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RADIOCARBON

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INSTRUCTIONS TO CONTRIBUTORS

Manuscripts of radiocarbon papers should follow the recommendations in *Suggestions to Authors,* 5th ed.* All copy (including the bibliography) must be typewritten in *double space*. Manuscripts for vol 21, no. 3 must be submitted in *duplicate* before May 1, 1979, for vol 22, no. 1 before September 1, 1979.

General or technical articles should follow the recommendations above and the editorial style of the *American Journal of Science*.

Descriptions of samples, in date lists, should follow as closely as possible the style shown in this volume. Each separate entry (date or series) in a date list should be considered an *abstract,* prepared in such a way that descriptive material is distinguished from geologic or archaeologic interpretation, but description and interpretation must be both brief and informative, emphasis placed on significant comments. Date lists should therefore not be preceded by abstracts, but abstracts of the more usual form should accompany all papers (eg, geochemical contributions) that are directed to specific problems.

Each description should include the following data, if possible in the order given:

1. Laboratory number, descriptive name (ordinarily that of the locality of collection), and the date expressed in years BP (before present, ie, before AD 1950). The standard error following the date should express, within limits of $\pm$ 1σ, the laboratory's estimate of the accuracy of the radiocarbon measurement, *as judged on physicochemical (not geologic or archaeologic) grounds.*

2. Substance of which the sample is composed: if a plant or animal fossil, the scientific name if possible; otherwise the popular name, but not both. Also, where pertinent, the name of the person identifying the specimen.

3. Precise geographic location, *including latitude-longitude coordinates.*

4. Occurrence and stratigraphic position in precise terms; use of metric system exclusively. Stratigraphic sequences should *not* be included. However, references that contain them may be cited.

5. Reference to relevant publications. Citations within a description should be to author and year, with specific pages wherever appropriate. References to published date lists should cite the sample no., journal (R for Radiocarbon), years, vol, and specific page (eg, M-1832, R, 1968, v 10, p 97). Full bibliographic references are listed alphabetically at the end of the manuscript, in the form recommended in *Suggestions to Authors.*

6. Date of collection and name of collector.

7. Name of person submitting the sample to the laboratory, and name and address of institution or organization with which submitter is affiliated.

8. Comment, usually comparing the date with other relevant dates, for each of which sample numbers and references must be quoted, as prescribed above. Interpretive material, summarizing the significance and implicity showing that the radiocarbon measurement was worth making, belongs here, as do technical matters, *eg,* chemical pretreatment, special laboratory difficulties, etc. Calendar estimates, reported in AD/BC may be included, citing the specific calibration curve used to obtain the estimate.

Illustrations should not be included unless absolutely essential. They should be original drawings, although photographic reproductions of line drawings are sometimes acceptable, and should accompany the manuscript in any case, if the two dimensions exceed 30cm and 23cm.

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* Suggestions to authors of the reports of the United States Geological Survey, 5th ed, Washington, DC, 1958 (Government Printing Office, $1.75).

NOTICE TO READERS

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 9th International Conference on Radiocarbon Dating, Los Angeles/La Jolla, 1976. 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 AD/BC, citing the specific calibration curve used to obtain the estimate.

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.

Citations. A number of radiocarbon dates appear in publications without laboratory citation or reference 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, covering all published ^{14}C measurements through Volume 7 of

RADIOCARBON, and incorporating revisions made by all laboratories, has been published. It is available to all subscribers to RADIOCARBON at $10.00 US per copy.

Publication schedule. Beginning with Volume 15, RADIOCARBON has been published in three issues: Winter, Spring, and Summer. The deadline for v 21, no. 3 is May 1, 1979. Contributors who meet our deadlines will be given priority but publication is not guaranteed in the following issue.

List of laboratories. The comprehensive list of laboratories at the end of each volume now appears in the third number of each volume.

Index. All dates appear in index form at the end of the third number of each volume.

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EDITORIAL STATEMENT TO 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.

The editors have recently agreed to an expanded role for the Journal. In addition to date lists, the editors will now consider technical or interpretative articles on all aspects of ^{14}C. In general, the type of material presented at International Radiocarbon conferences is appropriate for inclusion in Radiocarbon. Articles containing scientific knowledge based on ^{14}C data broadens the scope of the Journal.

All correspondence and manuscripts should be sent to the Managing Editor, Radiocarbon, Box 2161, Yale Station, New Haven, Connecticut 06520.

The Editors

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PRECISE ^{14}C MEASUREMENT BY LIQUID SCINTILLATION COUNTING

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INTRODUCTION

Radiocarbon dating involves a comparison of the count rate of sample carbon with that of modern reference standard material. To calculate a date the ratio Z must be determined where

$$Z = \frac{N_s - N_b}{N_m - N_b} \tag{1}$$

in which N_s = gross sample count rate (cpm),

N_m = gross reference standard count rate (cpm) determined with National Bureau of Standards oxalic acid, 95 percent of the specific activity of which is taken to be that of a sample aged AD 1950,

N_b = background count rate (cpm).

As the sample, reference standard, and background are prepared and counted in the same way, it is generally assumed that any inaccuracies in experimental technique will be the same for each. For this reason radiocarbon dates are usually quoted with a precision (standard deviation, SD) based on the statistics of counting alone and makes no allowance for errors associated with technique apart from sample dilution and isotopic enrichment. However, in practice, sample, reference standard, and background are not counted in identical fashion, as the precision of a date is improved by accumulating counts from reference standard and background over a prolonged period. As a result, sample, reference standard, and background may be counted on different occasions, and there is a possibility that different errors may arise in each with a resulting loss of accuracy. It should be possible to eliminate this difficulty if *constant* preparatory and counting conditions can be provided by investigating (and correcting for) all foreseeable sources of error. This paper describes such an investigation, the object being to achieve an overall precision on a radiocarbon date of about ±20 yrs in order to make a detailed calibration of the radiocarbon time scale (Pearson and others, 1977).

As the age of sample carbon is given by 8033 $\log_e \frac{Z}{0.95}$ (Callow, Baker, and Hassall, 1965) this target requires a precision of about ±0.25

percent of Z. It was desired to develop a system capable of measuring two samples a week to this precision, assuming the material to have an age equal to one half-life. Sample size was not a limiting factor.

The procedure adopted was to convert sample carbon to benzene according to the method of Barker, Burleigh, and Meeks (1969), but scaled up to produce at least 16 ml benzene per sample, and then assess the ^{14}C content of the benzene in a liquid scintillation spectrometer. A preliminary outline account of the procedure has appeared elsewhere (Pearson and others, 1977).

EVALUATION OF ERRORS AND REQUIREMENTS OF THE COUNTING SYSTEM

The errors encountered in a liquid scintillation dating system fall into three distinct groups. There are, first, the errors associated with the statistics of counting; second, those associated with the uncertainty remaining after corrections have been made to improve the accuracy of measurement; and third, those consequent on the uncertainty surrounding the reproducibility of external source channels ratio (p 10) and the assumption that vial efficiency and background are constant (p 17). The last two groups of errors will be considered together and termed correction errors.

If these correction errors are assumed to be independent of each other and specific to sample, reference standard, and background respectively, each count rate will have to be corrected in turn to give the count rate appropriate to the standard conditions. Errors associated with the corrections made to the components of N_s, N_m, and N_b will each contribute to the total error in the ratio Z. To determine how much error can be allowed in each individual component and so assess what will be required of the counting system, it is necessary first to consider the way in which errors will be propagated through the components.

The general equation for the propagation of errors in a function $X = f(a, b, \ldots n)$ where a, b . . .n are independent variables is

$$\mathrm{Var}(X) = \mathrm{Var}(a)\left(\frac{df}{da}\right)^2 + \mathrm{Var}(b)\left(\frac{df}{db}\right)^2 + \ldots \mathrm{Var}(n)\left(\frac{df}{dn}\right)^2 \quad (2)$$

Terms beyond the first differential are considered insignificant as they are unlikely to be more than about 5 percent of the first differentials in magnitude. There may be significant effects due to covariance between sample, standard, and background, but calculation suggests that the likely error (to be propagated along with other errors) is equivalent at most to ±3 yrs, and, for simplicity, this source of error has been ignored.

From (1) and (2) the variances due to the three components are:

$$\mathrm{Var}(Z) = \mathrm{Var}(N_s)\left(\frac{dZ}{dN_s}\right)^2 + \mathrm{Var}(N_m)\left(\frac{dZ}{dN_m}\right)^2 + \mathrm{Var}(N_b)\left(\frac{dZ}{dN_b}\right)^2 \quad (3)$$

and substituting from (1) following differentiation

$$\mathrm{Var}(Z) = \mathrm{Var}(N_s)\left(\frac{1}{N_m - N_b}\right)^2 + \mathrm{Var}(N_m)\left(\frac{N_s - N_b}{(N_m - N_b)^2}\right)^2 + \mathrm{Var}(N_b)\left(\frac{N_m - N_s}{(N_m - N_b)^2}\right)^2$$

Dividing through by $Z^2 = \left(\frac{N_s - N_b}{N_m - N_b}\right)^2$ gives $\frac{\mathrm{Var}(Z)}{Z^2} = \frac{\mathrm{Var}(N_s)}{(N_s - N_b)^2}$

$$+ \frac{\mathrm{Var}(N_m)}{(N_m - N_b)^2} + \mathrm{Var}(N_b)\left(\frac{N_m - N_s}{(N_s - N_b)(N_m - N_b)}\right)^2 \quad (4)$$

The maximum permissible error in Z is ±0.25 percent. Hence

$$\frac{\mathrm{Var}(Z)}{Z^2} = \left(\frac{0.25}{100}\right)^2 = \frac{\mathrm{Var}(N_s)}{(N_s - N_b)^2} + \frac{\mathrm{Var}(N_m)}{(N_m - N_b)^2} + \mathrm{Var}(N_b)\left(\frac{N_m - N_s}{(N_s - N_b)(N_m - N_b)}\right)^2 \quad \ldots (5)$$

From this equation it is possible to evaluate the relative significance of the errors in the components of N_s, N_m, and N_b. In order to obtain optimum precision on a radiocarbon date in a fixed period of time, the conditions of operation should be such as to give identical fractional errors for each component. However, in the present investigation, a major portion of the error allowance was awarded for sample measurement so as to reduce counting time to a minimum and allow two samples to be measured each week. Although the correction errors on the background all involve the linear addition or subtraction of counts, the correction errors on the sample and reference standard are of two types: the fractional or percentage errors which result from changes in efficiency and errors of the additive type. As it is not possible, at this stage, to evaluate these combinations of correction errors, the variances of each component were assumed to be equal, that is,

$$\mathrm{Var}(N_s) = \mathrm{Var}(N_m) = \mathrm{Var}(N_b) = x^2$$

This assumption increases the error allowance on the sample because the count rate of the sample will generally be less than that of the reference standard. The error allowance on the reference standard is correspondingly reduced, but the standard could still be measured to a high precision as counts could be accumulated over a period of months. To simplify the equations let $N_s = 0.5\ N_m = 1$ and substitute into (5).

Then

$$\frac{\mathrm{Var}(Z)}{Z^2} = \left(\frac{0.25}{100}\right)^2 = \frac{x^2}{1} + \frac{x^2}{4} + \frac{x^2}{4} \text{ when } N_b = 0 \quad \ldots (6)$$

$$\frac{\mathrm{Var}(Z)}{Z^2} = \left(\frac{0.25}{100}\right)^2 = \frac{x^2}{0.83} + \frac{x^2}{3.64} + \frac{x^2}{3.01} \text{ when } N_b = 0.1(N_s - N_b) \quad (7)$$

$$\frac{\mathrm{Var}(Z)}{Z^2} = \left(\frac{0.25}{100}\right)^2 = \frac{x^2}{0.69} + \frac{x^2}{3.36} + \frac{x^2}{2.33} \text{ when } N_b = 0.2(N_s - N_b) \quad (8)$$

Consider eq (6) above. The three terms on the right refer to the fractional variances in N_s, N_m, and N_b respectively (5), and it is clear that the fractional variance of the sample is four times that of the standard or background. This gives a basis, albeit approximate, on which to work. The fractional variance of N_s is 0.667 of the total error, that is,

$$\frac{\mathrm{Var}(N_s)}{(N_s - N_b)^2} = 0.667\left(\frac{\mathrm{Var}(Z)}{Z^2}\right) = 0.667\left(\frac{0.25}{100}\right)^2 = \left(\frac{0.204}{100}\right)^2$$

The corresponding fractional variance for N_m is

$$\frac{\mathrm{Var}(N_m)}{(N_m - N_b)^2} = 0.167\left(\frac{\mathrm{Var}(Z)}{Z^2}\right) = 0.167\left(\frac{0.25}{100}\right)^2 = \left(\frac{0.102}{100}\right)^2$$

and for N_b

$$\mathrm{Var}(N_b)\left(\frac{(N_s - N_m)}{(N_m - N_b)\,(N_s - N_b)}\right)^2 = 0.167\left(\frac{\mathrm{Var}(Z)}{Z^2}\right) = 0.167\left(\frac{0.25}{100}\right)^2$$

$$= \left(\frac{0.102}{100}\right)^2$$

Similar evaluations of eqs (7) and (8) allow the effect of background level on the fractional errors on the components due to N_s, N_m, and N_b to be determined:

Background level	$\frac{\mathrm{SD}\,(N_s)}{N_s - N_b}$	$\frac{\mathrm{SD}\,(N_m)}{N_m - N_b}$	$\frac{\mathrm{SD}\,(N_b)\,(N_m - N_s)}{(N_s - N_b)\,(N_m - N_b)}$
$N_b = 0$	0.204 percent	0.102 percent	0.102 percent
$N_b = 0.1(N_s - N_b)$	0.204 percent	0.098 percent	0.107 percent
$N_b = 0.2(N_s - N_b)$	0.204 percent	0.093 percent	0.111 percent

It can be seen that changes in the background component from 0 to 20 percent of the net sample count rate have little effect. A background of 15 percent of the net sample count rate was taken as a realistic aim, that is,

$$N_b = 0.15\,(N_s - N_b) \tag{9}$$

The fractional errors are then 0.204, 0.095, and 0.109 percent, respectively.

