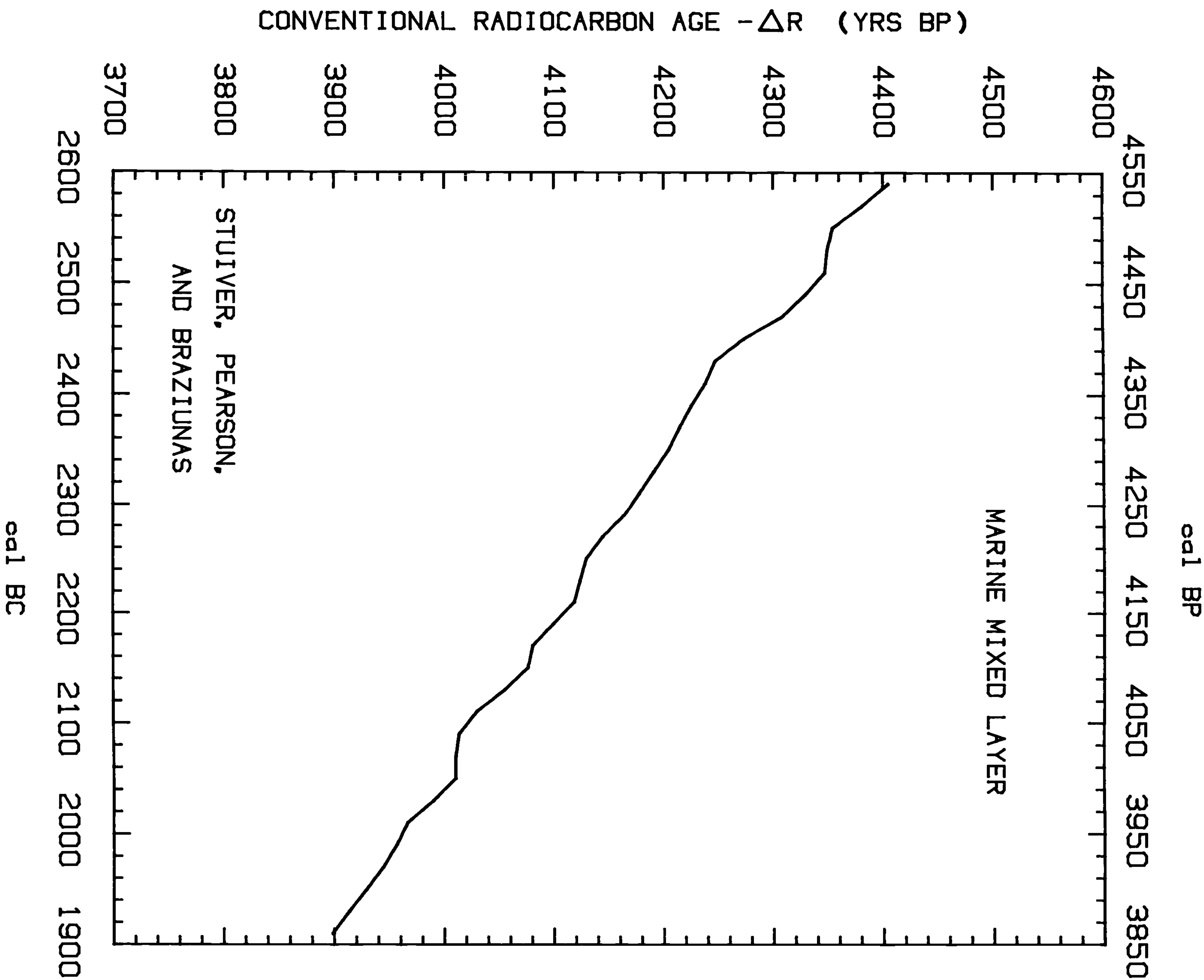

CONVENTIONAL RADIOCARBON AGE −ΔR (YRS BP)
3700
3800
3900
4000
4100
4200
4300
4400
4500
4600
cal BP
4550
4450
4350
4250
4150
4050
3950
3850
cal BC
2600
2500
2400
2300
2200
2100
2000
1900
MARINE MIXED LAYER
STUIVER, PEARSON, AND BRAZIUNAS

Fig 111

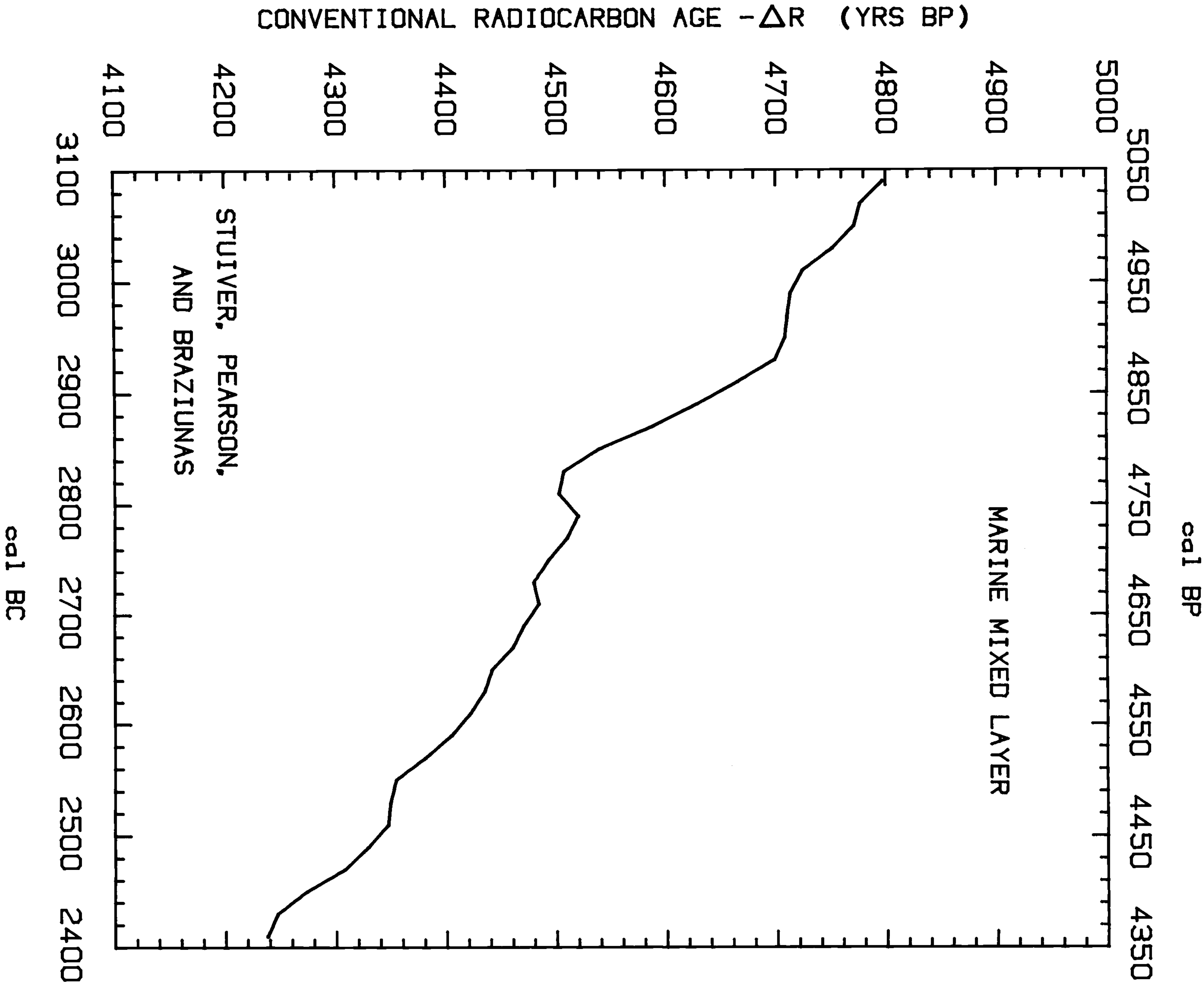

CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
5000
4900
4800
4700
4600
4500
4400
4300
4200
4100
cal BP
5050
4950
4850
4750
4650
4550
4450
4350
MARINE MIXED LAYER
STUIVER, PEARSON,
AND BRAZIUNAS
cal BC
3100
3000
2900
2800
2700
2600
2500
2400

Fig 11J

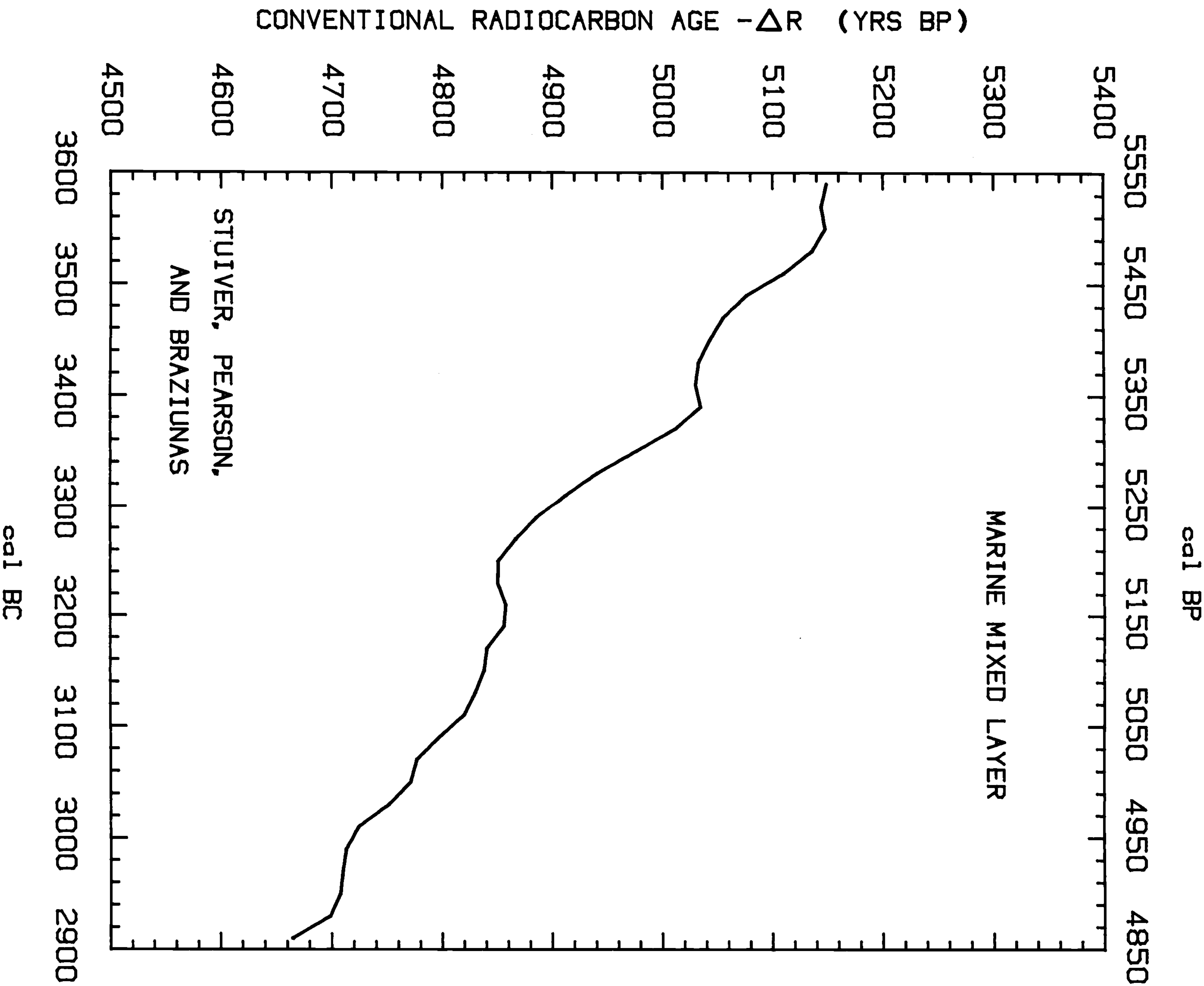
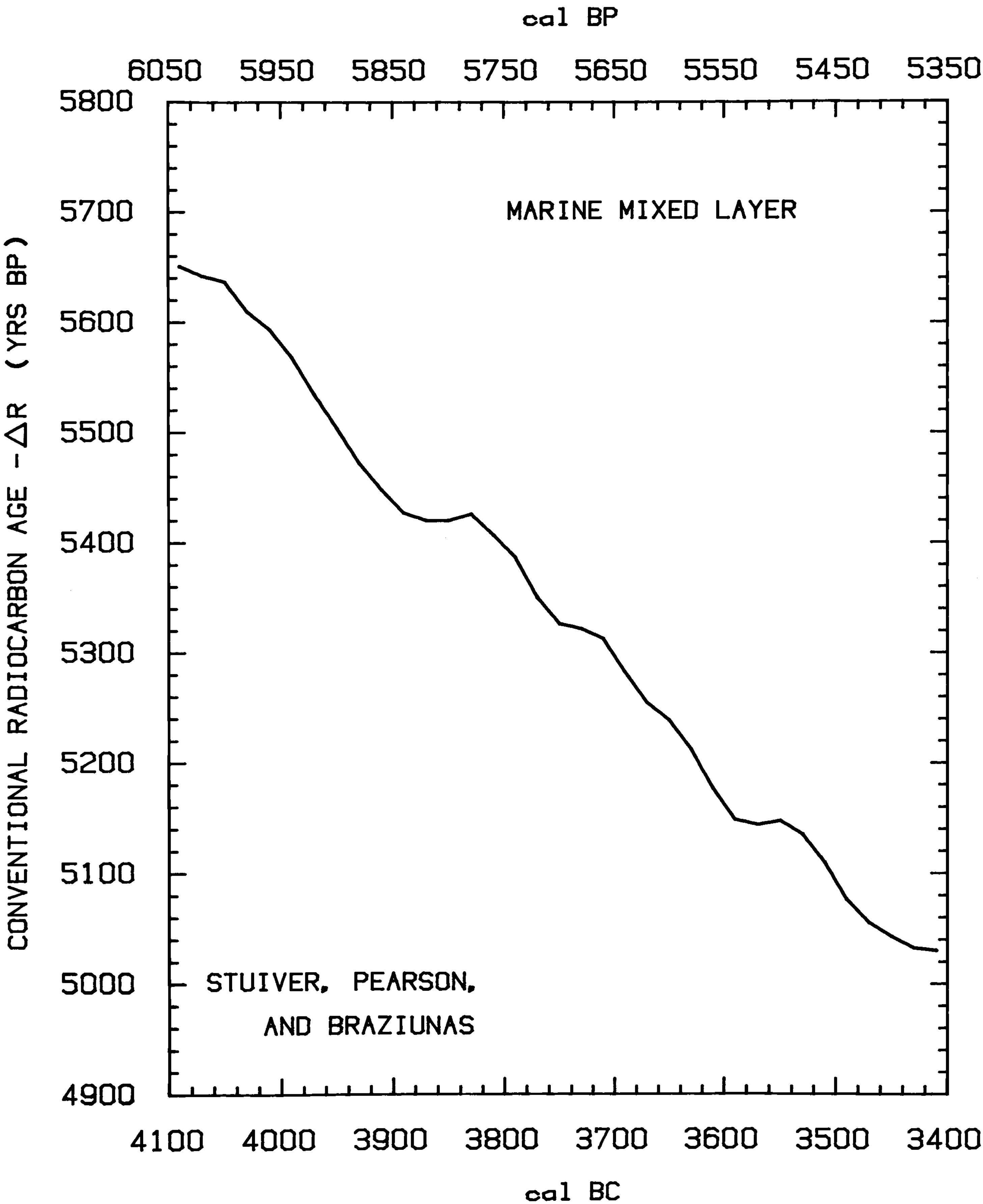

CONVENTIONAL RADIOCARBON AGE −ΔR (YRS BP)
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400
cal BP
5550
5450
5350
5250
5150
5050
4950
4850
cal BC
3600
3500
3400
3300
3200
3100
3000
2900
MARINE MIXED LAYER
STUIVER, PEARSON, AND BRAZIUNAS

Fig 11K


cal BP
6050
5950
5850
5750
5650
5550
5450
5350
CONVENTIONAL RADIOCARBON AGE −ΔR (YRS BP)
5800
5700
5600
5500
5400
5300
5200
5100
5000
4900
MARINE MIXED LAYER
STUIVER, PEARSON,
AND BRAZIUNAS
4100
4000
3900
3800
3700
3600
3500
3400
cal BC
Fig 11L

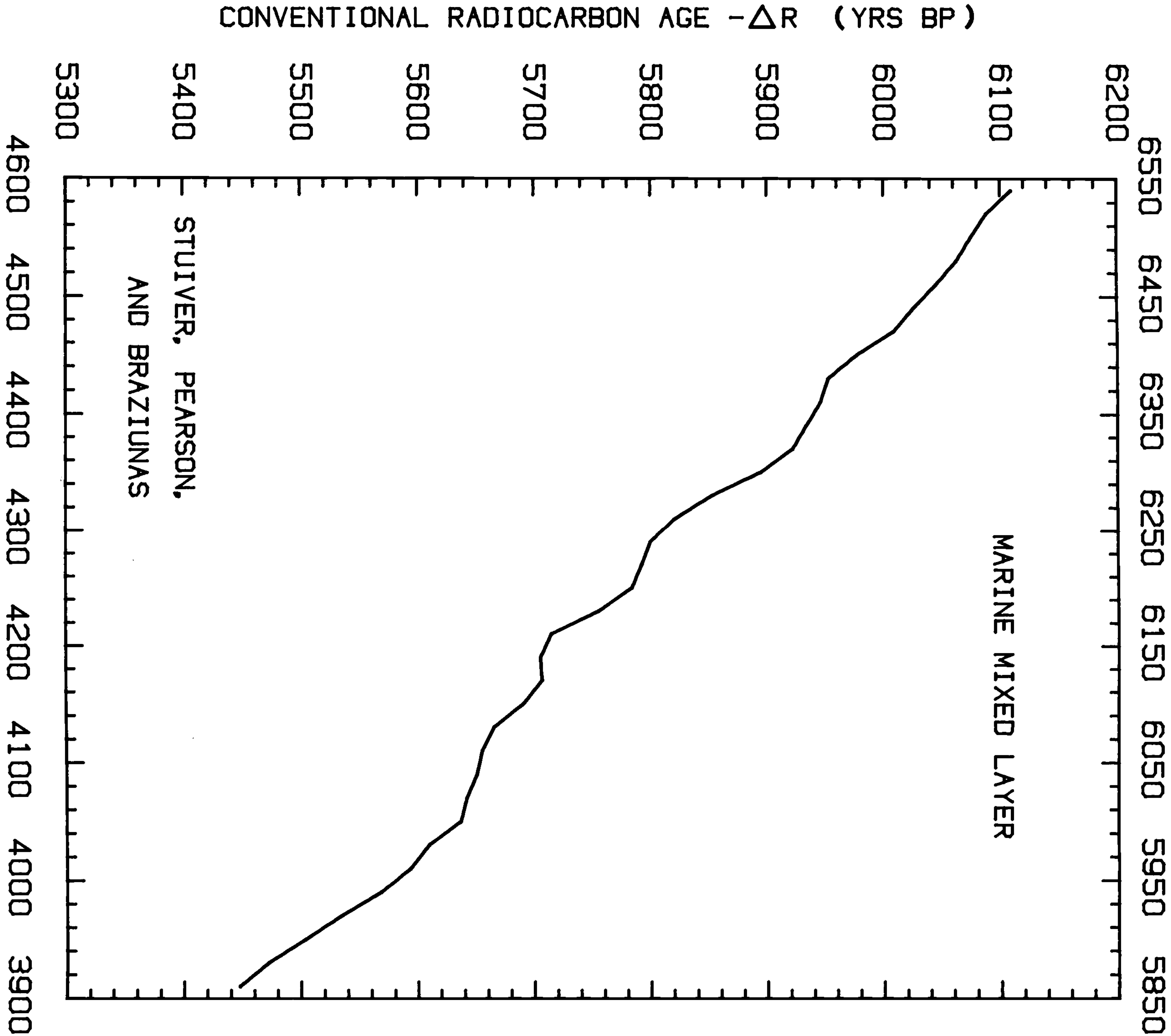

CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
5300
5400
5500
5600
5700
5800
5900
6000
6100
6200
cal BP
6550
6450
6350
6250
6150
6050
5950
5850
cal BC
4600
4500
4400
4300
4200
4100
4000
3900
MARINE MIXED LAYER
STUIVER, PEARSON,
AND BRAZIUNAS

Fig 11M

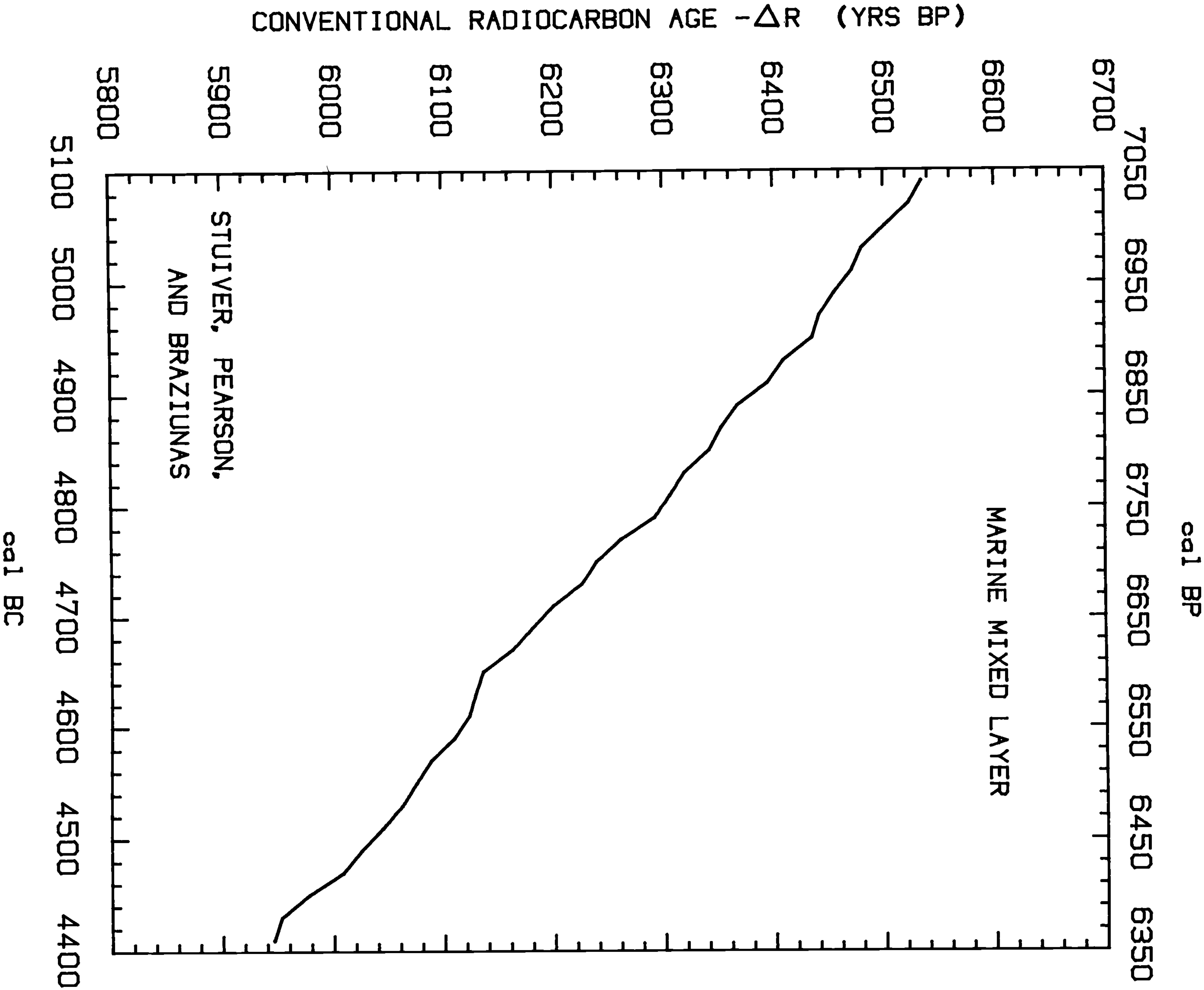

CONVENTIONAL RADIOCARBON AGE −ΔR (YRS BP)
5800 5900 6000 6100 6200 6300 6400 6500 6600 6700
cal BP
7050 6950 6850 6750 6650 6550 6450 6350
MARINE MIXED LAYER
STUIVER, PEARSON,
AND BRAZIUNAS
5100 5000 4900 4800 4700 4600 4500 4400
cal BC

Fig 11N

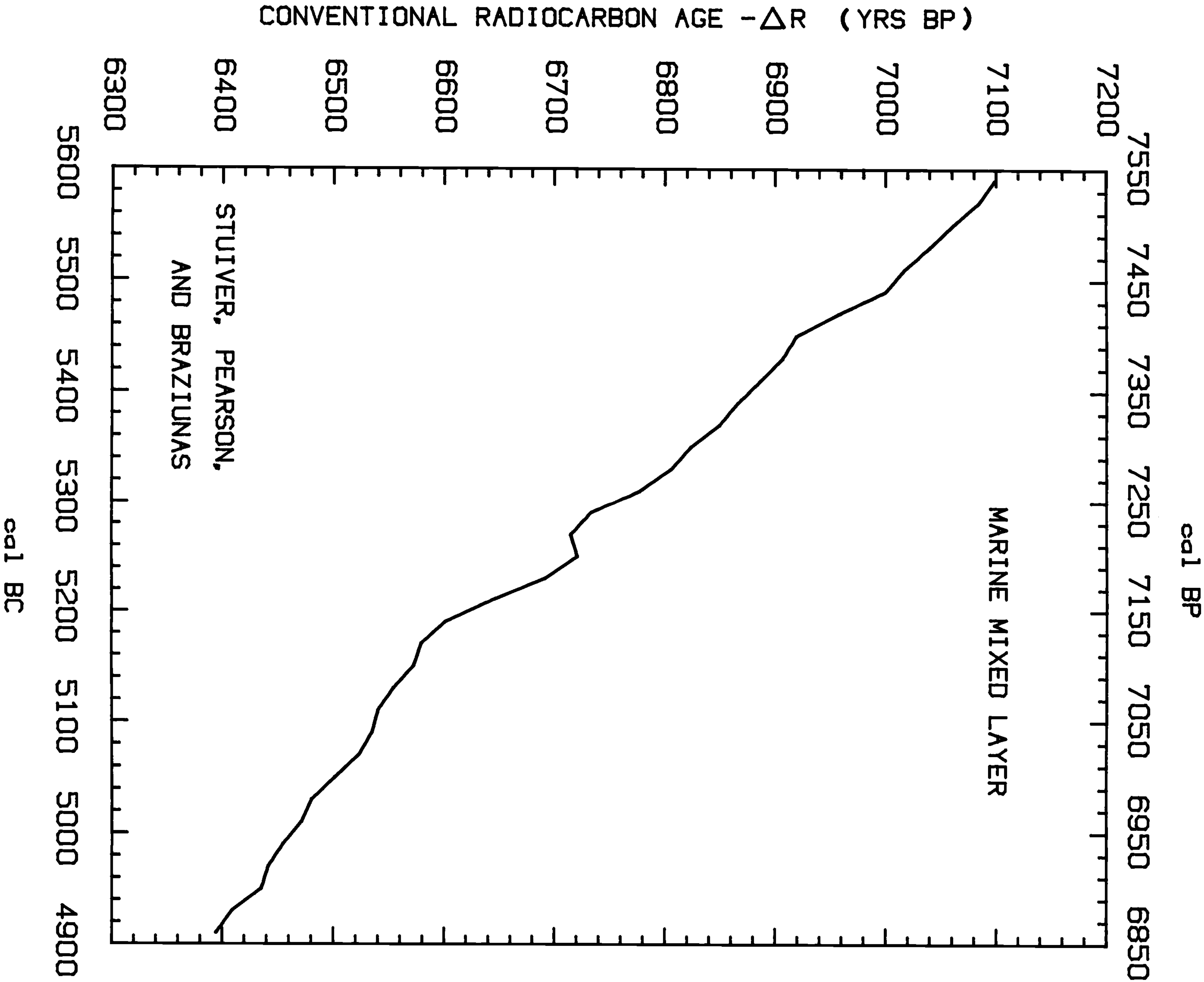

CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
6300
6400
6500
6600
6700
6800
6900
7000
7100
7200
cal BP
7550
7450
7350
7250
7150
7050
6950
6850
cal BC
5600
5500
5400
5300
5200
5100
5000
4900
STUIVER, PEARSON, AND BRAZIUNAS
MARINE MIXED LAYER