Since these error allowances include a combination of both correction errors and counting errors, a further breakdown of the error allowance is necessary. Twelve factors likely to give rise to correction errors in the final result in a liquid scintillation counting system were envisaged. (As the samples were not to be diluted with inactive benzene no allowance has been made for dilution errors.)

Isotopic enrichment
Background variation with barometric pressure
Reproducibility of external source channels ratio
Loss of sample benzene
Variation of efficiency with weight of vial contents

Variation of background with weight of vial contents
Contamination with ^{3}H
Contamination with ^{222}Rn
Variation of efficiency with "purity" (p 10)
Variation of background with "purity" (p 11)
Variation of efficiency between vials
Variation of background between vials

Since the ultimate accuracy of a ^{14}C measurement is dictated by the limitations of the counter used, it was intended to select an instrument capable of a stability that would allow correction to standardized conditions to within ±0.025 percent for efficiency and ±0.025 percent of net sample count rate for background. The accuracy of purely physical measurements can often be improved by repetition, and it was estimated that an accuracy of ±0.01 percent could be achieved in this way for measurement of weight, atmospheric pressure, and isotopic enrichment. It was hoped to achieve the same level of accuracy for all the individual correction factors but to take account of additional errors (such as those due to the human element and those involved in determining the magnitude of factors for which corrections have to be applied) the allowable precision on each correction was raised to ±0.025 percent in the case of fractional errors or ±0.025 percent of net sample cpm for errors involving the linear accumulation of counts. The total cumulative error due to the 12 factors listed above gives a precision (calculated from the root mean square value of individual errors) equivalent to ±0.087 percent of net sample count rate. However, only half the corrections are of the fractional type, the remainder being additive, and, since these are equivalent to ±0.0125 percent of net *standard* count rate, the cumulative correction errors on the reference standard is only 0.068 percent of net reference standard count rate. The correction errors involved in standardizing background measurement are all of the additive type and give a cumulative error equivalent to 0.061 percent of net sample count rate. Knowing these correction errors, it is now possible to calculate the residual error allowance that can be allocated to N_s (0.185 percent) and N_m (0.066 percent). From these figures, the requirements of the counting system can soon be deduced.

Consider first the sample component. It is required that

$$\frac{SD\,(N_s)}{N_s - N_b} = 0.185 \text{ percent}$$

Substituting from (9), it can be shown that

$$\frac{SD\,(N_s)}{N_s} = 0.87 \times 0.185 \text{ percent} = 0.161 \text{ percent}$$

Such a fractional error requires that about 386,000 counts be observed. If the ^{14}C efficiency is 70 percent, a half-life sample will give a count rate of about 5 cpm/g carbon or 5.75 cpm/g including background. Allowing 2.75 days to count each sample means that a total of 23,000 counts will be accumulated per g carbon. To achieve the desired precision 16.8 g carbon must therefore be measured. This will result in a net count rate of 84 cpm and a background of about 12.6 cpm.

The remaining error on the reference standard component $\frac{SD\ (N_m)}{N_m - N_b}$ is 0.066 percent so that

$$\frac{SD\ (N_m)}{N_m} = 0.93 \times 0.066 \text{ percent} = 0.061 \text{ percent}$$

To achieve this precision the reference standard must be counted for approx 3×10^6 counts. As the count rate N_m will be about 181 cpm, this will take 16,600 min, that is, 1 day a week for about 11 weeks.

The overall fractional error allowance for the background is 0.109 percent. Substituting for N_s, N_m, and N_b into the third term of eq (5) yields

$$\frac{SD\ (N_b) \times 97}{84 \times 181} = 0.109 \text{ percent}$$

Hence SD $(N_b) = 0.174$ cpm.
Now the correction error on the background was shown above to be equivalent to 0.061 percent of net sample count rate, that is, 0.051 cpm. The remaining error that can be allowed for background counting is then 0.166 cpm. To count a background of 12.6 cpm to a precision of ± 0.166 cpm requires about 6000 counts, that is, about 8 hours counting time.

THE COUNTER

After a survey of the instruments then available, using the above specification as a guide, a Philip's Liquid Scintillation Analyzer, type PW 4510 was purchased in 1970 and modified as follows: A matched pair of photo-multiplier tubes was selected for low background in the ^{14}C energy range, and the light guides were altered to give the highest possible figure of merit for ^{14}C. The counter was installed in a single story building and surrounded on three sides with a concrete shield with 30-cm-thick walls and 75cm overhead. The background count rate was then 9.3 cpm. The long-term temperature control of the instrument was improved by the addition of automatic defrosting, and a second circulatory fan was installed to minimize the temperature gradient within the counter cabinet.

The basic assembly had 21 independently-programmable trays each containing up to 20 samples, stored in the temperature-controlled cabinet and cycled automatically. The samples were measured by coincidence counting (resolving time 10 ns), and after coincident pulse summation, the spectrum of voltage pulse height was analyzed in three separate and independent channels set to monitor, respectively, ^3H (a possible and variable contaminant in the water supply used in the synthesis of benzene from sample carbon), ^{14}C, and, ^{222}Rn, which was a major source of contamination in both the water supply and the lithium metal used in the synthesis of benzene (Pearson, unpub.). External monitoring facilities were provided by a 7 μCi ^{133}Ba collimated source using two additional, independent channels.

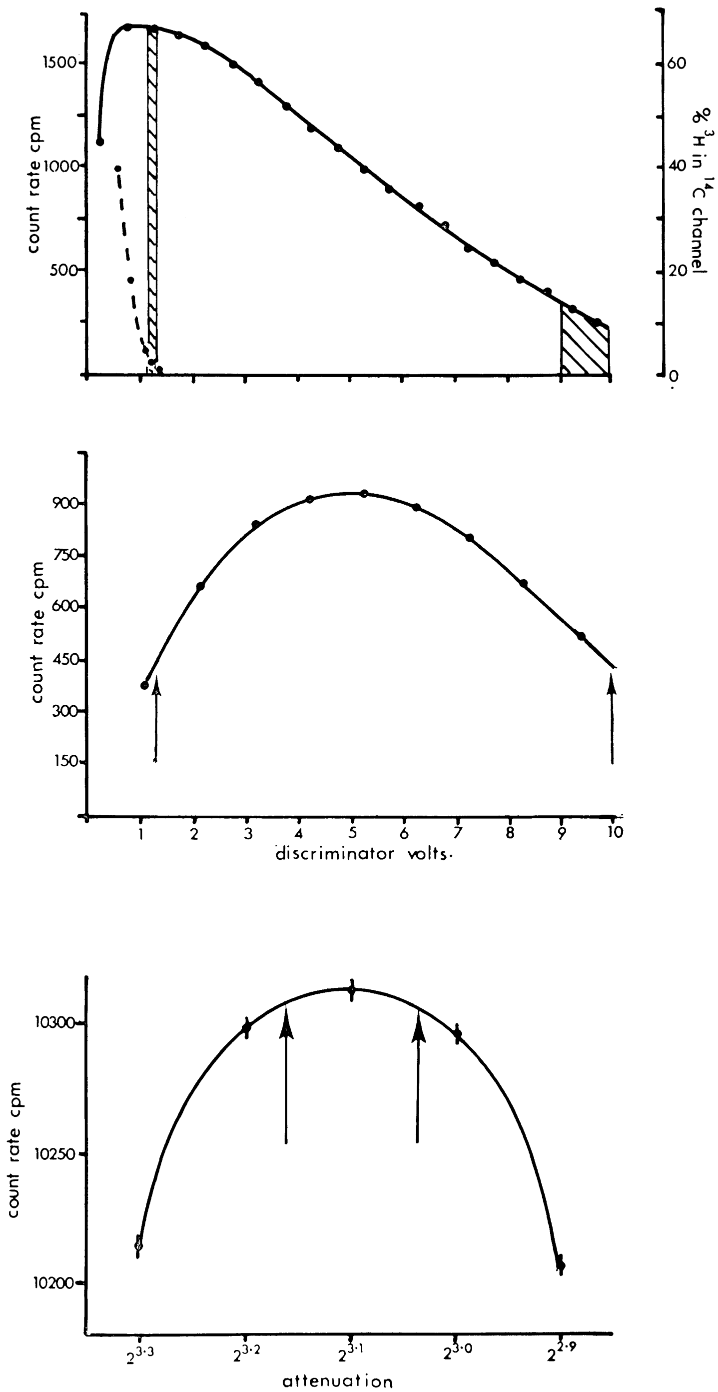
Particular care was taken to set up the instrument in such a way as to elicit from it the best performance. Since ^{3}H was the isotope with the lowest energy to be measured and therefore required the highest overall gain, this channel was used to determine the operating voltage of the photomultipliers, the voltage being increased until the highest count rate was obtained for a ^{3}H source at a low attenuation setting and with a dynamic range of 25:1.

Each photomultiplier tube was then set to give the maximum pulse height by adjusting the focusing grid voltage and then the acceleration voltage. The high voltage supply to each tube was next adjusted to balance the tubes so that each gave a similar pulse height spectrum when observing the same counting vial. Finally, the ^{3}H channel attenuation was readjusted to give the maximum count rate.

To set the ^{14}C channel so as to exclude any major contribution from ^{3}H but yet operate at balance point, the discriminators were initially fixed to give a dynamic range of about 7:1. The amplifier gain was then increased to give the maximal count rate within this dynamic range. To ensure that corrections could be made within the designated limits for any counts recorded in the ^{14}C channel from contaminant ^{3}H, the discriminators on the ^{3}H channel were altered to reduce the efficiency (to about 30 percent) with a dynamic range of only 12:1. (Approx 8 percent of the ^{14}C counts observed in the ^{14}C channel then contributed to the ^{3}H channel.) To keep the error caused by any ^{3}H contribution to the ^{14}C channel below ± 0.025 percent of the net sample count rate of ^{14}C, that is, below ± 0.02 cpm, this value was set as the SD of the error in the assessment of ^{3}H contributions to the ^{14}C channel. It was calculated that ^{3}H could be determined under all conditions to better than ± 1 cpm, thus allowing a maximum of 2 percent of the net ^{3}H count rate to contribute to the ^{14}C channel. The lower level discriminator in the ^{14}C channel was set to 1.30 volts which in fact gave a contribution of about 1 percent (fig. 1A), allowing for a possible increase in contribution if there were a rise in overall gain. The limit of detection for ^{3}H in the ^{3}H channel was 0.04 cpm with ^{14}C-free benzene.

Because at this stage, the gain of the ^{14}C channel had been fixed and the lower level discriminator had been set to reduce the ^{3}H contribution, it was no longer possible to use the conventional method (Dyer, 1974) to reestablish a balance point in the ^{14}C channel. The balance point is the most stable point for counting operations, since the net loss of counts from the channel due to any variation in overall gain is minimal. As gain is a percentage function, any change in gain increases each part of the pulse height spectrum by the same proportion. The effect of such a change can be represented by an equal percentage change in the upper and lower level discriminator voltages defining the channel. The counts in the area bounded by the movement of the upper discriminator voltage are then

FIGURE 1


count rate cpm
1500
1000
500
% ³H in ¹⁴C channel
60
40
20
0
count rate cpm
900
750
600
450
300
150
1
2
3
4
5
6
7
8
9
10
discriminator volts
count rate cpm
10300
10250
10200
2^3.3
2^3.2
2^3.1
2^3.0
2^2.9
attenuation

A.

B.

C.

equal to the counts in the area defined by the movement of the lower discriminator voltage (fig. 1A).

To simulate the effect of a change in gain, a scan of the ^{14}C voltage pulse height spectrum was therefore made by varying the lower level discriminator voltage and setting the channel width at 10 percent of this voltage. Figure 1B shows an almost symmetrical pulse height distribution; for balance point operation the upper and lower level discriminator settings must intersect the curve at an identical count rate on either side of the peak. The lower level discriminator had already been set at 1.30 volts; to intersect the curve at the same count rate the upper level was now fixed at 10.0 volts. By this means balance point could be set accurately since the discriminator levels could be adjusted to within 1 percent, while attenuation settings, which are normally used to find the balance point, could only be set to the nearest incremental position, giving a possible deviation of 3.5 percent.

With these settings the dynamic range was 7.7:1, the efficiency (E) for ^{14}C was about 73 percent, and the net count rate for the reference standard was 122.9 cpm. The figure of merit E^2/N_b was 574, and $(N_m - N_b)^2/N_b$ was 1624.

The ^{222}Rn channel was set immediately above the end point energy for ^{14}C with maximal channel width.

PULSE HEIGHT VARIATION

The photomultiplier tubes were sensitive to temperature, but they were housed in a refrigerated cabinet set at $10 \pm 1°C$; they would, however, not experience the whole of the fluctuation within these limits because the variations were short term, and there was a shield of high thermal capacity around the photomultiplier tubes. No significant change in gain was observed between laboratory temperatures of 9° and 25°C.

The relative voltage pulse heights are the voltage pulse heights obtained per unit energy absorbed on different occasions or under different conditions. Relative voltage pulse height may be affected by the presence

← A. Pulse height spectrum for ^{14}C and ^{3}H in the ^{14}C channel. Counts were determined with a 0.5 volt channel width (—●—). The shaded trapezoidal areas are bounded by the movement of discriminator voltage levels required for a 10 percent decrease in gain; these areas are approximately equal. Contribution made by ^{3}H to the ^{14}C channel (—●—). Sources were flame-sealed vials containing ^{14}C and ^{3}H-labelled benzene, respectively, each giving the same relative voltage pulse height.

B. Pulse height spectrum for ^{14}C in which count rates were determined as a function of the lower discriminator voltage, channel widths being equal to 10 percent of this voltage for each measurement. A and B are the two discriminator levels intersecting the count rate curve at identical count rates on either side of the peak (see text).

C. Pulse height spectrum for ^{14}C around the balance point, determined by change of attenuation with fixed discriminator settings. The graph corresponds to the central region of (B). The points show count rates at each successive attenuation setting. A curve drawn by eye through these points would not be sufficiently accurate to allow corrections to the required precision, and the curve has therefore been calculated from the slight differences in area between pairs of trapezia like those shown in (A); for each consecutive unit change of gain setting, the count rate was found to fall according to the series 1, 3, 6, 10, 15, . . . calculated from the slight differences in area between pairs of trapezia 6, 10, 15, . . . The balance point is at the peak of the curve, and the arrows indicate a change in gain of ± 4.5 percent from this point; if no correction were made, there would be a drop of 0.034 percent in counting efficiency at these limits.

of solutes which may quench or increase pulse height. Mass spectrometric analysis of samples of benzene synthesized from cellulose failed to reveal any significant traces of toluene or other foreign compounds. Furthermore, scintillation grade benzene (which was used for background measurements) gave just the same relative voltage pulse height spectrum as synthesized benzene and, therefore, contained no significant impurities; however, this was not true of all samples of Analar benzene. The concentration of oxygen (which has a quenching effect, Birks, 1970) in samples of benzene, will depend on the ambient temperature and pressure at the time the vial is filled, but as the vials were hermetically sealed any differences in concentration would persist even though the samples were all finally measured at the same temperature.

The external ^{133}Ba source was used to monitor the purity of each sample of benzene by examining its pulse height spectrum on each occasion that it was counted. The Compton electron continuum produced in the vial from the ^{133}Ba γ-radiation corresponds roughly to the ^{14}C β-spectrum and is therefore subject to the same factors that influence pulse height variation. The pulse height spectrum from the ^{133}Ba was split into two portions, each measured in a separate channel, in such a way that the ratio of counts for lower to higher energies was about 2 to 1. Any change in overall gain would affect the relative voltage pulse heights, moving pulses from one channel to the other, thus changing the ratio of the count rates for the two channels. The magnitude of this change was determined in experiments using ^{14}C benzene quenched with varying amounts of methanol. Over the range of gain changes accepted, the ratio increased by 1 percent for a 1.5 percent decrease in relative voltage pulse height. The ratio was also used on a long-term basis to monitor variations of relative voltage pulse height due to changes in overall gain irrespective of sample purity. The term "purity" is used to refer to any deviation in the ratio, whether due to the presence of some impurity in the benzene or to other factors affecting overall gain.

At least 40 external source channels ratio determinations were accumulated for each sample of benzene counted, the mean value being used as an index of variation in pulse height. The SD attached to this mean ($\pm$0.5 percent) was that of a single measurement, as there was no certainty that repeated measurements would fall within a normal distribution.

Balance point operation reduces the effect that small changes in relative voltage pulse height may have on efficiency, but it does not provide a *constant* counting efficiency. Maximum efficiency can only be obtained for a particular pulse height spectrum within a defined channel at one particular gain setting, the balance point position (fig. 1C). Since any changes in relative voltage pulse height cause a deviation from this point and reduce counting efficiency, it was necessary to make the appropriate corrections, so simulating a constant efficiency. The balance point position was initially set using benzene of average purity, selected from among samples of scintillation grade benzene and synthesized benzene. This sample of average purity yielded an external source channels ratio of 1.95, and in subsequent work, all ^{14}C benzene count rates were corrected to this value of channels ratio.

It was assumed in the work of Pearson and others (1977) that, within limits, efficiency was proportional to the external source channels ratio. To achieve the required precision, the maximum permissible deviation of the external source channels ratio was limited to ±3 percent, that is, ±4.5 percent deviation in relative voltage pulse height, when efficiency was reduced by 0.034 percent of net count rate. Correction factors were calculated at 1 percent deviation intervals giving about 0.01 percent change in efficiency for each percent change in channels ratio. Because the external source channels ratio was measured to ±0.05 percent, the SD error on this correction was 0.005 percent of net cpm. (The assumption that efficiency is proportional to the channels ratio is only an approximation, as it can be seen from fig. 1A that any change in gain results in a net loss of counts from the channel equivalent to the difference in area between the pairs of trapezia. Fig. 1C is a curve that takes into account these differences in area; it would provide a more accurate basis for assessing the correction factors.)

Since background measurements have a quite different energy spectrum to that derived from ^{14}C, it was necessary to determine the effect of variation in pulse height on background. Vials filled with the standard quantity of ^{14}C-free benzene were measured at intervals over a 100-fold range of attenuation, each measurement being made to better than ±1 percent. Over the relatively narrow range of pulse heights accepted, each 1 percent increase in external source channels ratio caused a fall of 0.041 cpm in background. When this relationship was used to calculate the background corresponding to a channels ratio of 1.95 ± 0.05 percent there remained an error in the correction of about ±0.02 cpm; because it was uncertain whether external source channels ratio measurements would fall into a normal distribution, it was decided to use 2 SD limits, that is, ±0.041 cpm (equivalent to ±0.070 percent of net sample cpm).

THE VIALS

As plastic vials proved unsatisfactory for counting benzene, vials (20 ml) of low-potassium glass with screw-on plastic caps containing a cork and aluminum seal were chosen. Following preliminary trials with 500 such vials which yielded a large spread of background measurements, a group of twenty vials within a weight range of 14.2 to 14.3g was selected. The cork and aluminum seals were found to allow an excessive loss of benzene—more than 5mg per day. New seals were therefore made with a disc of viton rubber (1.5mm thick) giving compression and high restitution, followed by a PTFE disc (0.4mm thick), providing a low friction backing to reduce the possibility of creasing in the final disc, which was made of high purity tin (0.1mm thick), chosen for its properties of compression and reflection. With this type of seal, losses were reduced to 1mg per day. As the physical shape of the vials above a volume of 18ml varied from vial to vial, the internal scatter of photons and the solid-angle geometry of light emission were standardized by spraying the vials above 18 ml with matt white paint, covered in turn with black paint to reduce optical feedback from one photomultiplier to the other.

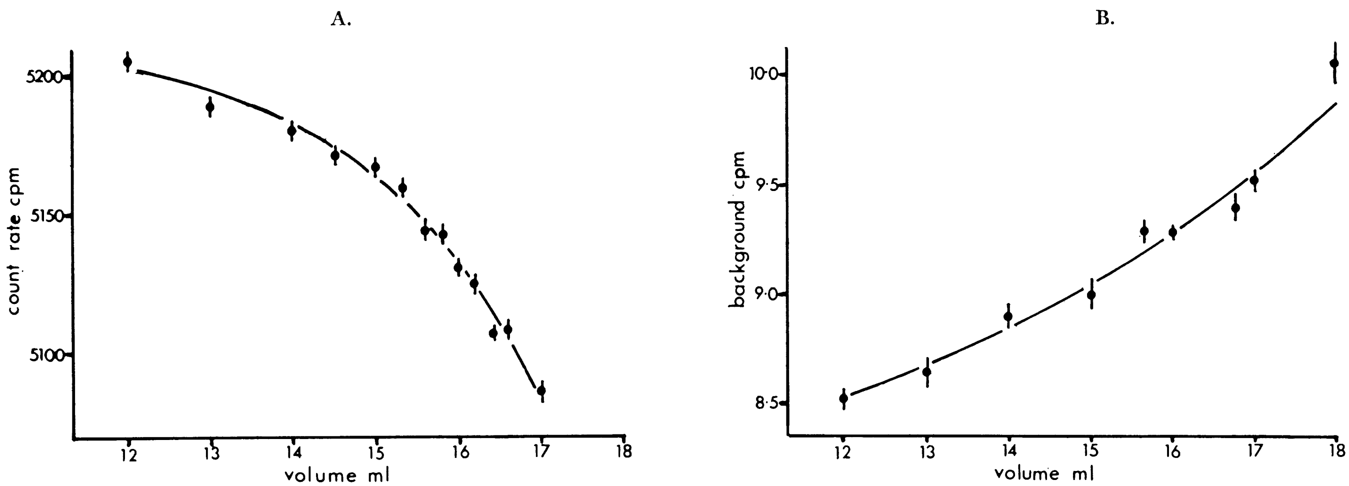
To ensure that each vial was filled with the same amount of sample and scintillant (so reproducing identical geometry, energy-photon conversion, and background counts), filling was monitored by weight rather than volume. The scintillant was a solution of butyl-PBD and PBBO in scintillation grade toluene, giving final concentrations in the vial of 10g/1 and 0.6g/1, respectively (Dyer, 1974).

The vials to be filled were first cleaned with Decon 90, dried, and weighed with and without the final sealing cap. Slightly less than 15ml of sample benzene was then pipetted into the vial. A specially made filling cap (similar to the sealing cap but with a hole drilled through the shell) was weighed and screwed on to seal the vial. The additional sample benzene required to make up a total of 13.1325g was added by means of a micrometer-controlled pipette through a very fine hypodermic needle, a second needle being inserted into the vial for pressure equilibration; the appropriate number of drops was added, and the final weight checked. The addition of 1.1340g of scintillant was achieved in the same manner. Finally the filling cap was replaced with the permanent sealing cap, care being exercised to ensure that no more than 3mg of the mixture was lost by evaporation at this stage. The weight was finally checked before the vial was loaded into the counter, so that losses of sample benzene before counting could be calculated. After the required period of counting, the vial was weighed again.

It was discovered that the weight of a plastic vial cap can itself change by more than 5mg in a matter of minutes. The extent of this change in weight depends on humidity, temperature, and time, and it may be as large as 40mg over a period of 14 days. A correction was made for such changes in weight, determined by experiments with empty vials conducted under the routine conditions. Weight loss could then be estimated to $\pm$10mg, equivalent to an error of $\pm$0.070 percent, a figure representing the maximum error rather than a SD error. (More recently caps made of low-lead aluminum alloy have been used as they show no change in weight with temperature or humidity and bring the accuracy of weight measurement to $\pm$3mg, that is, $\pm$0.021 percent.)