Fig 11O

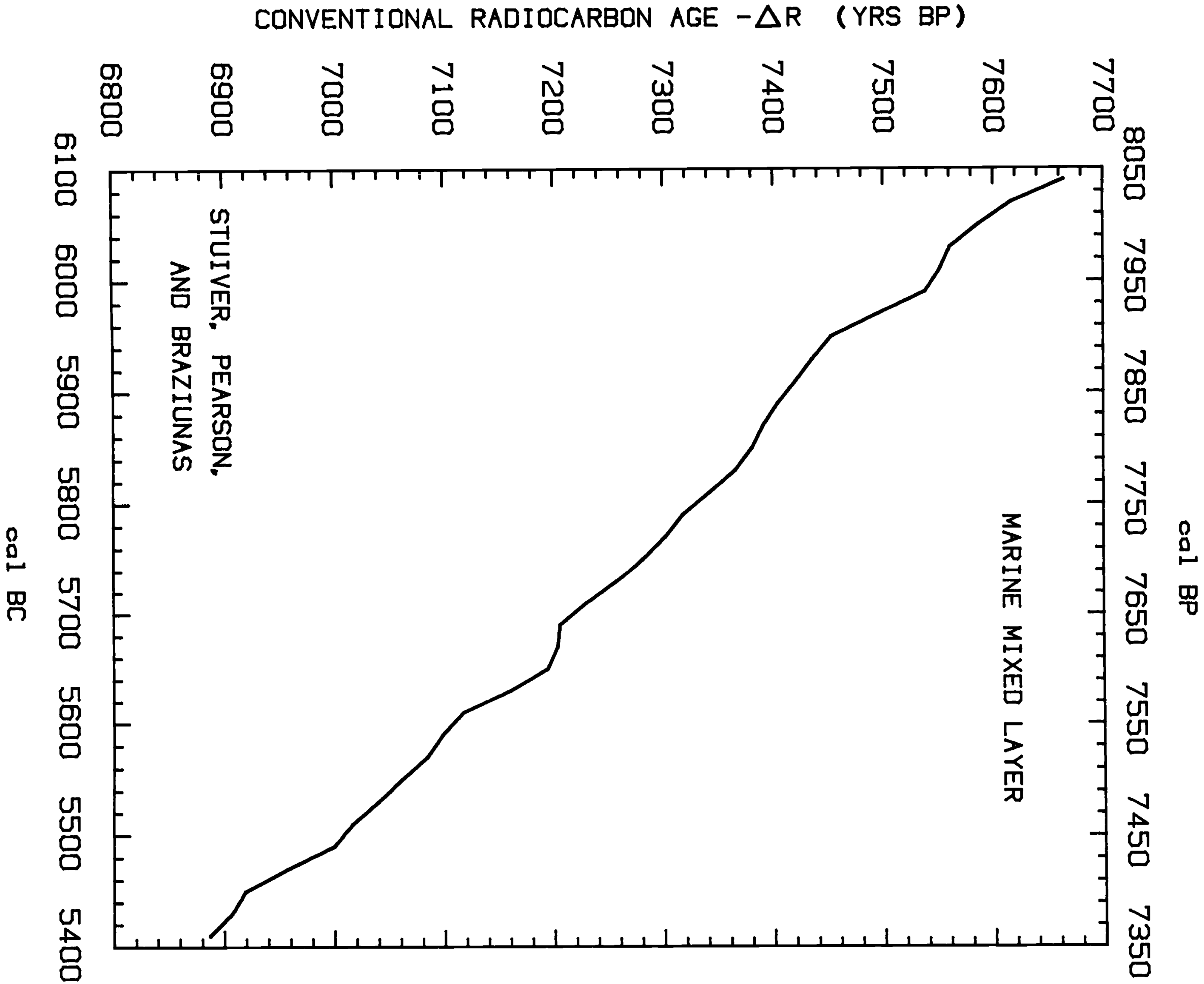
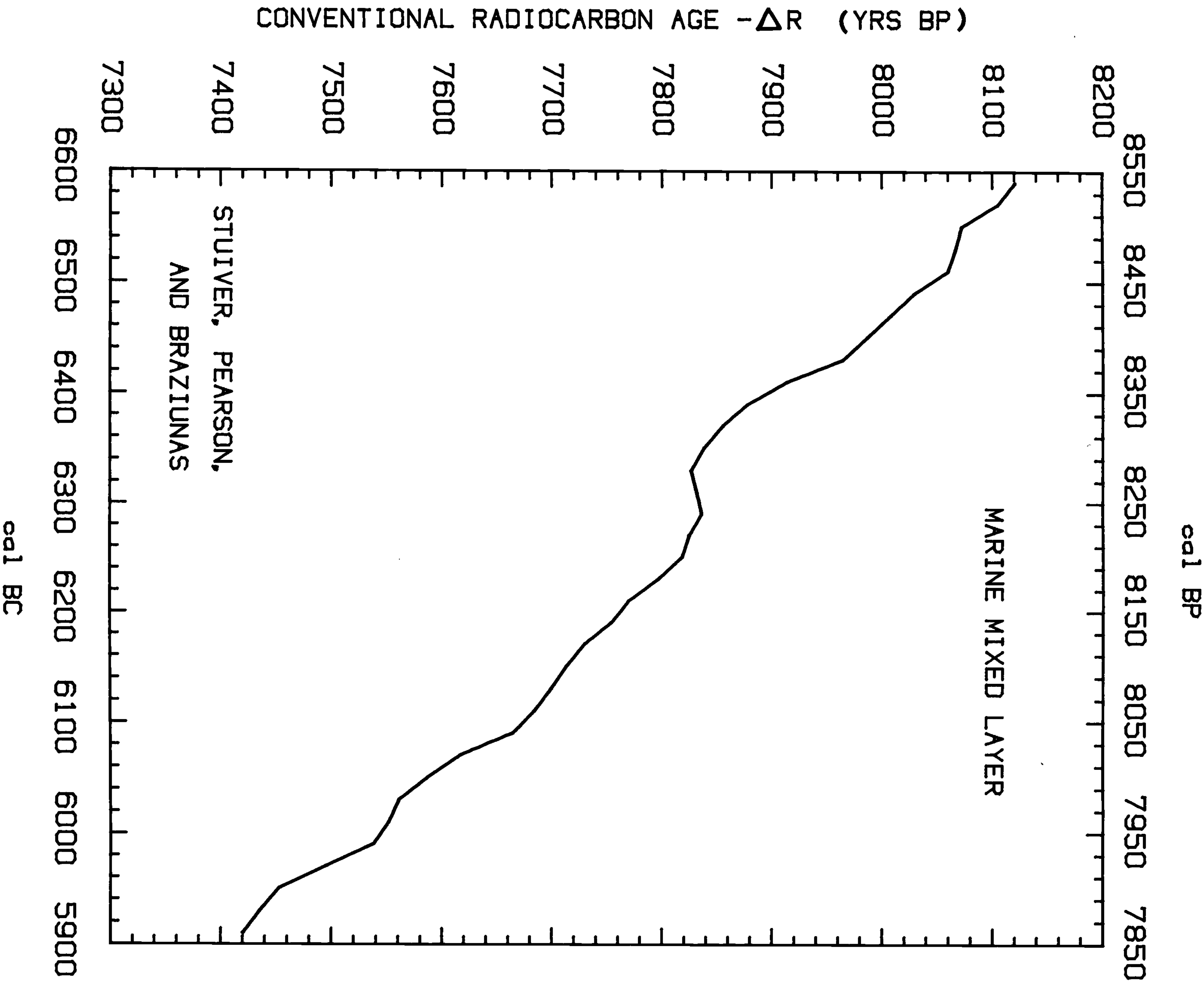

CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
6800
6900
7000
7100
7200
7300
7400
7500
7600
7700
cal BP
8050
7950
7850
7750
7650
7550
7450
7350
cal BC
6100
6000
5900
5800
5700
5600
5500
5400
MARINE MIXED LAYER
STUIVER, PEARSON, AND BRAZIUNAS

Fig 11P


CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
7300
7400
7500
7600
7700
7800
7900
8000
8100
8200
cal BP
8550
8450
8350
8250
8150
8050
7950
7850
cal BC
6600
6500
6400
6300
6200
6100
6000
5900
STUIVER, PEARSON,
AND BRAZIUNAS
MARINE MIXED LAYER
Fig 11Q

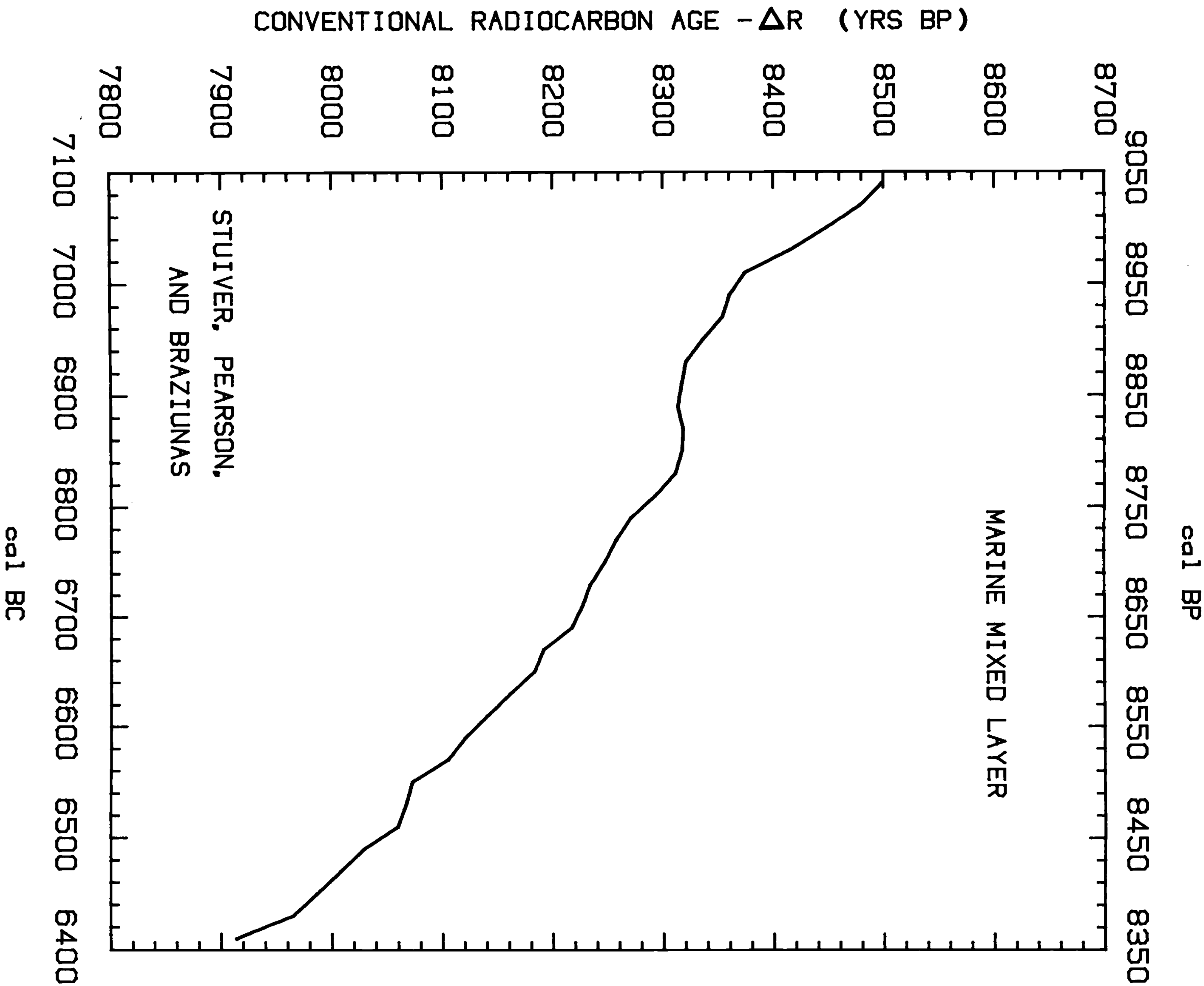

CONVENTIONAL RADIOCARBON AGE −ΔR (YRS BP)
7800
7900
8000
8100
8200
8300
8400
8500
8600
8700
9050
8950
8850
8750
8650
8550
8450
8350
cal BP
7100
7000
6900
6800
6700
6600
6500
6400
cal BC
STUIVER, PEARSON,
AND BRAZIUNAS
MARINE MIXED LAYER