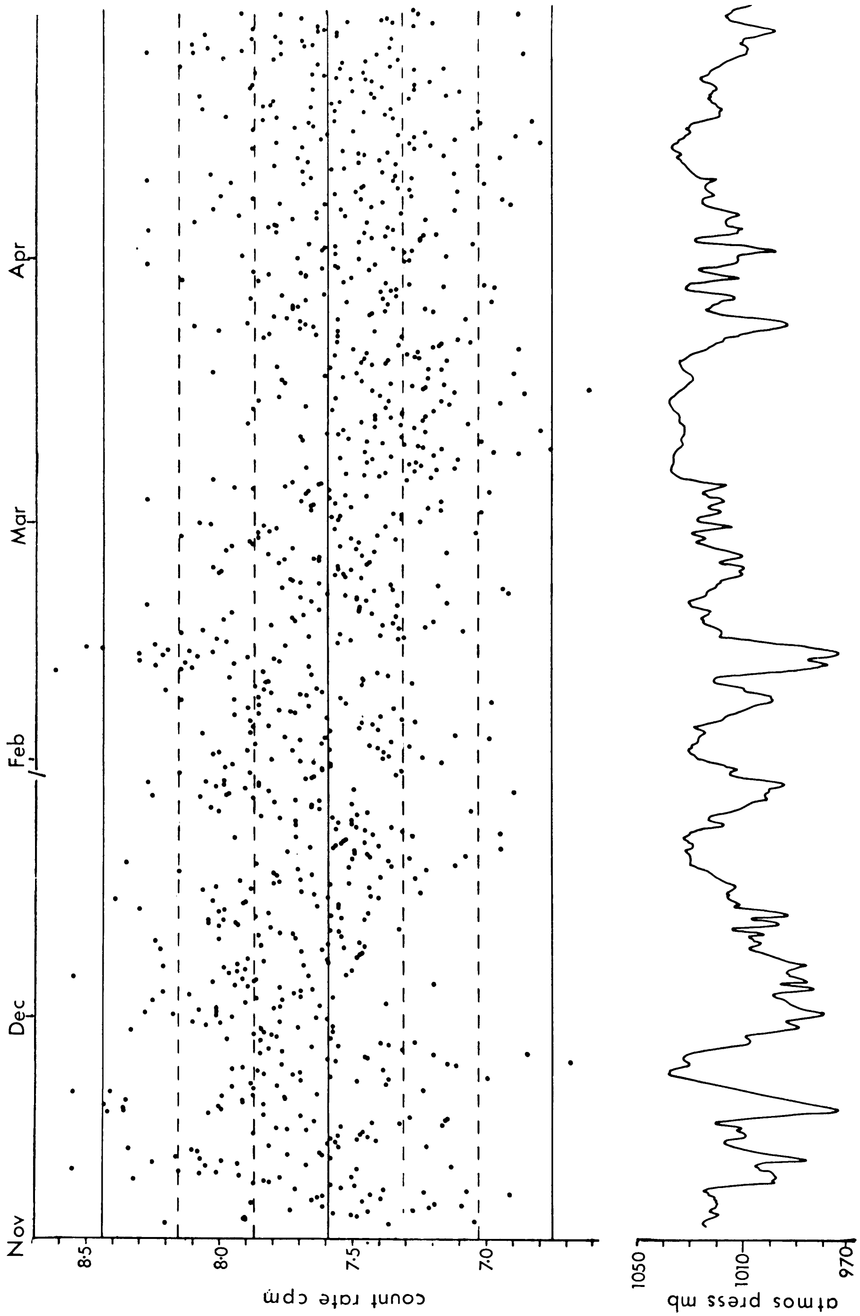
Although the vial caps gave a good seal, over the long periods needed to count samples of low specific activity, appreciable losses owing to evaporation sometimes occurred—up to 50mg over 2 to 3 months. Such weight losses affect efficiency as a result of small changes in the solid-angle geometry presented by the sample to the photomultiplier. Around the standard weight of 14.2666g benzene plus scintillant, the count rate rises by 0.001 percent per mg loss in weight (fig. 2A). This relationship was used to calculate the count rate of each sample or reference standard at the standard weight, assuming that the weight losses were linear over the entire counting period. Since the vial weight could only be measured to $\pm$10mg, the maximum error remaining after this correction was estimated to be $\pm$0.01 percent of net cpm.

FIGURE 2



A. Efficiency of counting ^{14}C in relation to volume of sample. A constant quantity of ^{14}C benzene (10 ml, 10^5 dpm) was diluted with successive aliquots of scintillation grade benzene in such a way that the ratio of scintillant to benzene remained constant.

B. Variation of background in relation to volume of scintillation grade benzene, the proportion of scintillant to benzene remaining constant. Efficiency and background were both taken to be linear functions of volume within the range 16 $\pm$ 0.1 ml.


Nov
Dec
Feb
Mar
Apr
8·5
8·0
7·5
7·0
count rate cpm
1050
1010
970
atmos press mb

A.

B.

C.

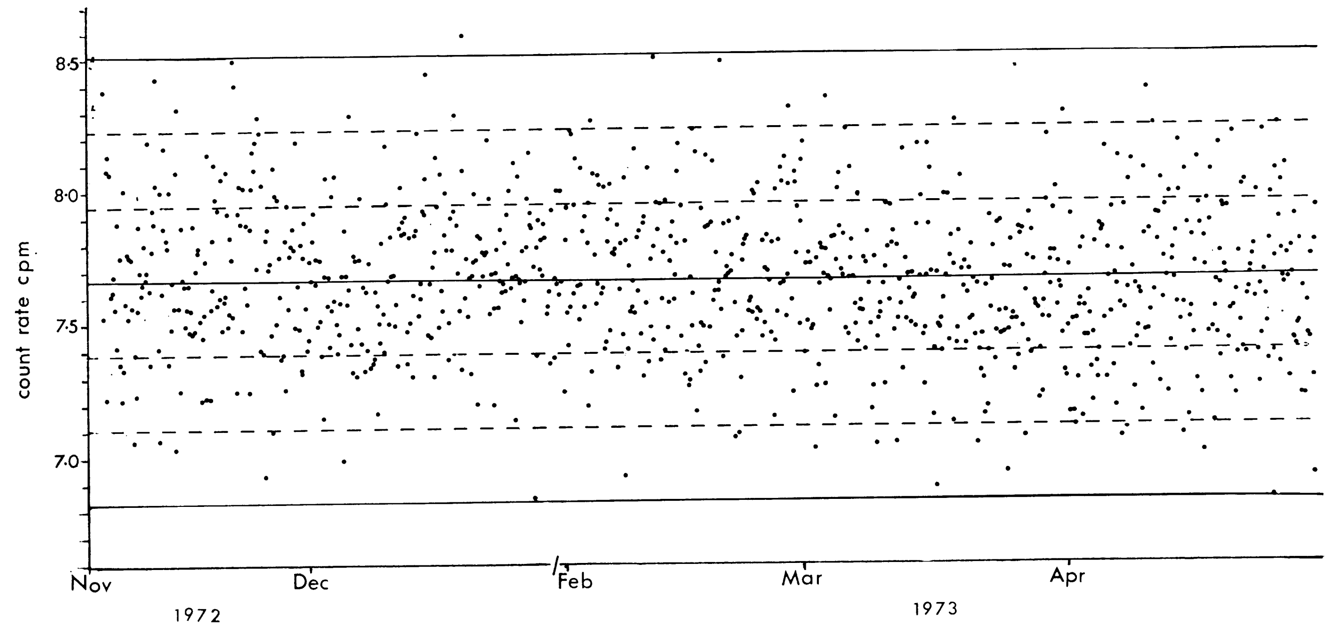


Fig. 3. Background measurements made with a single vial containing ^{14}C-free toluene twice a day over a 6 month period (with an interval of 1 month as shown after the first 2 months). The horizontal lines show mean cpm and 1, 2 and 3 SD limits above and below the mean. (A) Observed values. Note that the mean value for the first 3 months is higher than that in the subsequent period. (B) Corresponding atmospheric pressure chart showing the opposite trend, being higher in the last 3 months. The same inverse relationship is also evident in some of the short-term fluctuations. (C) The same data as in (A), corrected for atmospheric pressure changes. No adjustment was made to the overall gain during the 6-month period nor was there any correction for changes in gain, that is, "purity"; the slow downward drift in count rates indicates a progressive decline in gain.

Background counts were found to fall by 0.00029 cpm per mg loss of weight (fig. 2B), a relationship that was used to calculate background count rates at the standard weight; the error (maximal error) on this correction was ±0.003 cpm, that is, ±0.005 percent of net sample cpm.

A further correction was applied to allow for the loss of sample benzene during the counting period. The overall weight of benzene and scintillant lost during the counting period was known, but only 98.3 percent (w/w) of this weight was due to the loss of benzene (the remainder being due to loss of toluene). The mean weight of benzene present during the counting period was used to calculate the count rate for the standard weight of benzene (13.1325g); the estimated error on this correction was ±0.076 percent of net cpm. As the estimate of the weight error (±10mg) used to derive this correction was a maximum figure, no additional error component was included to allow for the precision within which the differential loss of benzene was determined.

BACKGROUND DETERMINATION: INFLUENCE OF ATMOSPHERIC PRESSURE

The long-term stability of background determination was initially assessed with the two flame-sealed vials containing 15ml of ^{14}C-free toluene and scintillant that were supplied with the counter. The vial backgrounds were each counted for 100 min (to give a precision of about ±3 percent) twice a day. Counting was continued over a 9-month period. Although the count rate was sufficient to ensure a close approximation to a normal distribution, nevertheless, the count rates were found to vary beyond the expected distribution (fig. 3A), only 60.7 percent of the counts falling within one SD of the mean compared to the theoretical 68.3 percent. The deviations from the expected numbers of counts falling within one, between one and two, and beyond two SD were significant at the 1 percent level.

Investigation of periods where a number of points came together outside 2 or 3 SD limits from the mean revealed that barometric pressure was extreme at these times (fig. 3B). There was in fact a significant regression with a coefficient of −0.0120 cpm per mbar increase in pressure. When the background measurements for the 9-month period were corrected to a barometric pressure of 1010 mbar, the counts so obtained fell into a normal distribution (fig. 3C), 68.5 percent of the results then being within one SD from the mean and other percentages in similar agreement with the theoretical values.

This effect of atmospheric pressure was also found to be important under the routine working conditions. Background measurements were accumulated with vials containing 16ml *benzene* and scintillant over a 2-yr period. When the counts recorded were corrected for weight loss, a high degree of correlation was again revealed, with a coefficient of −0.0127 cpm per mbar increase in pressure. This relationship was used to correct each measurement to a standard pressure of 1010mbar. At least 40 pressure readings were taken for each sample determination (and more for standards and backgrounds). It was estimated that the error on the mean atmospheric pressure, including the error inherent in the correlation coefficient, would be ±1 mbar, that is, ±0.013 cpm, which is equivalent to 0.019 percent of net sample cpm.

COUNTING PROCEDURE

The schedule of counting operations is shown in table 1.

The count rate of the high activity ^3H and ^{14}C toluene sources were plotted daily to provide quality control charts for their respective channels, as was the external source channels ratio. This information was used to index the long-term drift of the instrument. Toluene was chosen rather than benzene as the relative voltage pulse height per m.e.v. from toluene is greater than that from benezene, so that tolune was not counted at balance point for either ^3H or ^{14}C, rendering any changes in overall gain more readily detectable. After about a year, the external source channels ratio (and also the counts from the radioactive toluene sources) showed a change in gain sufficient to cause a 3 percent shift from balance point. The channels ratio was then returned to 1.95 by adjusting the photomultiplier voltages and cleaning the light guides and the end windows of the photomultipliers.

Quality control charts were also kept for the observed count rates in the ^3H and ^{14}C channels and the external source channels ratio for all standard and background measurements. The replicate count rates observed in successive counting cycles from each sample were corrected for atmospheric pressure and then submitted to a χ^2 test to detect any unexpected deviation.

Any ^{222}Rn present in a sample would make a significant contribution to both the ^3H and ^{14}C channels and for this reason care was taken to remove contaminating radon during sample preparation. The high efficiency of the ^{222}Rn channel enabled any remaining contamination to be recognized and the samples rejected at an early stage.

At the end of the counting period, the mean count rate for a sample or reference standard was first corrected for any change in the background that would have occurred due to deviation from the standard conditions

TABLE 1
Schedule of counting operations

	Counting time allowed in each cycle of 12 h	Period of time in counter
5 samples	100 min each	About 3 weeks
2 reference standards	40 " "	One renewed every 3 months to allow overlap between the two (it was not known whether weight loss from vials would be linear over longer periods).
Background vials	100 "	Normally 3.5 days
Flame-sealed ^3H toluene standard	4 "	Continuous: monitors ^3H
Flame-sealed ^{14}C toluene standard	4 "	" " ^{14}C
Flame-sealed ^{14}C-free toluene standard	40 "	" " background

of the variable components of background, that is to say atmospheric pressure, "purity", and weight loss. The net count rates were then evaluated by subtracting the current grand mean value of background under standard conditions. Corrections were finally made to sample and reference standard counts for changes in isotopic enrichment and efficiency (due to weight loss, "purity", and loss of sample). In this way, each count rate was brought to standard conditions. The corrected values for reference standard and background for a particular vial were then compared with the values accumulated previously for that vial and used to calculate again grand mean values for standard and background; the values never fell outside the range expected of a normal distribution, indicating that there had been no significant change of efficiency or background with time, and (by inference) that the corrections were accurate.

The individual grand mean values of background and reference standard were determined for each of the 12 individual vials currently in use. No indication of any significant differences in vial efficiency emerged from experiments in which (A) the reference standard was determined to better than 0.1 percent, or (B) a high specific activity ^{14}C source was counted to ±0.029 percent. It was concluded that any change in efficiency between vials lay within these latter limits.