Fig 11R

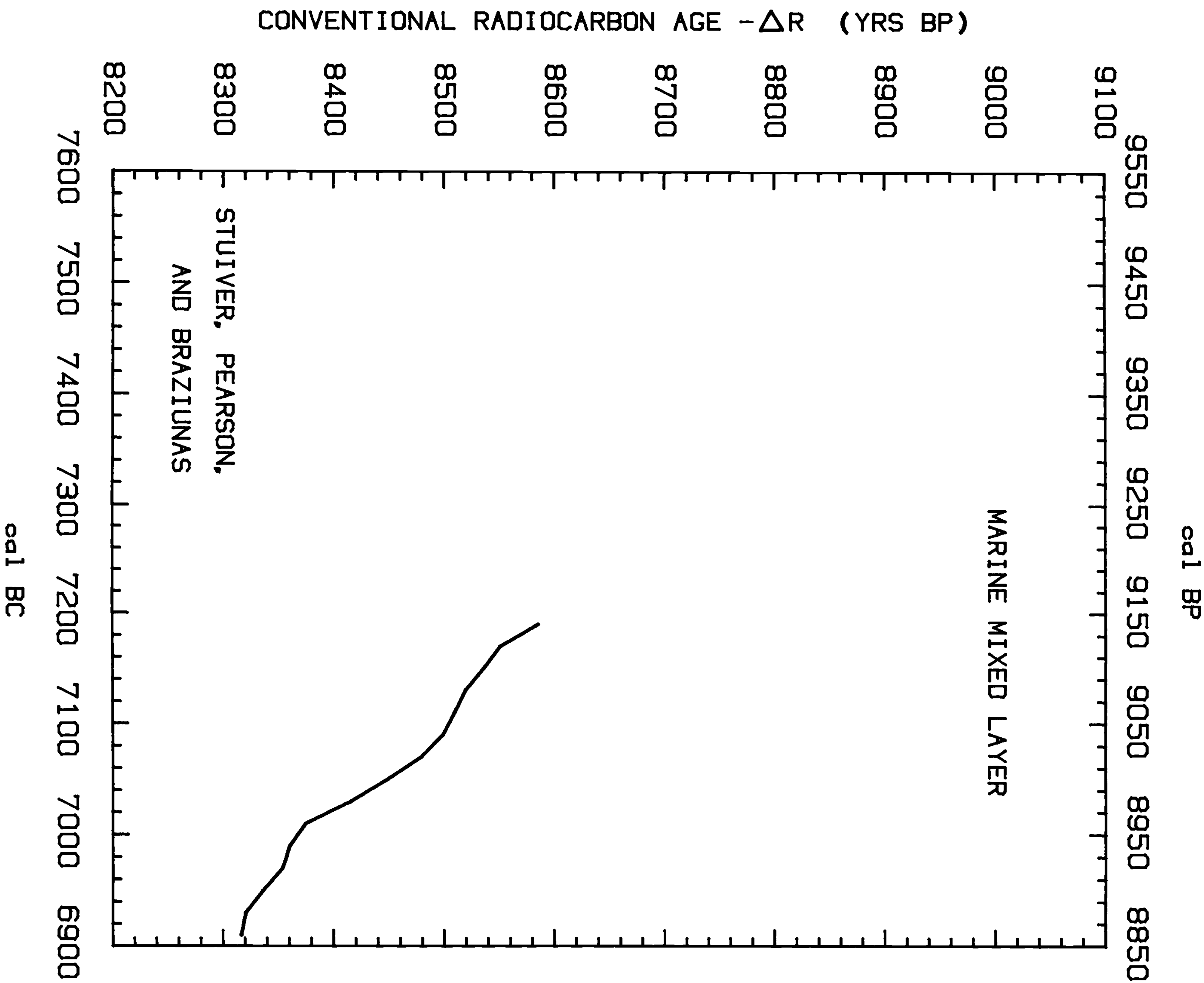

CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
8200
8300
8400
8500
8600
8700
8800
8900
9000
9100
cal BP
9550
9450
9350
9250
9150
9050
8950
8850
cal BC
7600
7500
7400
7300
7200
7100
7000
6900
STUIVER, PEARSON, AND BRAZIUNAS
MARINE MIXED LAYER

Fig 11S

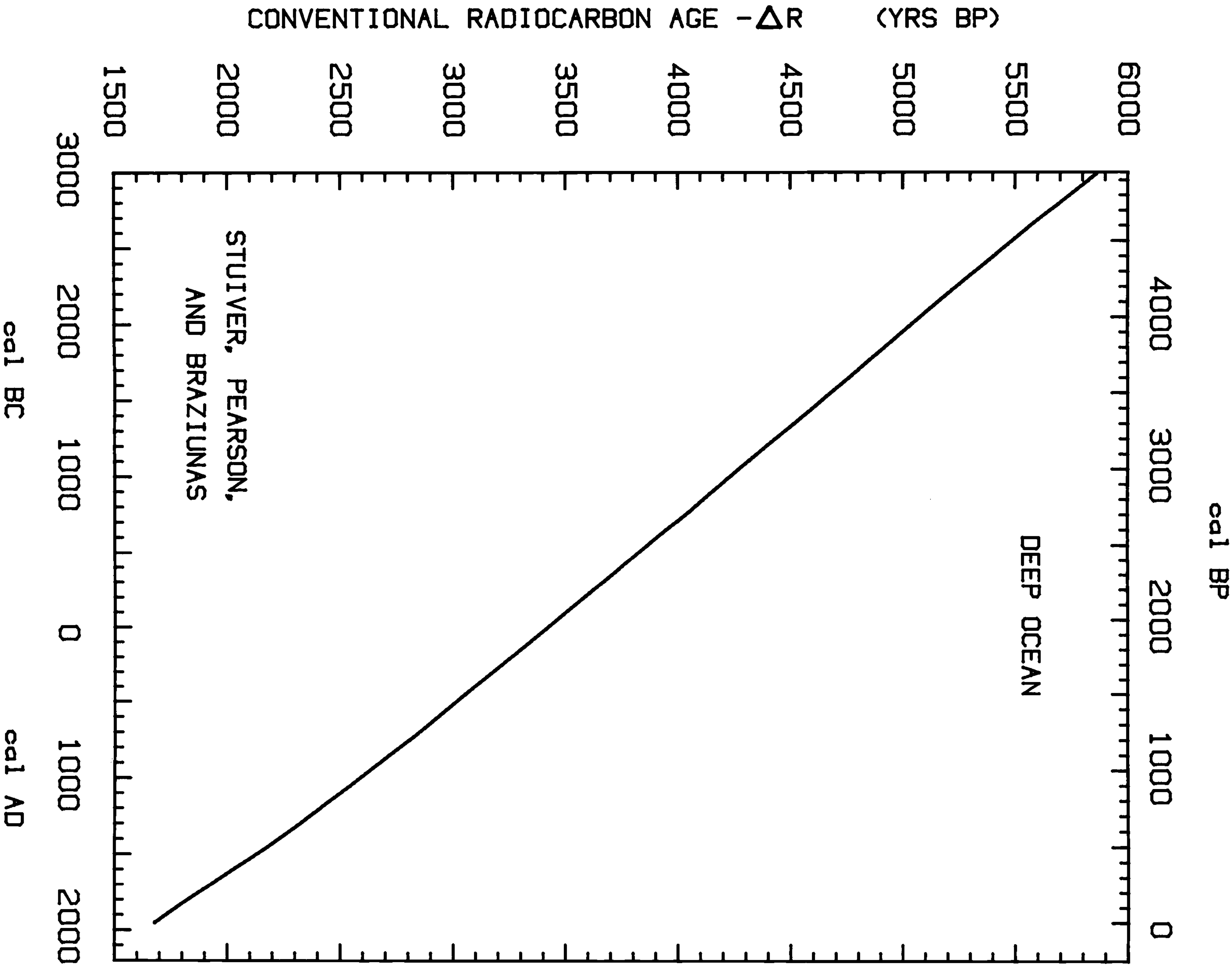


Fig 12. Deep ocean conventional ^{14}C ages *vs* cal AD/BC (cal BP) ages. ΔR is discussed in the text.

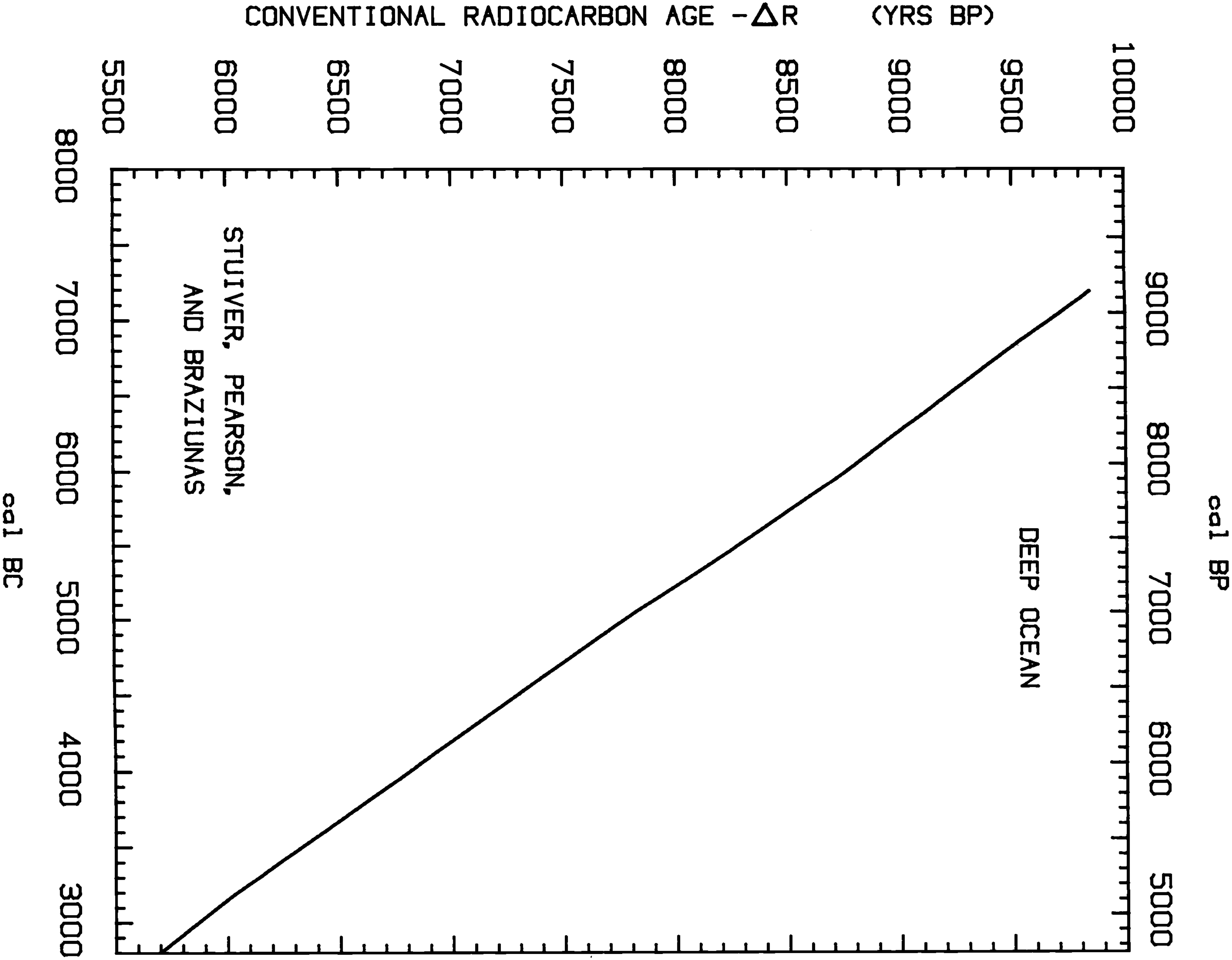

CONVENTIONAL RADIOCARBON AGE -ΔR (YRS BP)
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
cal BP
9000
8000
7000
6000
5000
cal BC
8000
7000
6000
5000
4000
3000
STUIVER, PEARSON, AND BRAZIUNAS
DEEP OCEAN

Fig 12B

TABLE 1
Marine radiocarbon ages and ΔR values of mostly shell samples of known historic age

MARINE SHELLS[a] REF[b]	REGION[c]	SAMPLE #	HISTORICAL AGE (cal AD)[d]	CONVENTIONAL SAMPLE ^{14}C AGE (^{14}C YRS BP)[e]	ΔR (^{14}C YRS BP)[f]
11,9	Diabasvika, Lagoya, Spitsbergen 80°34'N 18°35'E	U-121	1958[g]	670±80	180±80[h]
11,9	NE side of Nordre, Russoya, Murchisonfjorden, Spitsbergen 80°0'N 18°9'E	U-122	1958[g]	430±80	-60±80[h]
10	Magdalenafj., Spitsbergen 79°34'N 10°40'E	T-1541	1878	632±70	141±70
11,9	Tangen, Mushamna, Spitsbergen 79°30'N 14°E	U-133	1952[g]	530±70	40±60[h]
10	Adventbukta, Spitsbergen 78°15'N 15°36'E	T-1540	1878	622±70	131±70
10	Isfjorden, Spitsbergen 78°07'N 14°08'E	T-1539	1925	519±50	45±50
10	Bellsund, Spitsbergen ca. 77°40'N 14-16°E	T-1538	1926	549±50	75±50
10	Near Bear Island 74°07'N 19°04'E	T-1537	1900	523±50	46±50
	WEIGHTED MEAN OF ABOVE 8 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 25 YR				70±20
10	Rice Strait, Smith Sound, Ellesmere Island 78°45'N 74°55'E	T-1544	1898	744±70	266±70
10	Goose Bay, Jones Sound, Ellesmere Island ca. 76°45'N 89°00'E	T-1543	1900	893±70	416±70
10	Havnefjorden, Jones Sound, Ellesmere Island 76°30'N 84°30'E	T-1542	1899	774±70	297±70
	WEIGHTED MEAN OF ABOVE 3 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 45 YR				325±40
8	S of L. Pendulumoen and SE of Claveringoen, NE Greenland 74°35'N 18°23'W and 74°10'N 20°08'W	Lu-650	1899	591±38	114±38
8	Mackenziebugt, NE Greenland 73°28'N 21°30'W	Lu-609	1900	650±47	173±47
8	Mackenziebugt, NE Greenland 73°28'N 21°30'W	Lu-610	1900	620±54	143±54