Backgrounds were determined to ±0.3 percent. Although no significant difference in background between vials was detected, the possibility still exists that each vial has its own unique value, and for this reason two SD limits were used in the overall error estimation, that is, ±0.058 cpm equivalent to about 0.01 percent of net sample cpm. Final values for reference standard and background were, therefore, based on the corrected results for all the vials, accumulated over a 2-yr period.

After each count of a sample or reference standard, the vial was cleaned, dried, and filled with scintillation grade benzene to ensure that it gave a background measurement within the distribution already established for that vial.

The corrected count rates were used to calculate the radiocarbon date. To evaluate the precision of this date it is necessary to accumulate the errors remaining after the appropriate corrections have been made to each of the three components N_s, N_m, and N_b. For this purpose, additive errors must first be expressed as a fraction of the respective net cpm. The individual correction errors and counting errors on a sample measurement are propagated as the root mean square of the individual fractional errors. Hence, the fractional error on N_s is given by:

$$\frac{\mathrm{Var}(N_s)}{(N_s - N_b)^2} = (a^2 + b^2 + \ldots + n^2)$$

and

$$\frac{\mathrm{Var}(N_m)}{(N_s - N_b)^2} = (a_1^2 + b_1^2 + \ldots + n_1^2)$$

where a, b, . . . n are individual fractional errors on samples and a_1, b_1 . . . n_1 are errors on the reference standard. The individual count rate errors on the background measurements (a_2, b_2, . . . n_2) are summed in the same way.

$$\mathrm{Var}(N_b) = a_2^2 + b_2^2 + \ldots n_2^2$$

Substituting these values into eq (5)

$$\frac{\mathrm{Var}(Z)}{Z^2} = (a^2 + b^2 + \ldots n^2) + (a_1^2 + b_1^2 + \ldots n_1^2)$$
$$+ (a_2^2 + b_2^2 + \ldots n_2^2)\left(\frac{N_m - N_s}{(N_m - N_b)(N_s - N_b)}\right)^2$$

The error on an age determination is then given by the expression

$$8033 \log_e \left(1 \pm \frac{SD\ (Z)}{0.95\ Z}\right) \text{ yrs}$$

DISCUSSION

It was desired initially to measure the ^{14}C activity of two samples per week each aged about one half-life and to derive a radiocarbon date within an overall precision of ±0.25 percent, that is, approx ±20 yrs. To achieve this precision it was hoped to keep the error on each factor to less than ±0.025 percent of net cpm or (in the case of additive errors) that equivalent to ±0.025 percent of net sample cpm. This target was achieved for all the factors apart from the four discussed below. The correction errors on some of the factors were so low as to allow these four to be slightly greater than ±0.025 percent. Thus the correction error on variation of efficiency with purity was only ±0.005 percent of net cpm, and the variation of background with weight was equivalent to an error of ±0.005 percent of net sample cpm. No ^3H or ^{222}Rn contamination was detected at all (and the limits of detection were so fine as to ensure that no significant error was introduced through failure to monitor contamination actually present).

The four factors with larger correction errors are:

1. variation of background with "purity" (±0.041 cpm, equivalent to an error of ±0.070 percent of net sample cpm);
2. variation of background between vials (±0.058 cpm, equivalent to an error of ±0.01 percent of net sample cpm);
3. correction for loss of sample benzene (±0.076 percent of net cpm); and
4. correction for isotopic enrichment. Individual measurements on the mass spectrometer were made to give a correction to the observed net count rate of ±0.02 percent. However, when analyses were repeated on subsequent occasions, the overall SD error on the correction had to be increased to ±0.05 percent to cover the separate measurements.

The combined total error on all twelve factors was estimated to be equivalent to about ±0.156 percent of net sample cpm—much greater than that desired (±0.087 percent). Taking account of the counting errors, it was finally estimated that under the routine working conditions radiocarbon dates had an overall precision of ±0.31 percent, or about ±25 yrs.

In the evaluation of allowable errors, above, it was assumed, for ease of calculation, that all the errors followed a normal distribution; however as discussed, some of the errors were taken to be maximum errors, some were set at 1 SD level of an assumed normal distribution, and the remainder at 2 SD levels. As these assumptions may exaggerate the magnitude of the combined errors, a further examination of three factors has recently been made (since the work of Pearson and others, 1977). With the changes set out below the combined errors on the twelve factors now come to about ±0.07 to 0.08 percent of net sample cpm which is well within the target set. This, together with improved precision on reference standard and background obtained by continued accumulation of counts, now brings the overall precision to about ±0.25 percent, that is, ±20 yrs.

1. Variation of background with "purity." Continuous monitoring of the ^{14}C toluene vial showed a downward drift in the overall gain of the counter over a year, and the external source channels ratios over this period formed a normal distribution around the regression line. The error on "purity" can, therefore, be reduced to that calculated from the SD of the mean value. This is derived from at least 40 measurements and is, thus, less than 0.17 of the correction based on a single measurement, thus reducing the large background error of ±0.041 cpm to ±0.012 cpm. (It should perhaps be pointed out that the reduced error on "purity" compensates for the increased error arising in the correction of efficiency for "purity" following adoption of the curved relationship shown in fig. 1C, thus maintaining the estimated error on this correction at less than 0.005 percent of net cpm.)

2. Variation of background between vials. A closer examination of the combined distributions of all the background measurements has shown no significant differences between vials after a period of more than 4 yrs. Therefore, the original safeguard of 2 SD is not necessary. The error can now be reduced to 1 SD on a more precise mean value and then approaches the desired figure of ±0.025 percent of net sample cpm.

3. Correction for loss of sample benzene. Improvements in the accuracy of weighing due to the new vial caps brings the error on the correction down to ±0.021 percent of net sample count rate.

Perhaps the most interesting error source to emerge from this work is the effect of atmospheric pressure on background measurement. If no correction were made for atmospheric pressure, background measurements could not be held within a normal distribution, and it would no longer be appropriate to use a grand mean value accumulated from a long series of measurements because such a mean would relate to the average atmospheric pressure over the whole period of measurement. In addition, samples that were not measured over the same time period as their associated backgrounds would be biased. The magnitude of this bias depends on the variation in atmospheric pressure and on the ratio of sample volume to the total volume in the vial, because background counts are related to the total volume in the vial, while the sample counts are dependent on the amount of sample carbon in the form of benzene. It can be shown that a 20 mbar change in pressure can result in an inaccuracy of about 100 yrs in a half-life sample if the vial contains 5ml sample in a total volume of 15ml. Samples are sometimes counted in radiocarbon dating laboratories at an even greater dilution, and pressure changes may exceed 20 mbar, so that inaccuracies as large as 400 yrs are easily possible. Although the need to consider atmospheric pressure in gas counting has long been appreciated, recognition of the corresponding need in liquid scintillation systems is new. The importance of atmospheric pressure in this connection can probably be attributed to its inverse relationship with the intensity of cosmic radiation (Rochester, 1962; Lapointe and Rose, 1962), since cosmic radiation accounts for about half the background count rate observed.

Some of the other factors that have been investigated may also be the source of major errors, if no correction is made. Thus, it can be shown that failure to correct for the effect of variation in the weight of vial contents on vial efficiency and background could cause an inaccuracy of about 11 yrs, and if the error in weighing or pipetting vial contents exceeds ± 5mg, the inaccuracy would increase markedly. Again, the error resulting from failure to operate continuously and precisely at balance point could introduce an error of 80 yrs. Failure to correct for errors in background measurement will become more serious if the sample is much diluted with inactive benzene. Those involved in radiocarbon dating should be alert to the various possible sources of error and recognize that the precision quoted on a date may be quite unrealistic if the error sources have not been investigated in detail.

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DESIGN, CONSTRUCTION AND CALIBRATION OF A HIGH ACCURACY CARBON-14 COUNTING SET UP

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ABSTRACT. The construction and performance of a proportional CO_2 counter system is described by which an over-all accuracy is obtained of 1.3‰ after a two-day counting period.

INTRODUCTION

Natural fluctuations of atmospheric ^{14}C on time scales of a decade to a century, as established by the ^{14}C measurement of tree rings, have a magnitude of a few permil to a few percent, while the recent dilution of ^{14}C by the combustion of fossil fuels also amounts to a few percent.

In order to make the fullest possible use of the ^{14}C record, the accuracy of measurement, which usually is 4-5‰, should be improved, preferably to about 1‰, in fact, a technical improvement by a factor of 20. Apart from the geophysical implication, such accurate measurements can be used for the dendrochronologic calibration of the ^{14}C time scale. Also, floating tree chronologies from different parts of the world can be anchored firmly in time by "wiggle matching", provided the wiggles are well identified (De Jong, Becker, and Mook, 1979).

CHOICE OF COUNTING GAS

A statistical precision of 1‰ (one standard deviation) is attained by the accumulation of a million counts. If this has to be accomplished in two one-day counting periods, the counter has to contain two moles of carbon, as the specific disintegration rate of carbon-14 in modern material is 13.5 dpm/g C. Two moles of carbon are equivalent to 50 L NTP of CO_2 gas. In order to avoid enormous counter volumes we have to choose a higher than usual gas pressure.

Use of a different gas, such as ethane, reduces the above requirement considerably as more carbon atoms are being stored in one molecule of gas. In all instances, the sample is first converted into CO_2 by combustion. The use of a counting gas like ethane, however, requires a more elaborate sample preparation procedure.

The additional steps would introduce an open-system procedure, with greater danger of contamination. A principal draw-back of the ethane preparation would also be a possible production of higher hydrocarbons which introduces an uncertainty in the amount of carbon brought into the counter. Therefore, we decided to adhere to our CO_2 tradition. The sensitivity of CO_2 to electronegative impurities in the counter does not pose a serious problem, if the combustion is accompanied by sufficient purification stages.

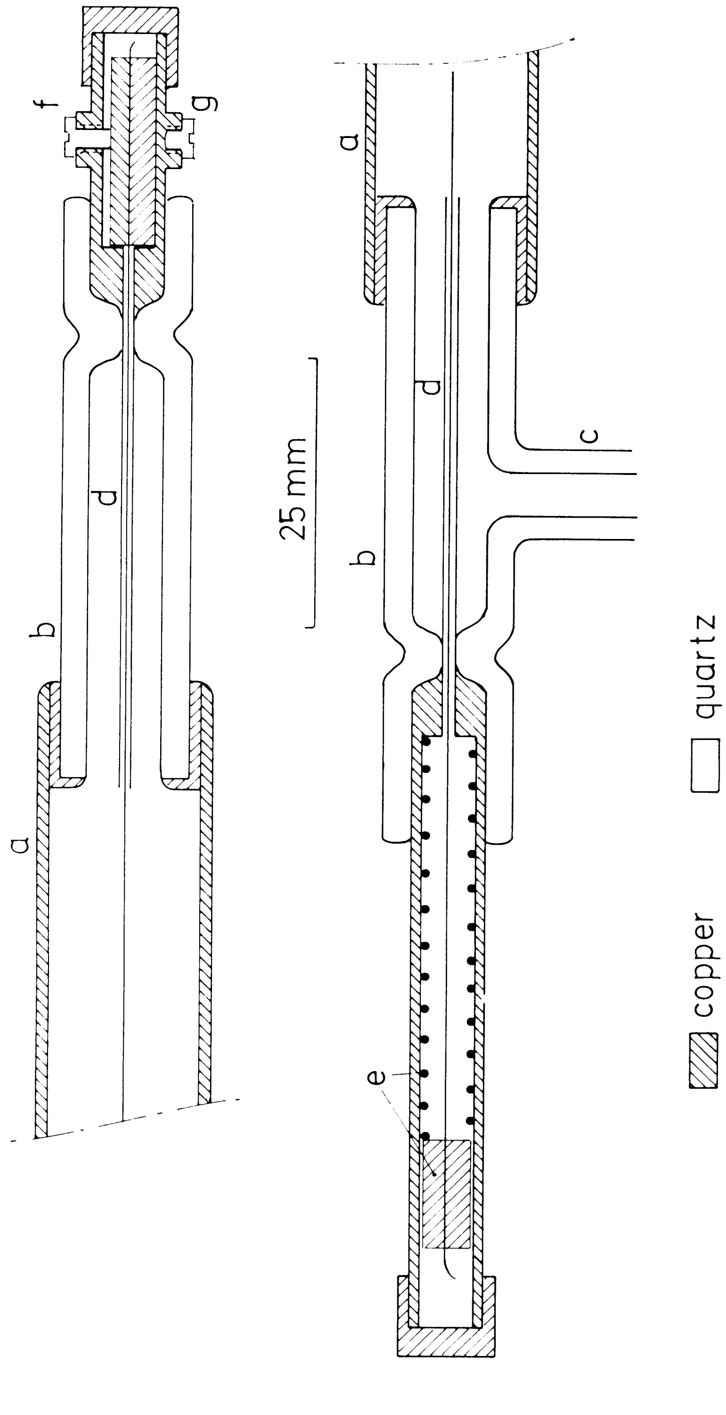


Fig. 1. Construction of the small counter. (a) Counter wall, copper; (b) insulator quartz; (c) gas inlet, quartz; (d) wire support, steel needle; (e) spring and sliding piston; (f) wire fixing screw; (g) electrical contact.

A PRELIMINARY EXPERIMENT WITH HIGH GAS PRESSURES

The large amount of gas needed inevitably leads to the use of high pressures of the counting gas. In order to investigate the properties of CO_2 as a counting gas, such as the amplification and the sensitivity for electronegative impurities (Brenninkmeyer and Mook, 1979) at these pressures, a small counter was constructed for use at pressures up to 16 atm. The construction was kept as simple as possible (fig. 1).

Cosmic ray muon events were minimized by an anticoincidence arrangement using a cylinder of plastic scintillator that surrounded the working volume of the counter. The scintillator was viewed from both ends by two photomultiplier tubes working in coincidence. The distance between the scintillator and the photomultipliers was bridged by cylindric perspex lightguides surrounding the counter endpieces and fitted with holes to accommodate the gas inlet and the signal and high-voltage wires. The shielding consisted of 10cm of lead bricks. Measurements have been performed up to pressures of 16 atm. In practice, a limit on the pressure is posed by the gas purity resulting from a standard treatment on the combustion system. The results were used to calculate the optimal dimensions of the high-precision counting system.

The absolute determination of the gas multiplication factor was based on the relative variation of the high voltage, the gas pressure and the puls height discriminator level (Groeneveld, 1977). The muon counting rates are determined as a function of the high voltage for a number of pressures and discriminator settings. It has been shown from general considerations (Rossi and Staub, 1949) that the gas amplification can be expressed as

$$\frac{\ln M}{aE_a} = f\left(\frac{E_a}{p}\right) \qquad (1)$$

where M is the amplification factor, a is the radius of the central wire, E_a

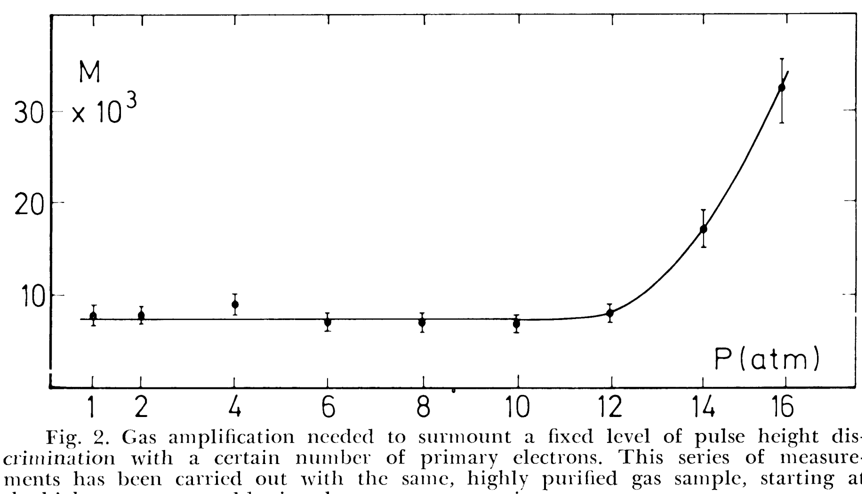


Fig. 2. Gas amplification needed to surmount a fixed level of pulse height discrimination with a certain number of primary electrons. This series of measurements has been carried out with the same, highly purified gas sample, starting at the highest pressure and letting the gas escape stepwise.

the electric field strength at the wire surface, and p the gas pressure. Using Groeneveld's method, a curve of $(\ln M)/aE_a$ against E_a/p is constructed that enables us to calculate the gas amplification for all counter dimensions, voltages, and pressures. Our values nicely fitted a similar curve of Grootes (1977) up to pressures of 12 atm. Above this pressure the calculated amplification that is needed to pass a fixed discriminator level increases for ^{14}C in a drastic manner (fig. 2).

The capture of electrons by electronegative impurities has adequately been described as a three-body process (Herzenberg, 1969). The rate of loss of electrons by attachment to an impurity like O_2 depends on the concentration of both O_2 and CO_2. The original excited O_2, caused by the electron attachment, releases the electron after a short lifetime (5×10^{-12} s, Spence and Schulz, 1972) unless the O_2^{-*} is stabilized by colliding with a CO_2 molecule within this time span. If we are dealing with a gas with a constant impurity fraction, Brenninkmeyer and Mook (1979) have shown that the increase in gas multiplication required to offset the loss of primary electrons by attachment obeys the relation

$$\ln \frac{M}{M_o} = \frac{c^2\, f\, K\, p^3\, b^2 \ln b/a}{2\mu V} \tag{2}$$

where a and b are the radii (in cm) of the central wire and the counter respectively, V is the high-voltage applied, p is the filling pressure (in torr), f is the impurity fraction (in ppm), and $c^2/2\mu \cong 10^{21}$; the attachment coefficient K is a constant, depending on the nature of the trace gases (O_2, SO_2, NO_2, H_2O). Since, in our case, $\ln M$ was found to be more nearly proportional to $p^{1.5}/V$, some process other than this three-body attachment seems to be effective. Without further investigation of this effect we decided to keep the CO_2 pressures below 10 atm.

In practice, even the limit of 10 atm is not within reach as already at lower pressures the effect of impurities will severely hamper the performance of the counter. Therefore, we also studied the highest tolerable level of electron attachment with the small counter. Predetermined amounts of O_2 have been added to a previously purified sample. The resulting shift and distortion of the characteristic curve is shown in figure 3.

The distortion is due to the fact that primary electrons originating close to the wall suffer more electron attachment than those formed near the wire. Both the 1 and 5 ppm curves at 12 atm and the 5 ppm curve at 6 atm are unacceptable, as they do not provide a stable working point. The uncertainty in the purity correction to be applied becomes too large.

The question now is what these curves mean in terms of pulse height loss. For both pressures, the voltage at which the gas amplification equals 8000 has been calculated. At these voltage levels, the percentage of primary electrons starting at the counter wall and reaching the wire has been calculated, using eq 2. For the 1 ppm and the 5 ppm curve at 6 atm and the 1 ppm curve at 12 atm these fractions are 78, 29, and 26 percent respectively. It should be noted that p^3/V differs by a factor of 5.5 for both working voltages chosen, so that 1 ppm O_2 at 12 atm should indeed have a slightly larger effect than 5 ppm at 6 atm. Our knowledge about the impurity correction does not allow a correction to be applied for impure samples showing this primary electron loss to be more than 30 percent, leading to a decreased counting rate of several percent. This corresponds to a loss of primary ionization electrons that is three times as high as the amount of loss calculated for other counters in operation at our laboratory. As they leave the combustion system, the samples usually have a lower apparent O_2 concentration (equivalent to a maximum primary electron loss of 5 percent).

DESIGN AND CONSTRUCTION OF THE HIGH-ACCURACY SYSTEM

General considerations.—In designing the detection system the error due to the counting statistics of the ^{14}C beta decay should be the only error significantly influencing the accuracy of the measurement. Errors in temperature, pressure, and time measurements, and in the background and impurity correction should be an order of magnitude smaller. A low background is desirable as it allows the detection of instabilities more easily.

The amount of counter filling is about 50 L STP. The maximum working length, 80cm, is limited by the length of the available GM anticoincident counters. In our laboratory, other ^{14}C counters, with a working voltage of 7000 V, have no detectable spurious pulses due to electrical leakage across the insulators, provided they are kept clean and dry. At a gas amplification factor of 8000, the counter(s) are operated on the counting plateau.

With the above limitations, the wire diameter needed to achieve a gas amplification of 8000 has been calculated for several possible counter configurations and gas pressures by using the experimentally determined curve of $(\ln M)/aE_a$ versus E_a/p. Subsequently, the loss of primary electrons between the counter wall and the wire was derived for an O_2 concentration of 0.2 ppm, thus providing an estimate for the severity of the impurity effect (Tans, 1978).

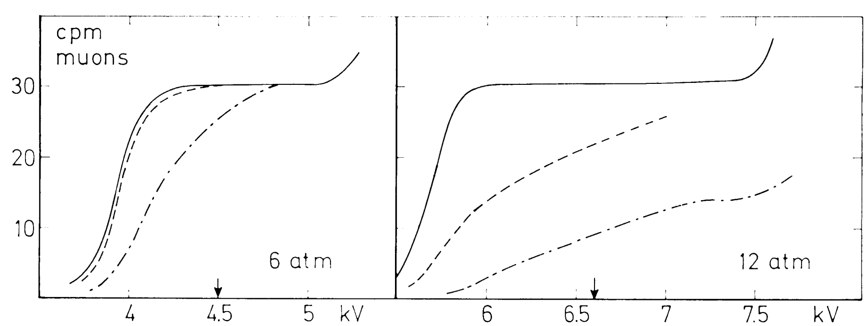


Fig. 3. Muon counting characteristics. The effect of small amounts of oxygen on the counter performance. The arrows indicate the voltages at which the gas amplification factor equals 8000. Curves are presented for pure gas (solid line) and gas containing 1 ppm of O_2 (dashed line) and 5 ppm of O_2 (dash-point line).

It is not possible to operate satisfactorily a large counter at high pressures because of the effect of the impurities. From those configurations that could meet our 70 percent criterion for the impurity effect we have chosen the system consisting of 7 counters operating at 6 atm, as it provides the smallest overall diameter, which is important for attaining a low background.

High-purity quartz is the ideal material for our counters. It is radiochemically pure, and the counters can be isolated electrically from each other by applying a conductive coating to both the inside and outside. The inside is connected to a negative high voltage, while the outside is grounded. If the thickness of the quartz tube is small, the counter wall, itself, has a large capacity (in our case 3 nF for each counter). Together with the resistance that is embodied in the high-voltage connecting plug

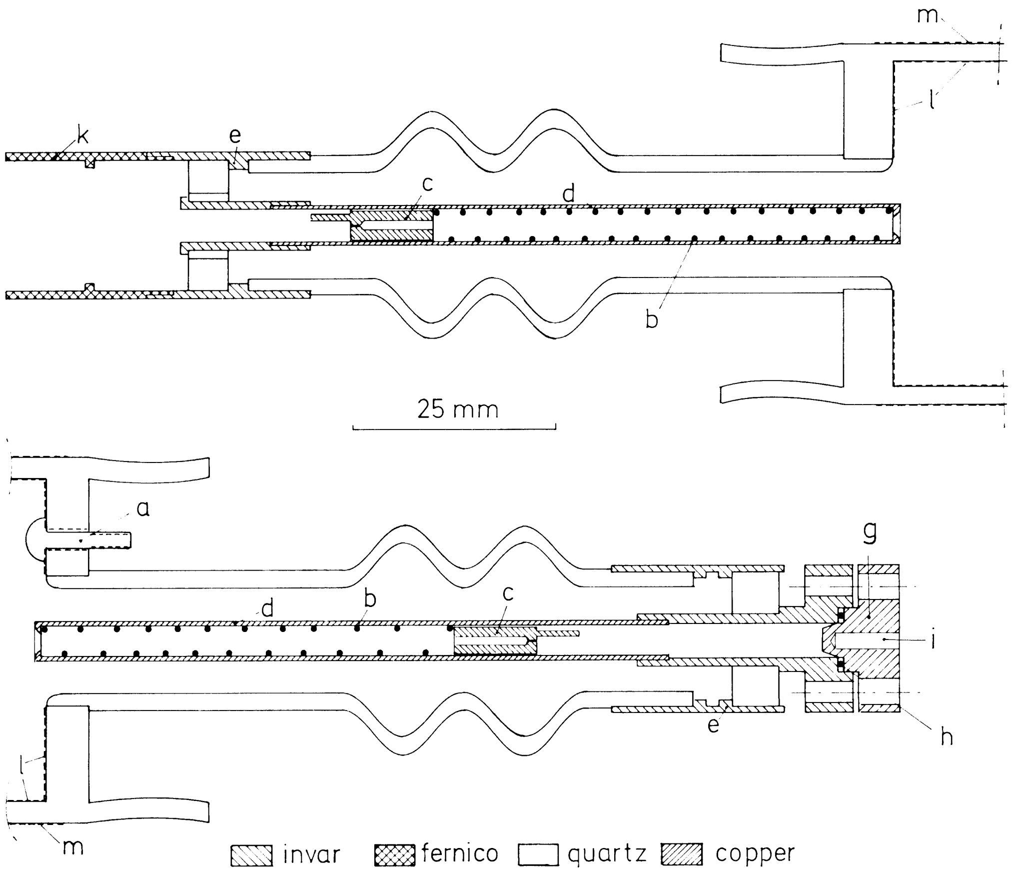


Fig. 4. Design of the end pieces of the counters. (a) high voltage connection; (b) spring for tensioning of the central anode wire; (c) moving piston to which the wire is attached; (d) wire support; (e) guard rings; (g) removable end plug; (h) gold ring; (i) socket for connection to the preamplifier; (k) fernico (54 percent Fe, 29 percent Ni, 17 percent Co), to match the thermal characteristics of the pyrex gas inlet: (l) conductive layer of 0.01 μm of gold; (m) conductive layer, silver paint.

it serves as a high-voltage integrating filter. In this way, spurious pulses caused by leakage of charge from the internal lead shield to the external counter wall are avoided.