TABLE 1 (continued)

REF[b]	REGION[c]	SAMPLE #	HISTORICAL AGE (cal AD)[d]	CONVENTIONAL SAMPLE ^{14}C AGE (^{14}C YRS BP)[e]	ΔR (^{14}C YRS BP)[f]
MARINE SHELLS[a]					
8	Fame Oer, Scoresby Sund, NE Greenland 70°50'N 22°33'W	Lu-643	1899	641±39	164±39
17	S cove, Nyhavn, NE Greenland (ca. 72°N 23°W)	Y-606	1957	550±70	60±70[h]
	WEIGHTED MEAN OF ABOVE 5 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 20 YR				140±20
10	Tanafjord, Finnmark, N Norway 70°30'-71° N ca. 28°30'E	T-1535	1876	584±70	91±70
9	Komagfjord, Finnmark, N Norway 70°16'N 23°24'E	T-958	1922	548±75	75±75
10	Vadso, Finnmark, N Norway 70°04'N 29°45'E	T-1536	1857	543±50	41±50
10	Tromso, Troms, N Norway 69°39'N 18°58'E	T-1534	1857	553±50	51±50
	WEIGHTED MEAN OF ABOVE 4 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 10 YR				60±30
3	Faxa Bay, Kollafjord, Iceland 64°N 22°W	L-576C	1946	543±51	56±51
3	Faxa Bay, Kollafjord, Iceland 64°N 22°W	L-576H	1900	631±51	154±51
3	Faxa Bay, Kollafjord, Iceland 64°N 22°W	L-576I	1840	715±51	203±51
	WEIGHTED MEAN OF ABOVE 3 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 45 YR				140±30
9	Fjaerlandsfjorden, Sogn, Norway Btwn 61°13'N 6°34'E and 61°22'N 5°00'E	T-953	1909	541±80	70±80
9	Leikanger, Sognefjord, Norway 61°11'N 6°48'E	T-951	1912	438±75	-33±75
9	Vangsnes, Sognefjord, Norway 61°10'N 6°39'E	T-952	1920	500±75	27±75
9	North Sea, approx. half way btwn Bergen and Shetland 60°38'N 2°35'E	T-957	1906	494±75	21±75
10	Vikingbank, North Sea 60°38'N 2°35'E	T-1533	1906	469±50	-4±50

TABLE 1 (continued)

REF[b]	REGION[c]	SAMPLE #	HISTORICAL AGE (cal AD)[d]	CONVENTIONAL SAMPLE ^{14}C AGE (^{14}C YRS BP)[e]	ΔR (^{14}C YRS BP)[f]
MARINE SHELLS[a]					
9	Ideosen, Herdla, Hordaland, Norway 60°34'N 5°00'E	T-954A, T-954B	1923	457±60	-16±60
9	Sollesnes, Jondal, Hardanger, Norway 60°18'N 6°17'E	T-955	1908	532±75	61±75
9	Mosterhavn, Hordaland, Norway 59°42'N 5°24'E	T-956	1918	402±90	-70±90
	WEIGHTED MEAN OF ABOVE 8 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 15 YR				5±25
9	Brevikfjord, Telemark, Norway 59°03'N 9°42'E	T-959	1898	602±80	124±80
9	Gronholmsund, Risor, Aust-Agder, Norway 58°44'N 9°18'E	T-960	1905	385±75	-88±75
7	Near Kristingeberg, island of Skaftolandet, Bohuslan, Sweden 58°15'N 11°26'E	Lu-237	1896±8[g]	420±50	-59±50
12	Bohuslan, Sweden (ca. 58°N 12°E)	U-607	ca.1935	510±80	31±80
6	Haron, Bohuslan, Sweden 58°01'N 11°31'E	Lu-236	1935±15	430±46	-49±46
6	Roro, N archipelago of Goteborg, Sweden 57°47'N 11°37'E	Lu-235	1930±10	410±46	-65±46
6	Roro, N archipelago of Goteborg, Sweden 57°47'N 11°37'E	Lu-234	1930±10	370±57	-105±57
10	Skagerak, Norway 57°44'N 9°53'E	T-1532	1906	459±50	-14±50
	WEIGHTED MEAN OF ABOVE 8 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 25 YR				-40±20
14	Pavlov Harbor, Alaska, USA 55.5°N (162°W)	USGS-234	1937	700±50	219±50
	VALUE USED ON MAP FOR ABOVE SAMPLE				220±50
14	Orcas Is., Washington, USA 48.6°N (123°W)	USGS-177	1915±15	805±50	334±50
14	Orcas Is., Washington, USA 48.6°N (123°W)	USGS-190	1915±15	950±30	479±30

TABLE 1 (continued)

MARINE SHELLS[a] REF[b]	REGION[c]	SAMPLE #	HISTORICAL AGE (cal AD)[d]	CONVENTIONAL SAMPLE ^{14}C AGE (^{14}C YRS BP)[e]	ΔR (^{14}C YRS BP)[f]
14	Sooke, British Columbia, Canada 48.4°N (124°W)	USGS-170	1916	850±50	378±50
14	Esquimalt, British Columbia Canada 48.3°N (123°W)	USGS-133	1930	750±50	275±50
14	Yaquina Bay, Oregon, USA 44.6°N (124°W)	USGS-169	1916	840±35	368±35
14	Yaquina Bay, Oregon, USA 44.6°N (124°W)	USGS-189	1916	835±50	363±50
14	Sunset Bay, Oregon, USA 43.3°N (124°W)	USGS-233	1936	895±50	415±50
	WEIGHTED MEAN OF ABOVE 7 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 25 YR				390±15
3	Bay of Arcachon, France 44°35′N 1°25′W	L-599A	1952	846±42	-4±42[h]
	VALUE USED ON MAP FOR ABOVE SAMPLE				-5±40
2,3	Port Jefferson area, Long Island Sound, New York, USA 40°57′N 73°05′W	L-317A	1954	407±75	-83±75[h]
	VALUE USED ON MAP FOR ABOVE SAMPLE				-85±75
14	Bolinas Bay, California, USA 37.9°N (123°W)	USGS-248	1915±5	680±25	209±25
14	Half Moon Bay, California, USA 37.5°N (122°W)	USGS-280	1915±5	745±35	274±35
14	Monterey, California, USA 36.6°N (122°W)	USGS-178	1915±5	740±35	269±35
1	Monterey, California, USA (37°N 122°W)	UCLA-149	1878	566±55	75±55
14	Morro Bay, California, USA 35.4°N (121°W)	USGS-281	1947	750±35	262±35
1	Seal Beach, California, USA (34°N 119°W)	UCLA-1033	1921	553±48	80±48
14	San Diego, California, USA 32.7°N (117°W)	USGS-430	1915±5	735±35	264±35
	WEIGHTED MEAN OF ABOVE 7 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 35 YR				225±15

TABLE 1 (continued)

MARINE SHELLS[a] REF[b]	REGION[c]	SAMPLE #	HISTORICAL AGE (cal AD)[d]	CONVENTIONAL SAMPLE ^{14}C AGE (^{14}C YRS BP)[e]	ΔR (^{14}C YRS BP)[f]
2,3	Kouali Point, Tipasa, Algeria 36°40′N 2°30′E	L-241A	1954	357±83	-133±83[h]
	VALUE USED ON MAP FOR ABOVE SAMPLE				-135±85
1	Kino Bay, Sonora, Mexico (29°N 112°W)	UCLA-914	1935	993±53	514±53
1	Carmen Is., Gulf of California, Mexico (26°N 111°W)	UCLA-917	1911	1001±54	531±54
	WEIGHTED MEAN OF ABOVE 2 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 10 YR				520±40
1	Cedro Is., Baja California, Mexico (28°N 115°W)	UCLA-963	1939	614±51	132±51
1	Magdaleno Bay, Baja California, Mexico (25°N 112°W)	UCLA-939	1938	660±53	179±53
1	Cape San Lucas, Baja California, Mexico (23°N 110°W)	UCLA-916	1932	784±45	307±45
1	Mazatlan, Sinaloa, Mexico (23°N 106°W)	UCLA-913	1939	662±48	180±48
1	Isabel Island, Nayarit, Mexico (22°N 106°W)	UCLA-936	1938	688±50	207±50
1	Banderas Bay, Jalisco, Mexico (21°N 105°W)	UCLA-940	1938	606±50	125±50
1	Manzanillo, Colima, Mexico (19°N 104°W)	UCLA-915	1930	675±50	200±50
1	Guatulco Bay, Oaxaca, Mexico (16°N 96°W)	UCLA-938	1938	621±50	140±50
	WEIGHTED MEAN OF ABOVE 8 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 20 YR				185±15
3	Bahama Islands 26°N 78°W	L-576B	1950	428±42	-62±42
3	Bahama Islands 26°N 78°W	L-576G	1885±5	525±59	39±59

TABLE 1 (continued)

MARINE SHELLS[a]

REF[b]	REGION[c]	SAMPLE #	HISTORICAL AGE (cal AD)[d]	CONVENTIONAL SAMPLE ^{14}C AGE (^{14}C YRS BP)[e]	ΔR (^{14}C YRS BP)[f]
4	The Rocks, offshore of Florida Keys, USA 24°57'N 80°33'W	(annual coral rings)	"1850" (1800-1900)	518±16	13±16
3	Jamaica, B.W.I. 18°N 78°W	L-576A	1929-1930	423±42	-52±42
3	Jamaica, B.W.I. 18°N 78°W	L-576F	1884	425±41	-62±41
	WEIGHTED MEAN OF ABOVE 5 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 20 YR				-5±15
3	Oahu, Hawaii, USA 22°N 158°W	L-576J	1840-1841	629±51	117±51
	VALUE USED ON MAP FOR ABOVE SAMPLE				115±50
3	Off Bogan Island, Eniwetok Atoll 11°30'N 162°10'E	L-584A (coral)	1946	629±43	142±43
	VALUE USED ON MAP FOR ABOVE SAMPLE				140±45
16	Port Parker, Costa Rica (ca. 10°N 85°W)	UCLA-1254	1935	695±37	216±37
16	Secas Island, Panama (8°N 82°W)	UCLA-1256A	1934	403±51	-76±51
16	Secas Island, Panama (8°N 82°W)	UCLA-1256B	1935	507±49	28±49
16	Santiago Is., Galapagos Is. (0°N 91°W)	UCLA-1255A	1934	538±53	60±53
16	Santiago Is., Galapagos Is. (0°N 91°W)	UCLA-1255B	1934	745±82	267±82
16	Espanola Is., Galapagos Is. (0°N 90°W)	UCLA-1255C	1934	468±43	-10±43
16	Santa Cruz Is., Galapagos Islands (0°N 90°W)	UCLA-1255D	1932	443±40	-34±40
16	Guayaquil, Ecuador (ca. 3°S 80°W)	UCLA-1249A	1927	235±37	-240±37
16	Guayaquil, Ecuador (ca. 3°S 80°W)	UCLA-1249B	1927	536±45	61±45
	WEIGHTED MEAN OF ABOVE 9 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 50 YR				5±15

TABLE 1 (continued)

MARINE SHELLS[a]

REF[b]	REGION[c]	SAMPLE #	HISTORICAL AGE (cal AD)[d]	CONVENTIONAL SAMPLE ^{14}C AGE (^{14}C YRS BP)[e]	ΔR (^{14}C YRS BP)[f]
16	Northern Peru (ca. 10°S 80°W)	UCLA-1282	1935±5	700±49	221±49
16	Peru (ca. 14°S 78°W)	UCLA-1279	1935±5	1127±44	648±44
16	Antofagasta, Chile (24°S 70°W)	UCLA-1277	1925	626±34	152±34
16	Valparaiso, Chile (33°S 72°W)	UCLA-1278	1935±5	770±76	291±76
	WEIGHTED MEAN OF ABOVE 3 SAMPLES (WITH UCLA-1279 EXCLUDED) SCATTER σ IN UNWEIGHTED MEAN IS 40 YR				190±25
5	Torres Strait, Australian coast ca. 10°S 143°E	SUA-354/1	1875±3	480±67	-13±67
5	Torres Strait, Australian coast ca. 10°S 143°E	SUA-354/2	1875±3	463±84	-30±84
5	Torres Strait, Australian coast ca. 10°S 143°E	SUA-357	1909	404±84	-67±84
5	Garden Island, W. Australia 32°15'S 115°40'E	SUA-355	1930	454±84	-21±84
5	Adelaide, S. Australia ca. 35°S 139°E	SUA-393	1937±2	583±85	102±85
5	Narooma, N.S.W. Australia 36°13'S 150°07'E	SUA-356	1950	480±84	-10±84
	WEIGHTED MEAN OF ABOVE 6 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 25 YR				-5±35
3	Tahiti 18°S 149°W	L-576E	1957	515±42	25±42[h]
3	Moorea 18°S 149°W	L-576K	1883±3	553±42	65±42
	WEIGHTED MEAN OF ABOVE 2 SAMPLES SCATTER σ IN UNWEIGHTED MEAN IS 20 yr				45±30
5	New Zealand -----	----	1923	416±42	-57±42
5	New Zealand -----	----	1925	371±50	-103±50
5	New Zealand -----	----	1949	210±41	-280±41
13	Otago, New Zealand (ca. 45°S 170°E)	INS no. R.42	1955	446±42	-44±42[h]

TABLE 1 (continued)

MARINE SHELLS[a]

REF[b]	REGION[c]	SAMPLE #	HISTORICAL AGE (cal AD)[d]	CONVENTIONAL SAMPLE ^{14}C AGE (^{14}C YRS BP)[e]	ΔR (^{14}C YRS BP)[f]
	WEIGHTED MEAN OF ABOVE 3 SAMPLES (WITH -280±41 EXCLUDED) SCATTER σ IN UNWEIGHTED MEAN IS 20 YR				-65±25
15	Inexpressible Island, Antarctica (ca. 74°54'S 163°39'E)	QL-171 (seal)	1912	1390±40	919±40
15	Inexpressible Island Antarctica (ca. 74°54'S 163°39'E)	QL-173 (penguin)	1912	1300±50	829±50
	WEIGHTED MEAN OF ABOVE 2 SAMPLES SCATTER σ OF UNWEIGHTED MEAN IS 45 YR				885±30

NOTES

[a] Exceptions are marked.

[b] References are: (1) Berger et al., 1966; (2) Broecker and Olson, 1959; (3) Broecker and Olson, 1961; (4) Druffel and Linick, 1978; (5) Gillespie and Polach, 1979; (6) Hakansson, 1969; (7) Hakannson, 1970; (8) Hakansson, 1973; (9) Mangerud, 1972; (10) Mangerud and Gulliksen, 1975; (11) Olsson, 1960; (12) Olsson et al., 1969; (13) Rafter et al., 1972; (14) Robinson and Thompson, 1981; (15) Stuiver et al., 1981; (16) Taylor and Berger, 1967; and (17) Washburn and Stuiver, 1962.

[c] Our own estimates of missing coordinates are in parentheses.

[d] Age refers to calendar year of death. Only pre-1959 samples are listed.

[e] Conventional radiocarbon age is: taken directly from original listing (references 14, 15, and 17); assumed equivalent to reported "apparent age" (references 6 and 7); calculated from reported δ^{14}C or Δ^{14}C (references 1, 13, and 16); calculated from reported Δ^{14}C after removal of age correction (references 4, 5, 8, 9, and 12); calculated from reported Δ^{14}C after removal of age correction to 1958 (references 2 and 3); or calculated from reported Δ^{14}C after removal of age correction and fossil fuel correction (reference 10 and Rafter values listed in reference 5).

[f] Sigma in ΔR (σ_R) is minimum error based on reported error in conventional sample ^{14}C age.

[g] Exact year of death is not known.

[h] Computation is based on the model mixed layer radiocarbon age calculated for AD 1950

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A COMPUTER PROGRAM FOR RADIOCARBON AGE CALIBRATION

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The calibration curves and tables given in this issue of RADIOCARBON form a data base ideally suited for a computerized operation. The program listed below converts a radiocarbon age and its age error σ_s (one standard deviation) into calibrated ages (intercepts with the calibration curve), and ranges of calibrated ages that correspond to the age error. The standard deviation σ_c in the calibration curve is taken into account using $\sigma_{total} = \sqrt{\sigma_s^2 + \sigma_c^2}$ (see Stuiver and Pearson, this issue, for details). The program transforms radiocarbon ages into cal AD/BC(cal BP) ages. Probabilities within the cal age ranges are not included, this feature will be incorporated at later stage. The FORTRAN program and calibration data can be obtained for the cost of materials and shipping (US $5, prepaid and payable to the Quaternary Research Center) from the Quaternary Isotope Laboratory on a DS/DD floppy diskette. The calibration data were assembled from this calibration issue, and from the tabulations of Linick, Suess, and and Becker (Radiocarbon, 27, 20-32, 1985).