Construction and installation of the counter system.—The design of the endpieces is shown in figure 4. The quartz end flanges have been melted into the counter tube. The cleaning operations, the vacuum deposition of the gold film, and the assembly have been performed as described by Grootes (1977). However, a two-component epoxy, curing at 80°C, has been used. On one side, the counters are closed by a gold ring allowing to fit a new wire without taking apart any epoxy seal.

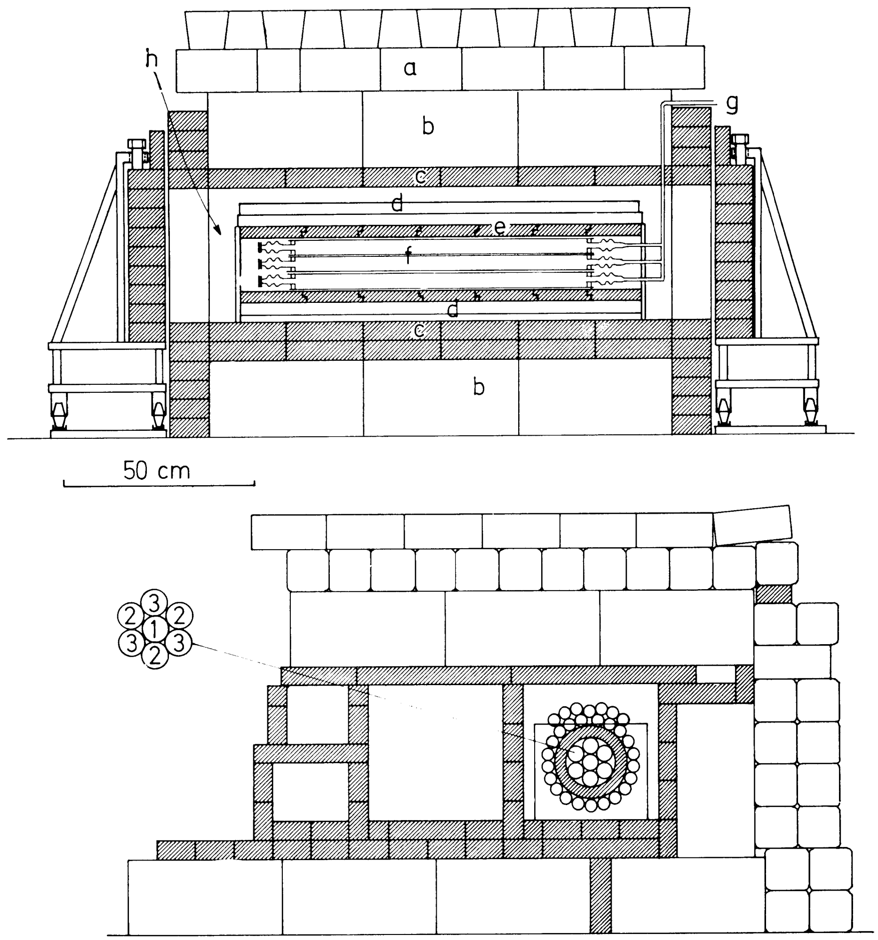


Fig. 5. Counter arrangement and shielding. (a) iron; (b) boron-paraffine; (c) lead; (d) Geiger-Müller anti-coincidence counters; (e) old lead; (f) proportional counters; (g) gas inlet; (h) electrical connections. Proportional counters with equal numbers are connected in parallel to the same preamplifier and can be operated as one separate counter.

The gas inlet connection is made by using two pyrex ball-joints pressed together by aluminium flanges. The viton O-rings of the joints do not deteriorate the gas purity. As a result, the removal or replacement of a counter is very simple.

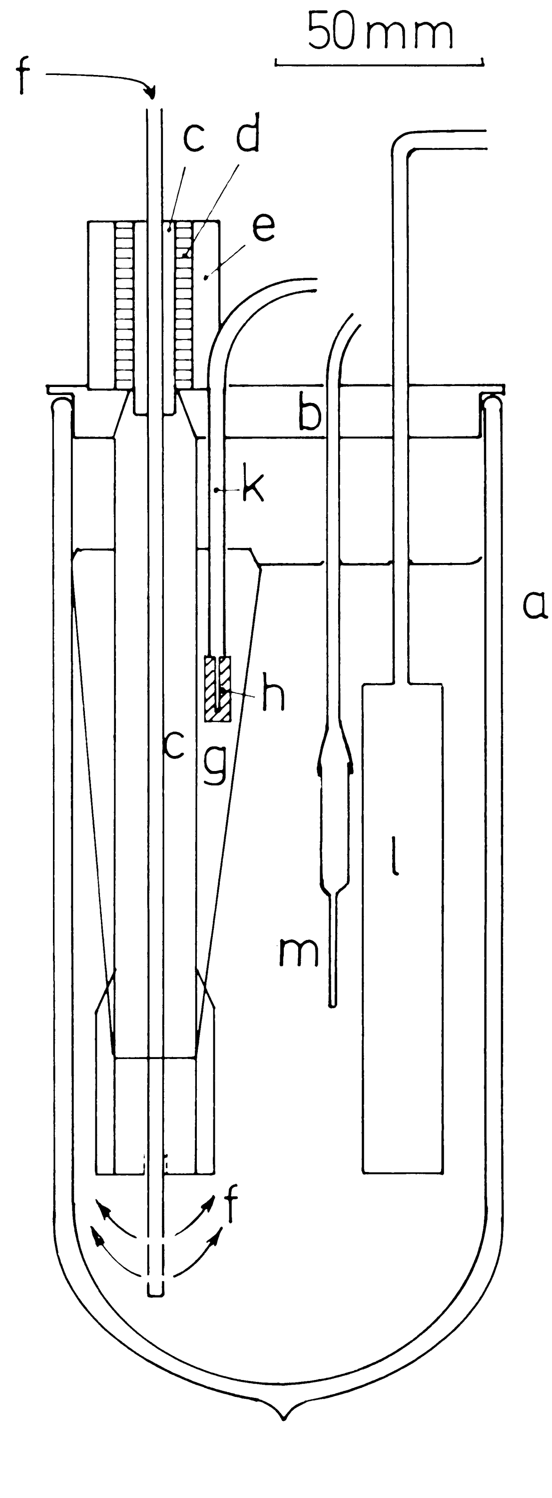
The counters are installed in a concentric arrangement (fig. 5A and B) inside a cylinder of specially selected old lead with a thickness of 2.5cm. They are made accessible by a front and a rear door of 10cm of lead on rail. The underground laboratory has a ceiling consisting of 1-m soil and concrete.

For reasons of electrical insulation, the temperature of the inner lead cylinder is kept a few degrees above room temperature. The temperature of the counters is measured by a platinum resistance thermometer with a reproducibility of 0.01°C (Doric DS-100). The platinum sensor is placed halfway between the counters.

The counters are connected such that, as an option, a sample can be admitted to only the central counter or to one of both sets of three surrounding counters (equal numbers in fig. 5B). In order to protect the counter wires and the electronics, the gas supply lines have been provided with pressure-sensitive switches that shut off the high-voltage power supply, if the pressure falls below a preset level.

Pressure measurement is by a conventional diaphragm manometer (Philips PCS transmitter D). The pressure is referred to a reference pressure of 5.697 atm, the vapor pressure of propylene at a temperature of 0.00°C. The reproducibility of the manometer is 0.001 times the total range of 0.5 atm. The reproducibility of the pressure measurement is, therefore, determined by the degree of control on the temperature of the water-ice mixture in which a propylene flask is immersed (fig. 6). An 0.01°C variation of this thermostat temperature is equivalent to an apparent change of the specific activity of the sample of 0.3‰. The temperature of the water-ice mixture is being monitored continuously with a platinum temperature sensor. The temperature variations are generally less than 0.01°C. The samples are stored at high pressure (~ 60 atm) in stainless steel containers. Filling of the counters proceeds by a controlled expansion from the storage bottles directly into the counters. It has been checked by ^{13}C measurements that within experimental limits of ±0.1‰ no isotopic fractionation occurs during this process, the time of expansion having been varied between a few minutes and a quarter of a minute. The valves of the storage bottles are manufactured completely from metal parts in order to preserve the purity of the gas during storage.

Signal processing.—The pulse-shaping networks, the preamplifiers, and amplifiers are located inside the shielding. The signal processing is depicted schematically in figure 7. The central counter and each set of three counters are not only operated in anti-coincidence with the GM counters but also with the other proportional counters. The pulses are separated into a high and a low-energy channel. The information obtained from the relative counting rates of both channels is used to determine a correction to the total counting rate due to differences in gas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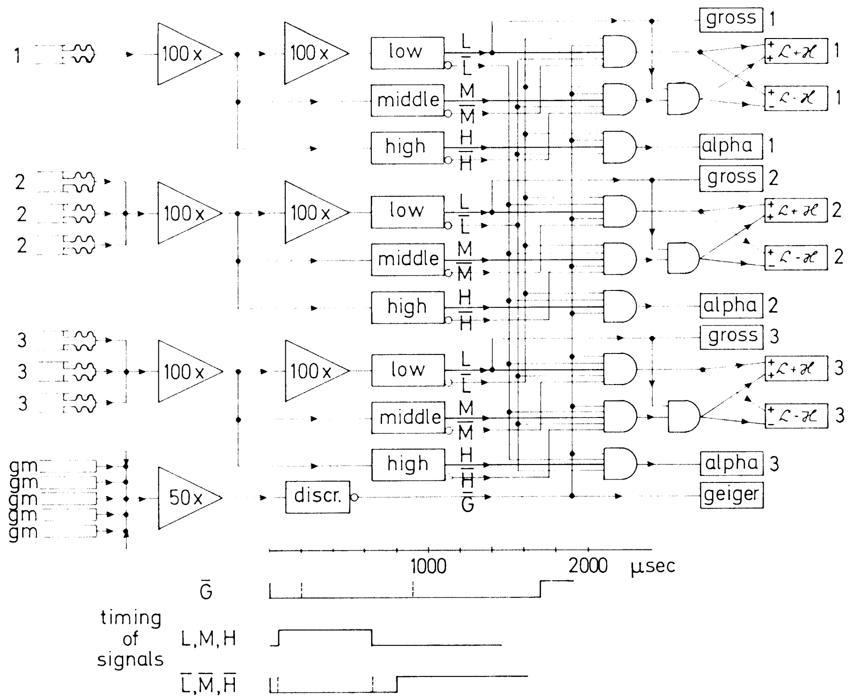

Fig. 7. Scheme of signal processing. The final counting channels are: grossmuons + beta's + background + alpha's; $L + H$ total ^{14}C beta + background; $L - H$ purity channel of ^{14}C beta + background; alpha, pulses above the maximum ^{14}C decay energy.

purity. The discriminators after the first amplifier define the separation between both channels and the upper threshold of the high-energy channel. The discriminator after the second amplifier defines the low threshold of the low-energy channel. The pulses from both channels are fed to up-down counters, one of them summing the channels ($L + H$), the other subtracting the counting rate of the high-energy channel from that of the lower one ($L - H$). In order to minimize the likelihood of pick-up in the cables connecting the inside of the shielding to the discriminators, pulses in the high-energy channel are accepted only if they have also been seen in the low channel. This increases the threshold for pick-up to the level of the low discriminator (at 5 V). Great care was taken that the electronic system did not contain ground loops.

← Fig. 6. Thermostat bath for the reference pressure vessel. (a) dewar; (b) cover, perspex; (c) heat exchanger, copper; (d) peltier cooling elements; (e) flow chamber for water cooling; (f) stream of dried air for stirring; (g) layer of ice; (h) thick walled copper tube with thermistor inside; (k) thin walled tube for thermistor leads; (l) propylene vessel; (m) platinum resistance temperature sensor. The manometer reference side and the immersed vessel are filled with ~ 12 atm of propylene. The thermostat bath is cooled to 0°C and the propylene partly condenses on the walls of the immersed vessel. The thermistor regulates the power supply to the peltier batteries. If the layer of ice becomes too thick, the batteries are switched to a lower power level.