The current commitment of the Quaternary Isotope Laboratory is to supply the 1986 version of the program. We do not yet pledge continuous updating, but will make an attempt if time and budget permit. The program is IBM PC-XT compatible; users are responsible for adaptation to non-compatible systems. A visual display (although not given here) is part of the floppy disk version. Future use of the program will surely lead to modifications and we welcome suggestions.

```
C
C Radiocarbon Calibration Program CALIB
C
C    The program converts radiocarbon ages to calibrated ages as
C  would be done if one manually plotted the calibration curve data*
C  on an X-Y axis and drew a line through the Y-axis corresponding to
C  the radiocarbon age.  Vertical lines drawn through these intercepts
C  to the X-axis, with linear interpolation between data points, give
C  the cal AD/BC ages.  Cal BP ages are calculated from 1950 so that
C  cal BP = 1950 - cal AD and cal BP = 1949 + cal BC.  The one year
C  difference in converting BC dates is caused by the absence of the
C  zero year in the AD/BC chronology.
C    To convert the standard error in the radiocarbon age into a range
C  of cal AD/BC (BP) ages the user must first determine whether to use
C  1) the laboratory quoted error or 2) increase the quoted error by a
C  known "error multiplier"  (Stuiver and Pearson, 1986, Radiocarbon,
C  28, 805-838.)  With the sample sigma entered,the program calculates
C  the total sigma for non-marine samples as:
C
C   1 Sigma = SQRT((sample sigma)^2 + (calibration curve sigma)^2)
C   2 Sigma = SQRT((2*sample sigma)^2 + (calibration curve sigma)^2)
C
C  (Stuiver, 1982, Radiocarbon, 24, 1-26). The calibration curve sigma
C  is the average of the standard deviaton of the 2 data points closest
C  to each intercept of the radiocarbon age Y.  Vertical lines drawn to
C  the X-axis through the intercepts of Y + 1 Sigma and Y - 1 Sigma with
C  the calibration curve give the ranges of cal AD/BC ages for 1 Sigma.
C  Likewise intercepts of Y + 2 Sigma and Y - 2 Sigma give the 2 Sigma
C  ranges.  For ranges and sample sigmas greater than 100 years the
C  ranges are rounded to the nearest ten years.  Ranges that overlap or
C  are closer together than one year, or ten if rounded, are reported as
C  one age range.
C    Marine samples are treated similarly except that the user must
C  determine the Delta R and the uncertainty in Delta R to use for
C  each sample based on its collection location (Stuiver ,Pearson, and
C  Braziunas, 1986, Radiocarbon, 28, 2B...)  The marine total sigma is
C  taken as:
C
C   1 Sigma = SQRT((sample sigma)^2 + (Delta R sigma)^2)
C   2 Sigma = SQRT((2*sample sigma)^2 + (Delta R sigma)^2).
C
C    Three datasets are provided. The twenty year atmospheric record
C  (2) is recommended for most non-marine samples although a ten year
C  record (1) is given for more detailed comparisons of younger samples.
C  The 20 year marine record (3) should be used with all marine samples.
C
C *Input from files:
C
C    1. ATM10.14C
C       10 yr atmospheric record to 2490 cal BC (circa 4200 14-C BP)
C    2. ATM20.14C
C       20 yr atmospheric record to 7210 cal BC (circa 8200 14-C BP)
C    Format(1. and 2.):  Year, Radiocarbon age, Sigma age
C                        (5X,F9.1,5X,I5,5X,I2)
C    3. MARINE.14C
C       20 yr marine model record to 7190 cal BC (circa 8585 14-C BP)
C         Format:  Year, Radiocarbon age
C                  (5X,F9.1,5X,I5)
C
C Output :
C
C    1. to printer LPT1 if desired
C
C    2. OUTFIL.14C    for listing, rename to save
C
C    3. PLTFIL.14C    for plotting
C         Format: sample id, # of intercepts, calibrated ages
C                 1 sigma value, # of ranges, ranges,
C                 2 sigma value, # of ranges, ranges
C                 (1X,A12,I2,n(F10.1,2X))
C                 2(1X,F8.1,I2,r(F10.1,2X))
C                     where n=repeat spec.= # of intercepts
C                     where r=repeat spec.= # of ranges
C
C Subroutines:
C
C   INRCP  to find  the intercept of a radiocarbon age with the
C          calibration curve
C   Calling sequence:  CALL INRCP(V,NPTS,INTPT,NINP)
C     where:
C           V = Y value (Radiocarbon age) to intercept curve
C           NPTS = # of data points  (current dimension = 1000)
C           INTPT = array of intercepting points (max = 40)
```

```
C          NINP = # of intercepting points
C
C   ABWRT   writes calibrated age to unit LO
C
C   BPWRT   writes age BP to unit LO
C
C   RWRT    write age ranges to unit LO
C
C Revision date: 7/18/86
C PJ Reimer
C Quaternary Isotope Laboratory
C Quaternary Research Center AK-60
C University of Washington
C Seattle, WA 98195
C
$STORAGE:2
      PROGRAM CALIB
C
      COMMON X(1000),Y(1000),S(1000)
      COMMON /WRRNG/ RANGE,SIGMA1,NRANG,NPTS,JAD
      COMMON /WRINT/ ABINT,BPINT,ENLNE
C
      INTEGER*2 AGE,ABINT,BPINT,INTX(40,2)
      INTEGER*2 IRANGE(20,2)
      INTEGER*2 LU(3),MINTX(40,2),MENT,NENT,NINP,NINTX(40,2)
      INTEGER*2 RANK(80),SIGAGE,TREF
C
      REAL*4 DELTAR,EINT(40)
      REAL*4 INTPT(40),MINT(40),RAGE,RANGE(20,2)
      REAL*4 REFDAT(4,2),SAMSIG,SIG1,SIG2,SIGMA1,TEMPR(40),UNCR
      REAL*4 YMAX
C
      CHARACTER COMMA*1,CHSIG*1
      CHARACTER CHPM*1,CHSQD*1,FMT*100,IAD(3)*2,ICL*4
      CHARACTER ID*2,IDSAM*12,JAD*2,LP*1,MREF(5)*1,NAME*10,NAMOUT*10
      CHARACTER NAMPLT*10,NREF(6)*1,SREF(6)*21,SREF2(6)*21,SREF1*21
      CHARACTER REF1*63,REF2(5)*63,REF3(2)*63,REFAL(9)*63
      CHARACTER SREF3(2)*21,STR1*15,STR2*16
C
      LOGICAL SKIP,ENLNE
C
      EQUIVALENCE (ID,IDSAM)
C
      DATA COMMA/','/,FMT/' '/
      DATA LU/0,200,6/
      DATA NAMOUT/'OUTFIL.14C'/,NAMPLT/'PLTFIL.14C'/
      DATA NAME/'CAL20.14C'/,IAD/'AD','BP','AD'/,ICL/'cal '/
C
C Reference for 10 yr atmospheric record
C
      DATA REF1/'Stuiver,M and Becker,B, 1986, Radiocarbon, 28, 2B....'/
      DATA SREF1/'(Stuiver and Becker) '/
C
C References for 20 yr atmospheric record
C
      DATA REF2/
     &'Stuiver, M and Pearson, GW, 1986, Radiocarbon, 28, 805-838.',
     &'Pearson, GW and Stuiver, M, 1986, Radiocarbon, 28, 839-632.   ',
     &'Pearson, GW, Pilcher, JR, Baille, MG, Corbett, DM and Qua, F,  ',
     &'1986, Radiocarbon, 28, 2B.....                                 ',
     &'Bidecadal weighted average of data from:                      '/
      DATA REFAL/'Linick, TW, Suess, HE and Becker, B, (LSB) 1985, ',
     &'Radiocarbon, 27, 20-32. [for the interval 5219-7199 BC    ',
     &'Stuiver, M, Kromer, B, Becker, B, and Ferguson, CW, (SKBF)   ',
     &'1986, Radiocarbon, 28, 2B....',
     &'Kromer, B, Rhein, M, Bruns, M, Schoh-Fischer, H, Munnich, KO,',
     &'Stuiver, M, and Becker, B, (KRBSMSB) 1986, Radiocarbon, 28,',
     &'2B..... [for the interval 5229 -7207 BC]',
     &'Linick, TW, Long, A, Damon, PE and Ferguson, CW, (LLDF)  1986.',
     &'Radiocarbon, 28, 2B.'/
C
      DATA SREF2/'(Stuiver and Pearson)','(Pearson and Stuiver)',
     &'(Pearson et al. 1986)','(20 yr. average of     ',
     &' LSB,SKBF,KRBSMSB,',' and LLDF)'/
C
      DATA REFDAT/1955.,-500.,-2500.,-5230.,-500.,-2490.,-5210.,-7210./
C
C Reference for 20 yr marine record
C
      DATA REF3/'Stuiver, M, Pearson, GW, and Braziunas, T, 1986.',
     &'Radiocarbon, 28, 2B.'/
      DATA SREF3/'(Stuiver, Pearson and','   Braziunas)        '/
C
      DATA STR1/'Calibrated age:'/,STR2/'Calibrated ages:'/
C
C  define character Plus and minus, sigma, and squared and formfeed
C
      CHPM = CHAR(241)
      CHSIG = CHAR(229)
      CHSQD = CHAR(253)
C
C Open files for text output and plotting
C
      OPEN(6,FILE='LPT1')
      OPEN(200,FILE=NAMOUT,STATUS='NEW')
      OPEN(300,FILE=NAMPLT,STATUS='NEW')
      DO 20  IWRITE=1,3
         LO=LU(IWRITE)
         IF(IWRITE.GT.2) THEN
            WRITE(*,25)
25          FORMAT(1X,'Output to Printer?  Y(es) or N(o) ')
            READ(*,'(A)') LP
            IF((LP.NE.'Y').AND.(LP.NE.'y')) THEN
               LEND = 2
               GOTO 20
            ELSE
               LEND = 3
            ENDIF
         ENDIF
         WRITE(LO,'(26X,A)') 'UNIVERSITY OF WASHINGTON'
         WRITE(LO,'(27X,A)') 'QUATERNARY ISOTOPE LAB'
         WRITE(LO,'(23X,A)') 'RADIOCARBON CALIBRATION PROGRAM 1986'
         WRITE(LO,*)
20    CONTINUE
      WRITE(*,30)
30    FORMAT(/,1X,'Select calibration curve dataset.',/,1X,
     &'1. 10 yr atmospheric record to 2490 cal BC (circa 4200 14-C BP)',
     &/,1X,
     &'2. 20 yr atmospheric record to 7210 cal BC (circa 8200 14-C BP)',
     &/,1X,
     &'3. 20 yr marine model to 7190 cal BC (circa 8585 14-C BP)')
      WRITE(*,40)
```

```
40    FORMAT(/,1X,'Enter selection:  '\)
      READ(*,*) ISET
      IF(ISET.GT.2) THEN
         NAME = 'MARINE.14C'
      ELSEIF (ISET.GT.1) THEN
         NAME = 'ATM20.14C '
      ELSE
         NAME = 'ATM10.14C '
      ENDIF
C
C  Read calibration file
C
      WRITE(*,50)
 50   FORMAT(//,3X,'READING CALIBRATION FILE---PLEASE WAIT ',/)
      OPEN(100,FILE=NAME)
      I = 1
100   IF(ISET.LT.3) THEN
         READ(100,110,END=180,ERR=970) YEAR,AGE,SIGAGE
110      FORMAT(5X,F9.1,5X,I5,5X,I2)
         X(I) = YEAR
         Y(I) = FLOAT(AGE)
         S(I) = FLOAT(SIGAGE)
      ELSE
         READ(100,120,END=180,ERR=970) YEAR,AGE
120      FORMAT(5X,F9.1,5X,I5)
         X(I) = YEAR
         Y(I) = FLOAT(AGE)
      ENDIF
      NPTS = I
      I = I + 1
      GOTO 100
180   NSAM = 0
      DO 185 J=1,4
        MREF(J) = ' '
185   CONTINUE
      YMAX = -1E30
      DO 190 J=1,NPTS
         YMAX = AMAX1(Y(J),YMAX)
190   CONTINUE
200   DO 250 I=1,LEND
         LO=LU(I)
         WRITE(LO,205) NAME
205      FORMAT(1X,'Calibration file:  ',A10,//)
         WRITE(LO,210)
210      FORMAT(' Lab #',11X,'Radiocarbon',4X,'calibrated age(s)',
     &          9X,'References')
         WRITE(LO,220)
220      FORMAT(' ',18X,'Age BP')
250   CONTINUE
300   WRITE(*,*)
      WRITE(200,'(//)')
305   WRITE(*,310)
310   FORMAT('  Enter sample ID   (or XX to end)' )
      READ(*,320) IDSAM
320   FORMAT(A12)
      IF((ID.EQ.'XX').OR.(ID.EQ.'xx')) GOTO 1000
      WRITE(*,330) COMMA
330   FORMAT('  Enter radiocarbon age BP',A,' standard error ')
      READ(*,*) RAGE,SAMSIG
      IF((RAGE.LE.0.0).OR.(RAGE.GE.YMAX)) THEN
         WRITE(*,340) 0,INT(YMAX-.5)
340   FORMAT(' VALID RADIOCARBON AGES FOR THIS DATA MUST BE BETWEEN',
     &I2,' AND',I5,' YRS BP')
         GOTO 305
      ENDIF
C
C  For Marine samples, enter reservoir correction Delta R.
C  Default Reservoir correction is 400 yrs,  Delta R = 0.
      IF(ISET.GT.2) THEN
         DELTAR=0.0
         UNCR=0.0
         WRITE(*,350)
350      FORMAT(1X,'Enter reservior correction Delta R')
         READ(*,*) DELTAR
         WRITE(*,360)
360      FORMAT(1X,'Enter Delta R standard deviation')
         READ(*,*) UNCR
      ENDIF
C
C Print sample ID and age
      DO 375 IWRITE=1,LEND
         LO=LU(IWRITE)
         WRITE(LO,370) IDSAM,RAGE,CHPM,SAMSIG
370      FORMAT(/,1X,A12,2X,F6.1,A3,F5.1,3X,\)
375   CONTINUE
C
C Subtract reservoir correction and add estimated extension to marine
C model
      IF(ISET.GT.2) THEN
         RAGE = RAGE - DELTAR
         NPTS = NPTS + 1
         X(NPTS) = 1954.
         Y(NPTS) = 493.
      ENDIF
C
C Add estimated bomb carbon influence to dataset
      NPTS = NPTS + 1
      X(NPTS) = 1955.
      Y(NPTS) = 0.
      S(NPTS) = 32.
C
C Find intercepts of Radiocarbon age with calibration curve
380   CALL INRCP(RAGE,NPTS,INTPT,NINP,INTX)
C
C Consolidate intercepts that round to the same year
C
400   DO 420 K=1,NINP-1
         INK1 = NINT(INTPT(K))
         INK2 = NINT(INTPT(K+1))
         IF(IABS(INK1-INK2).LT.1) THEN
            DO 410 K2=K+1,NINP-1
              INTPT(K2) = INTPT(K2+1)
410         CONTINUE
            NINP = NINP-1
         ENDIF
420   CONTINUE
C
C  Write to plot file PLTFIL.14C
C
      WRITE(FMT,430) NINP
430   FORMAT('(1X,A12,I2,'I2,'(F10.1,2X))')
      WRITE(300,FMT) IDSAM,NINP,(INTPT(K),K=1,NINP)
```

```
C
C Write to OUTFIL.14C for later listing, to screen, and printer
C
      DO 590 IWRITE=1,LEND
         LO = LU(IWRITE)
C
C  Check calibrated ages for appropriate references. If age falls
C  between datasets give both references.
C
         KREF = 1
         IF(ISET.GT.2) THEN
            SREF(1) = SREF3(1)
            SREF(2) = SREF3(2)
            JREF=2
         ELSEIF (ISET.GT.1) THEN
            TREF = 4
            IREF = 4
            DO 450 K=1,TREF
               NREF(K) = 'N'
               SREF(K) = ' '
450         CONTINUE
            DO 510 K=1,NINP
               DO 500 J=1,4
                  IF(INTPT(K).LT.REFDAT(J,2)) THEN
                     IF(INTPT(K).GT.REFDAT(J+1,1)) THEN
                        NREF(J) = 'Y'
                        NREF(J+1) = 'Y'
                        MREF(J) = 'Y'
                        MREF(J+1) = 'Y'
                        GOTO 510
                     ENDIF
                  ELSE
                     NREF(J) = 'Y'
                     MREF(J) = 'Y'
                     GOTO 510
                  ENDIF
500            CONTINUE
510         CONTINUE
            IF(NREF(4).EQ.'Y') THEN
               NREF(5) = 'Y'
                 NREF(6) = 'Y'
               TREF = 6
            ENDIF
            JREF = 0
            DO 515 K=1,TREF
              IF(NREF(K).EQ.'Y') THEN
                  JREF = JREF + 1
                  SREF(JREF) = SREF2(K)
               ENDIF
515         CONTINUE
         ELSE
            SREF(1) = SREF1
            JREF = 1
         ENDIF
C
C Set label to AD or BC
C
         IF(INTPT(1).LT.0.0) THEN
            IAD(1) = 'BC'
         ELSE
            IAD(1) = 'AD'
         ENDIF
         WRITE(LO,'(A4,A2,1X\)') ICL,IAD(1)
C
C Print calibrated ages
C
         DO 530 K=1,NINP
            J = K - 1
            ENLNE = .FALSE.
            IF((MOD(K,3).LE.0).OR.(K.EQ.NINP)) ENLNE = .TRUE.
            IF((MOD(J,3).LE.0).AND.(J.NE.0))  WRITE(LO,'(39X\)')
            ABINT = NINT(INTPT(K))
C
C Check to see if age will print out as zero then change to 1 , since
C there is no 0 AD/BC
C
            IF(ABINT.EQ.0) ABINT=1
            IF(INTPT(K).LT.0.0) THEN
               JAD = 'BC'
            ELSE
               JAD = 'AD'
            ENDIF
            IF(IAD(1).NE.JAD) THEN
               WRITE(LO,'(1X,A4,A2,\)') ICL,JAD
            ENDIF
            CALL ABWRT(LO)
            IF(ENLNE) THEN
               IF(KREF.LE.JREF) THEN
                  IF(MOD(K,3).EQ.2) WRITE(LO,'(6X\)')
                  IF(MOD(K,3).EQ.1) WRITE(LO,'(12X\)')
                  WRITE(LO,'(2X,A21)') SREF(KREF)
                  KREF=KREF + 1
               ELSE
                  WRITE(LO,*)
               ENDIF
            ENDIF

530      CONTINUE
C
C  calculate ages BP
C
         IF(ISET.GT.2) THEN
            WRITE(LO,535) DELTAR,CHPM,UNCR,ICL,IAD(2)
535         FORMAT(4X,'Delta R = ',F7.1,1X,A,F5.1,4X,A4,A2,1X\)
         ELSE
            WRITE(LO,'(32X,A4,A2,1X\)') ICL,IAD(2)
         ENDIF
         DO 540 K=1,NINP
            J = K - 1
            ENLNE = .FALSE.
            IF((MOD(K,3).LE.0).OR.(K.EQ.NINP)) ENLNE = .TRUE.
            IF((MOD(J,3).LE.0).AND.(J.NE.0))  WRITE(LO,'(39X\)')
            ABINT=NINT(ABS(INTPT(K)))
            IF(ABINT.EQ.0) ABINT = 1
            IF(INTPT(K).LT.0.0) THEN
               BPINT=1949 + ABINT
            ELSE
               BPINT=1950 - ABINT
            ENDIF
            CALL BPWRT(LO)
            IF(ENLNE) THEN
               IF(KREF.LE.JREF) THEN
                  IF(MOD(K,3).EQ.2) WRITE(LO,'(6X\)')
                  IF(MOD(K,3).EQ.1) WRITE(LO,'(12X\)')
```

```
               WRITE(LO,'(2X,A21)') SREF(KREF)
               KREF=KREF+1
            ELSE
               WRITE(LO,*)
            ENDIF
         ENDIF
540   CONTINUE
550   IF(KREF.LE.JREF) THEN
         WRITE(LO,'(57X,A21)') SREF(KREF)
         KREF=KREF+1
         GOTO 550
      ENDIF
590   CONTINUE
      JAD = IAD(1)
      IF(ISET.LT.3) THEN
C
C  Take calibration curve sigma to be the average of the nearest
C  points to the intercepts
C    Note: Y(INTX(I,1)) <= INTPT(I) < Y(INTX(I,2))
C      Where INTX(I,1) and INTX(I,2) are array elements of the data
C
         SIG1 = 0.0
         DO 610 I=1,NINP
           SIG1 = SIG1 + (S(INTX(I,1)) + S(INTX(I,2)))/2.0
610      CONTINUE
         SIG1 = SIG1/NINP
      ELSE
C
C For marine samples the standard deviation in Delta R takes the
C place of the unknown model calibration curve sigma.
C
         SIG1 = UNCR
      ENDIF
      DO 625 IWRITE=1,LEND
         LO=LU(IWRITE)
         WRITE(LO,620) IAD(1),IAD(2)
620   FORMAT(' Sigma**     and cal ',A2,'(cal ',A2,')  ranges:')
625   CONTINUE
C
C Find intercepts with RAGE +- SIGMA1 for 1 and 2*SAMSIG
C
      DO 890 IR=1,2
         SIGMA1 = SQRT(SAMSIG**2 + SIG1**2)
         V=RAGE + SIGMA1
         CALL INRCP(V,NPTS,EINT,NENT,NINTX)
630      V=RAGE - SIGMA1
         CALL INRCP(V,NPTS,MINT,MENT,MINTX)
C
C  Put both sets of intercepts in temporary storage.
C
C  If there are no intercepts (NENT = 0) at the old end of
C  the curve, assign the last year in the dataset
C
         IF(NENT.LE.0) THEN
             TEMPR(1) = X(1)
             INTX(1,1) = 1
             INTX(1,2) = 1
             NENT = 1
         ELSE
             DO 640 I=1,NENT
               TEMPR(I) = EINT(I)
               INTX(I,1) = NINTX(I,1)
               INTX(I,2) = NINTX(I,2)
640        CONTINUE
         ENDIF
C
C  The modern end of the curve will always have intercepts, though
C  perhaps only with bomb 14C (1955*).
C
         DO 647 I=1,MENT
            TEMPR(NENT+I) = MINT(I)
            INTX(NENT+I,1) = MINTX(I,1)
            INTX(NENT+I,2) = MINTX(I,2)
647      CONTINUE
C
C  LENT = total # of intercepts of age + sigma and age - sigma with
C  the calibration curve.
C
         LENT = MENT + NENT
C
C
C  Rank intercepts from oldest to youngest.
C
         DO 648 I=1,LENT
            RANK(I) = I
648      CONTINUE
         DO 660 I=2,LENT
            IPNT = RANK(I)
            J = I - 1
            JPNT = RANK(J)
            IF(TEMPR(IPNT).GE.TEMPR(JPNT)) GOTO 660
            KEEP = IPNT
            RANK(I) = JPNT
            DO 654 K=J-1,1,-1
               IF(K.EQ.0) GOTO 655
               KPNT = RANK(K)
               IF(TEMPR(KPNT).GT.TEMPR(IPNT)) THEN
                  RANK(K+1) = KPNT
               ELSE
                  GOTO 655
               ENDIF
654         CONTINUE
655         RANK(K+1) = KEEP
660      CONTINUE
C
C  Find ranges from ranked intercepts
C
         ICN = 0
         RS1 = RAGE + SIGMA1
         RS2 = RAGE - SIGMA1
         SKIP = .FALSE.
         DO 690 I=1,LENT-1
            IF(.NOT.SKIP) THEN
               IP1 = I+1
               IZ = INTX(RANK(I),1)
               NEXT = INTX(RANK(IP1),1)
C
C  If age +- sigma intercept is a single point, skip it
C
               IF((Y(IZ).EQ.RS1).AND.(Y(NEXT).GT.RS1)) GOTO 690
               IF((Y(IZ).EQ.RS2).AND.(Y(NEXT).LT.RS2)) GOTO 690
C
```

```
C Assign range values from TEMPR according to RANK
C
              ICN = ICN+1
              RANGE(ICN,1) = TEMPR(RANK(I))
              RANGE(ICN,2) = TEMPR(RANK(IP1))
C
C If intercept is a turning point in the curve , share it
C with the next range,  otherwise skip to next I
C
              IF((Y(IZ).NE.RS2).AND.(Y(IZ).NE.RS1)) THEN
                 SKIP = .TRUE.
              ELSE
              ELSE
                 SKIP=.FALSE.
              ENDIF
           ELSE
              SKIP=.FALSE.
           ENDIF
690     CONTINUE
        NRANG = ICN
C
C  Consolidate ranges that overlap or have gaps < 10 years
C       NRANG = # of distinct ranges
C
729     ICN = 1
730     IF(ICN.GE.NRANG) GOTO 740
        ICNP1 = ICN + 1
C
C  Replace overlapping ranges with maximum and minimum values
C
       IF((RANGE(ICN,2).GE.RANGE(ICNP1,1)).OR.
     &    ((RANGE(ICNP1,1)-RANGE(ICN,2)).LT.10.))THEN
           RANGE(ICN,1) = AMIN1(RANGE(ICNP1,1),RANGE(ICN,1))
           RANGE(ICN,2) = AMAX1(RANGE(ICNP1,2),RANGE(ICN,2))
C
C  Move rest of ranges into empty slot
          DO 735 K2=ICNP1,NRANG-1
            K2P1 = K2 + 1
            RANGE(K2,1) = RANGE (K2P1,1)
            RANGE(K2,2) = RANGE(K2P1,2)
 735      CONTINUE
          NRANG = NRANG - 1
          GOTO 730
        ENDIF
        ICN = ICN + 1
        GOTO 730
740     WRITE(FMT,741) ICN
        WRITE(300,FMT) SIGMA1,ICN,(RANGE(I,1),
     &    RANGE(I,2),I=1,ICN)
741     FORMAT('(1X,F8.1,I2,'I2,'(F10.1,2X,F10.1))')
C
C  Print ranges
C
        DO 885 IWRITE=1,LEND
          LO = LU(IWRITE)
          WRITE(LO,750) IR,CHSIG,SIGMA1
 750      FORMAT(' ',I2,1X,A,' = ',F5.1,3X\)
          DO 880 I=1,NRANG
            CALL RWRT(LO,I)
C
C  Skip to next line after 2 ranges are written
            IF((MOD(I,2).EQ.0).AND.(I.NE.NRANG)) WRITE(LO,'(/,16X,\)')
880       CONTINUE
          WRITE(LO,*)
885     CONTINUE
        SAMSIG = 2.0*SAMSIG
890   CONTINUE
C
C Form feed after 8 samples and write headings again
C
      NSAM = NSAM + 1
      IF((LP.EQ.'Y').AND.(MOD(NSAM,6).EQ.0)) THEN
         WRITE(6,891)
891      FORMAT('1RADIOCARBON CALIBRATION PROGRAM')
         WRITE(6,205) NAME
         WRITE(6,210)
         WRITE(6,220)
      ENDIF
      GOTO 300
970   WRITE(*,975)
975   FORMAT(' ERROR IN FILE READ')
1000  WRITE(*,1001)
1001  FORMAT(1X,'CLOSING FILES')
      CLOSE(100)
C
C Form feed to leave room for references if necessary
      LSAM = 5
      IF(ISET.EQ.2) LSAM = 3
      IF((MOD(NSAM,6).GE.LSAM).AND.(LP.EQ.'Y')) THEN
         WRITE(6,1002)
1002     FORMAT('1')
      ENDIF
      DO 1200 IWRITE=1,LEND
         LO = LU(IWRITE)
         WRITE(LO,'(///)')
         WRITE(LO,1003)
1003     FORMAT(1X,'References for datasets [and intervals] used:')
         IF(ISET.GT.2) THEN
            WRITE(LO,1010) REF3(1),REF3(2)
         ELSEIF (ISET.GT.1) THEN
            J = 0
            DO 1005 K=1,IREF
               J = J + 1
               IF(MREF(K).EQ.'Y') THEN
                  WRITE(LO,1010) REF2(J)
                  IF(K.EQ.3) THEN
                     J = J + 1
                     WRITE(LO,1010) REF2(J)
                  ENDIF
                  IF(K.GT.3) THEN
                     DO 1004 IRF=1,8
                        WRITE(LO,1010) REFAL(IRF)
1004                 CONTINUE
                  ENDIF
               ENDIF
1005        CONTINUE
         ELSE
            WRITE(LO,1010) REF1
         ENDIF
1010     FORMAT(1X,A63)
         WRITE(LO,1015)
1015     FORMAT(/,1X,'Comments:')
```

```
      WRITE(LO,1020)
1020  FORMAT(1X,'1955* represents influence of bomb C-14')
      WRITE(LO,1030)
1030  FORMAT(1X,'0* represents a "negative" age BP')
      IF(ISET.LT.3) THEN
         WRITE(LO,1040)  CHSQD,CHSQD
1040     FORMAT(1X,'** 1 sigma = square root of (sample sigma',A,
     &    '+ curve sigma', A,')')
         WRITE(LO,1050)  CHSQD,CHSQD
1050     FORMAT(1X,'   2 sigma = square root of [(2 sample sigma)',A,
     &     '+ curve sigma', A,']')
         WRITE(LO,1060) IABS(NINT(X(1)))
1060     FORMAT(1X,'>',I5,' BC represents end of calibration data ')
      ELSE
         WRITE(LO,1070)  CHSQD,CHSQD
1070     FORMAT(1X,'** 1 sigma = square root of (sample sigma',A,
     &    '+ uncertainty in Delta R', A,')')
         WRITE(LO,1080)  CHSQD,CHSQD
1080     FORMAT(1X,'   2 sigma = square root of [(2 sample sigma)',A,
     &     '+ Delta R sigma', A,']')
         WRITE(LO,1090) IABS(NINT(X(1)))
1090     FORMAT(1X,'>',I5,' BC represents end of calibration data ')
      ENDIF
1200  CONTINUE
2000  END
C
C
      SUBROUTINE INRCP(V,N,INTPT,NINPT,XYINT)
C
C Subroutine to find the intercepts of V with the straight line
C between two points of a dataset
C
C V = Y value for which the intercepts with the function are desired
C
C INTPT = array of intercepting points
C NINPT = # of intercepts
C N = # of data points
C XYINT = element #'s of the data array that V falls between
C
C
      COMMON X(1000),Y(1000),S(1000)
C
      REAL*4 V,INTPT(40),M,B,X3
      INTEGER*2 N,NINPT,XYINT(40,1)
C
      NINPT=0
10    DO 100 I=2,N
      X1 = X(I-1)
      X2 = X(I)
      Y1 = Y(I-1)
      Y2 = Y(I)
      IF(((V.GE.Y1).AND.(V.LT.Y2)).OR.((V.LE.Y1).AND.(V.GT.Y2))) THEN
          M = (Y2-Y1)/(X2-X1)
          B = Y1 - M*X1
          X3 = (V-B)/M
          NINPT = NINPT + 1
          INTPT(NINPT) = X3
          XYINT(NINPT,1) = I-1
          XYINT(NINPT,2) = I
      ENDIF
100   CONTINUE
      RETURN
      END
C
      SUBROUTINE ABWRT(LO)
C
      COMMON /WRINT/ABINT,BPINT,ENLNE
C
      CHARACTER MARK*1,COMMA*1
      INTEGER ABINT,BPINT,LO,NBINT
      LOGICAL ENLNE
C
      COMMA = ','
      MARK = '*'
C
      NBINT = IABS(ABINT)
      IF(ABINT.LT.1954) THEN
         IF(ENLNE) THEN
            WRITE(LO,'(1X,I4\)') NBINT
         ELSE
            WRITE(LO,'(1X,I4,A\)') NBINT,COMMA
         ENDIF
      ELSE
         NBINT = 1955
         IF(ENLNE) THEN
            WRITE(LO,'(1X,I4,A\)') NBINT,MARK
         ELSE
            WRITE(LO,'(1X,I4,2A\)') NBINT,MARK,COMMA
         ENDIF
      ENDIF
      RETURN
      END
C
      SUBROUTINE BPWRT(LO)
C
      COMMON /WRINT/ ABINT,BPINT,ENLNE
C
      CHARACTER MARK*1,COMMA*1
      INTEGER ABINT,BPINT,LO
      LOGICAL ENLNE
C
      COMMA = ','
      MARK = '*'
C
      IF(BPINT.GE.0) THEN
         IF(ENLNE) THEN
            WRITE(LO,'(1X,I4\)') BPINT
         ELSE
            WRITE(LO,'(1X,I4,A\)') BPINT,COMMA
         ENDIF
      ELSE
         BPINT = 0
         IF(ENLNE) THEN
            WRITE(LO,'(1X,I4,A\)') BPINT,MARK
         ELSE
            WRITE(LO,'(1X,I4,2A\)') BPINT,MARK,COMMA
         ENDIF
      ENDIF
      RETURN
      END
```

```
C
C
      SUBROUTINE RWRT(LO,IR)
C
      COMMON X(1000),Y(1000),S(1000)
      COMMON /WRRNG/ RANGE,SIGMA1,NRANG,NPTS,JAD
C
      REAL*4 RANGE(20,2),SIGMA1
      INTEGER NRANG,IRANGE(2),BRANG(2)
      CHARACTER IAD(3)*2,ICL*4,DASH*1,JAD*2,KAD*2,RMARK*1
C
      DATA DASH/'-'/
      DATA ICL/'cal '/
C
      RANGT = ABS(RANGE(IR,2)-RANGE(IR,1))
      ISIG = NINT(SIGMA1)
C
C Round range values to nearest ten if sigma > 100 and RANGE > 100 years
C Leave out ranges that will round to the same year (or ten years).
C
      IF((ISIG.GE.100).AND.(RANGT.GE.100.)) THEN
        IRANGE(1) = NINT(RANGE(IR,1)/10.) * 10
        IRANGE(2) = NINT(RANGE(IR,2)/10.) * 10
      ELSE
         IRANGE(1)=NINT(RANGE(IR,1))
         IRANGE(2)=NINT(RANGE(IR,2))
      ENDIF
      IF(IABS(IRANGE(1)-IRANGE(2)).GT.1) THEN
C
C  Calculate BP ranges
C
         DO 100 J=1,2
            K = 2*J - 1
            IF(RANGE(IR,J).LT.0.0) THEN
              BRANG(J) = 1949 - IRANGE(J)
              IAD(K) = 'BC'
            ELSE
              BRANG(J) = 1950 - IRANGE(J)
              IAD(K) = 'AD'
            ENDIF
100      CONTINUE
C
C Check to see if range is going to print out as zero then change
C to 1, since there is no 0 AD/BC.
C
150      DO 180 J=1,2
            IF (IRANGE(J).EQ.0) THEN
              IF(RANGE(IR,J).LT.0.0) THEN
                 BRANG(J) = 1950
                 IRANGE(J) = -1
              ELSE
                 BRANG(J) = 1949
                 IRANGE(J)= 1
              ENDIF
            ENDIF
180      CONTINUE
C
C  1954 AD is last possible year, since after 1954, the bomb C-14 signal
C  overwhelmed the natural variations; therefore any range >1954 AD prints
C  1955* and 0* BP.
C
         KAD=JAD
         DO 200 J=1,2
            K=2*J-1
            IF(RANGE(IR,J).GT.1954.) THEN
               IRANGE(J) = 1955
               RMARK = '*'
C
C  Check to see if RANGE(IR,1) and RANGE (IR,2) are either both AD
C    OR both BC and the same as the heading printed for calibrated ages.
C
               IF((IAD(1).EQ.IAD(3)).AND.(IAD(1).EQ.KAD)) THEN
                  WRITE(LO,'(I4,A\)') IRANGE(J),RMARK
               ELSE
                  WRITE(LO,'(A4,A2,I4,A\)') ICL,IAD(K),IRANGE(J),RMARK
                  KAD=IAD(1)
              ENDIF
C
C  X(1) is the first cal year for the dataset. Any range value >= X(1)
C  prints as >X(1) and >(1949-X(1)) BP though the actual range is
C  unknown
C
            ELSEIF (RANGE(IR,J).LE.X(1))THEN
               IRANGE(J) = NINT(ABS(X(1)))
               RMARK = '>'
               IF((IAD(1).EQ.IAD(3)).AND.(IAD(1).EQ.KAD)) THEN
                  WRITE(LO,'(A,I4\)') RMARK,IRANGE(J)
               ELSE
                  WRITE(LO,'(A4,A2,A,I4\)') ICL,IAD(K),RMARK,IRANGE(J)
                  KAD=IAD(1)
               ENDIF
            ELSE
               IRANGE(J) = IABS(IRANGE(J))
               IF((IAD(1).EQ.IAD(3)).AND.(IAD(1).EQ.KAD)) THEN
                  WRITE(LO,'(I4\)') IRANGE(J)
               ELSE
                  WRITE(LO,'(A4,A2,I4\)') ICL,IAD(K),IRANGE(J)
                  KAD=IAD(1)
              ENDIF
            ENDIF
            IF(J.LT.2) WRITE(LO,'(A\)') DASH
200      CONTINUE
C
C  Write BP ranges
C
         LSTBP=1949-NINT(X(1))
         DO 350 J=1,2
            IF(J.LT.2) THEN
               WRITE(LO,310)
310            FORMAT('('\)
            ENDIF
            IF(BRANG(J).LT.0) THEN
               BRANG(J) = 0
               RMARK = '*'
               WRITE(LO,'(I4,A\)') BRANG(J),RMARK
            ELSEIF (BRANG(J).GE.LSTBP) THEN
               BRANG(J) = LSTBP
               RMARK = '>'
               WRITE(LO,'(A,I4\)') RMARK,BRANG(J)
            ELSE
               WRITE(LO,'(I4\)') BRANG(J)
            ENDIF
```

```
            IF(J.LT.2) THEN
               WRITE(LO,'(A\)') DASH
            ELSE
               WRITE(LO,320)
 320           FORMAT(')',1X\)
            ENDIF
 350        CONTINUE
         ELSEIF (IRANGE(1).GE.1954) THEN
            RMARK='*'
            IRANGE(1) = 1955
            WRITE(LO,'(I4,A\)') IRANGE(1),RMARK
         ENDIF
         RETURN
         END
```

ERRATUM. Format 1070 should read:

```
1070      FORMAT(1X,'** 1 sigma = square root of (sample sigma',A,
     &      '+ Delta R sigma',A,')')
```