The relative position of the low and the middle discriminator thresholds is important for the stability of the system and the accuracy of the purity correction. The counters are always operated at the same high voltage which is chosen so that the gas amplification produces a pulse height spectrum cut in half by the middle discriminator. In other words, the operating voltage is chosen halfway the steep part of the high-energy channel counting characteristic. A small deterioration of gas purity then causes a relatively large shift of the spectrum into the lower channel. At the same time, the low discriminator threshold should

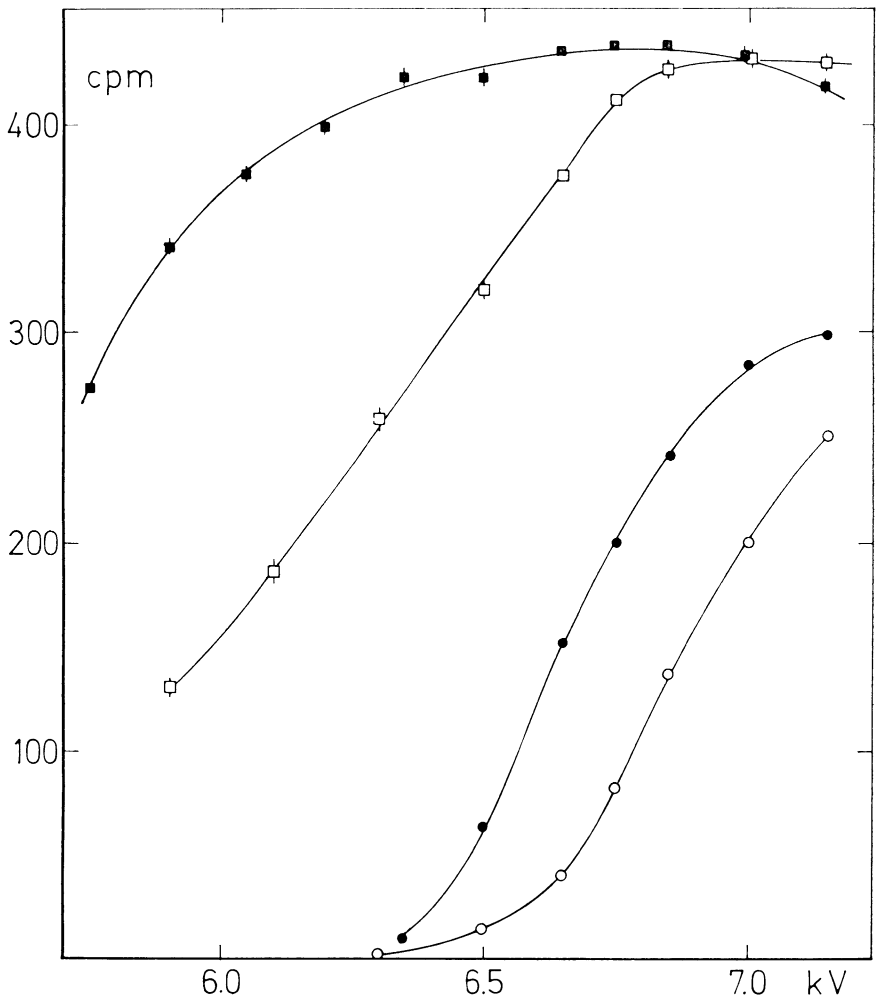

Fig. 8. ^{14}C counting characteristics with and without an artificial impurity (oxygen). The sample is 1963 oak wood. Squares, ^{14}C from both channels combined; circles, only the high energy channel; open and solid symbols, with and without additional oxygen (1.5 ppm), respectively.

be low enough that in this case few pulses only are lost from the total counting rate. Drift of the preamplifier is seen by the system as an apparent change in gas purity for which it is, to first order, automatically corrected. This correction procedure is not perfect as a real change in gas purity slightly influences the shape of the spectrum, whereas amplifier drift does not. The same is true for a drift of equal sign and of equal proportions simultaneously occurring to all thresholds. However, changes of the middle discriminator level and in the amplification of the second amplifier alone are interpreted by the system as variations in gas purity, and a correction to the total counting rate will then be applied. Drift of the low threshold alone results in real changes of the counting rate. The discriminator settings have been chosen such that a 5 percent drift of one of the last three factors would result in a 1‰ change of the counting rate.

The long-term stability (over a period of a year or more) is not relevant as all measurements are referred to a reference sample 0.95 times the activity of NBS oxalic acid, which is measured regularly.

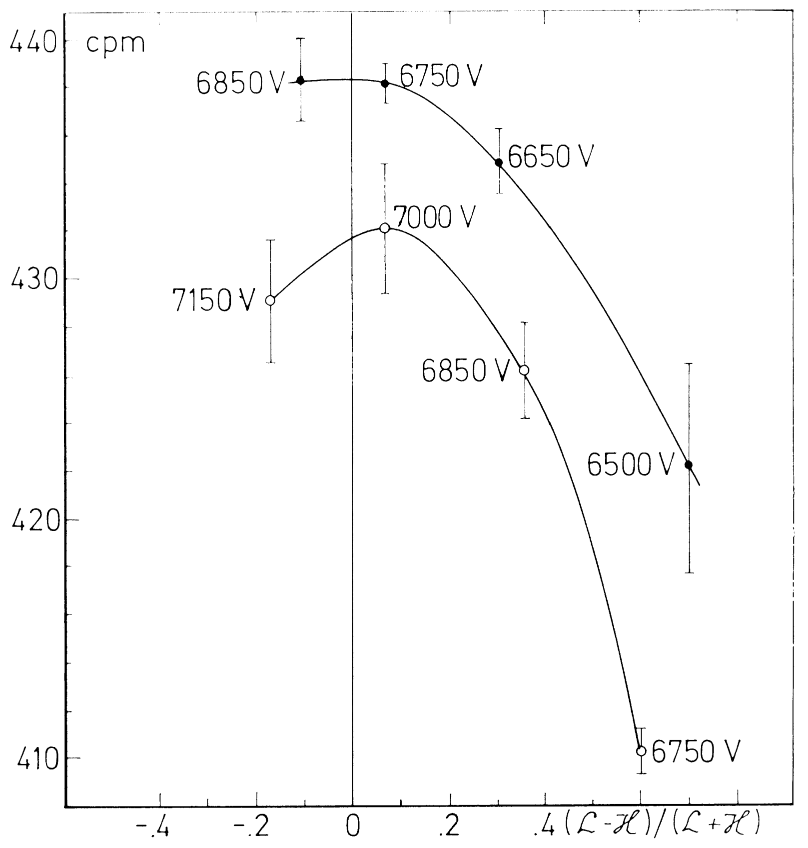

Fig. 9. The counting rate as a function of the relative purity, as defined by $(L - H) / (L + H)$. Open and solid circles, with and without additional oxygen (1.5 ppm). An increase of the high voltage does not entirely restore the counting rate to the value for high-purity gas.

PERFORMANCE OF THE COUNTER SYSTEM

^{14}C counting characteristics.—Only the calibration of the entire system is presented. Figure 8 shows part of the counting characteristics of the sum of both ^{14}C channels as well as of the high-energy channel alone. The working voltage is 6750 V, at which the gas amplification is calculated to be 9500. Also shown in figure 8, is the effect of additional O_2 at a concentration of about 1.5 ppm. The distortion of the counting characteristic is rather large due to the fairly large amount of O_2 added. The necessity of a fully empirical purity correction clearly emerges from figure 9, where the total ^{14}C counting rate has been plotted against the relative purity counting rate $(L - H)/(L + H)$. Merely a parallel displacement of the characteristic curve should have put both curves of figure 9 on top of each other. The empirical correction was determined by measuring oxalic acid for various levels of gas purity (fig. 10). The power curve fitted to these measurements is actually used for the purity correction of all samples. Below a relative impurity $(L - H)/(L + H)$ of 0.25, the type of function fitted hardly affected the purity correction. Samples above 0.25 have to be rejected for direct measurement and are to be repurified. In practice, however, our wood samples provide CO_2 showing $(L - H)/(L + H)$ values below 0.05.

The error due to the uncertainty of the purity correction (maximum 0.4‰ of the total net counting rate at present) has become smaller after additional oxalic acid measurements with different gas purities have become available.

Background.—The dependence of the background on the counter gas pressure is +4 percent/atm. This is of the same order of magnitude as has been found for other CO_2 counters currently in operation in our laboratory. Also the dependence of the background on atmospheric pressure (fig. 11) is comparable to that of the other counters: −2.3 percent/cm Hg.

The presence of a possible radioactive contamination or of spurious counts due to electronic imperfections would have resulted in a lower figure. The background is not influenced by the gas purity to within 0.05 cpm. Therefore, a purity correction is not applied to the background counting rate.

An analysis of the variations of the background with time clearly shows that the counters exhibit a memory effect (fig. 12). A careful comparison of the increase in the background counting rate and the activity of the samples that filled the counters just before the anthracite revealed that the memory effect is 0.2‰ after 4 hours of pumping. As this is the usual pumping time for anthracite, it becomes contaminated with 0.05 cpm each time it is admitted to the counters after a modern (250 cpm) sample. The standard for modern carbon, NBS oxalic acid, has not been affected by the memory effect to a measurable amount, as it was only admitted to the counter following modern samples that very nearly have the same activity.

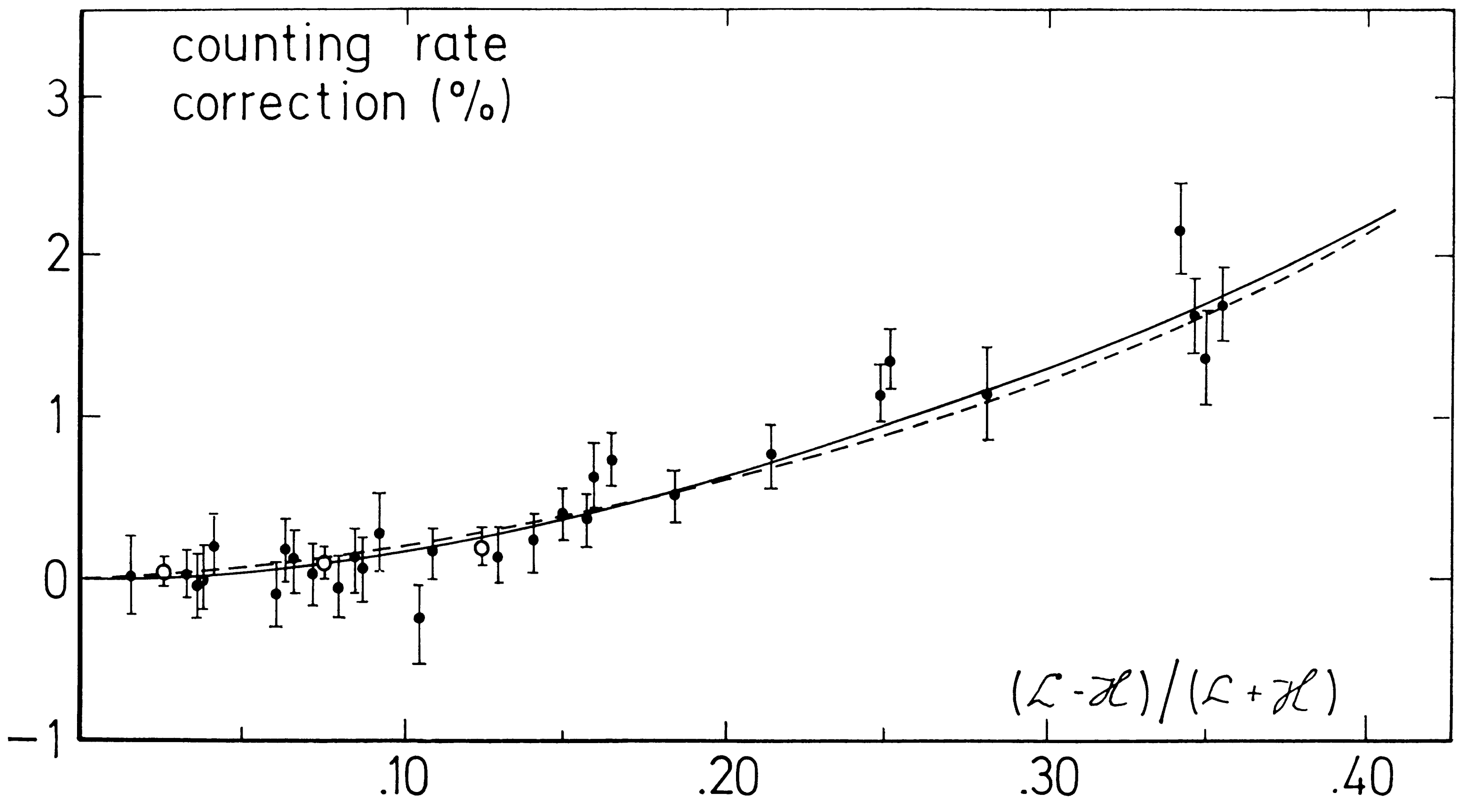

Fig. 10. Calibration of the purity correction by oxalic acid measurements. The full curve fit is a power curve: $11.4 \times \{(L-H)/(L+H)\}^{1.79}$. The broken curve fit is an exponential: $0.309 \times \{(\exp|5.37 \times (L-H)/(L+H)| - 1\}$. Open circles: weighted averages of measurements between 0 to 0.05, 0.05 to 0.10, and 0.10 to 0.15, respectively.

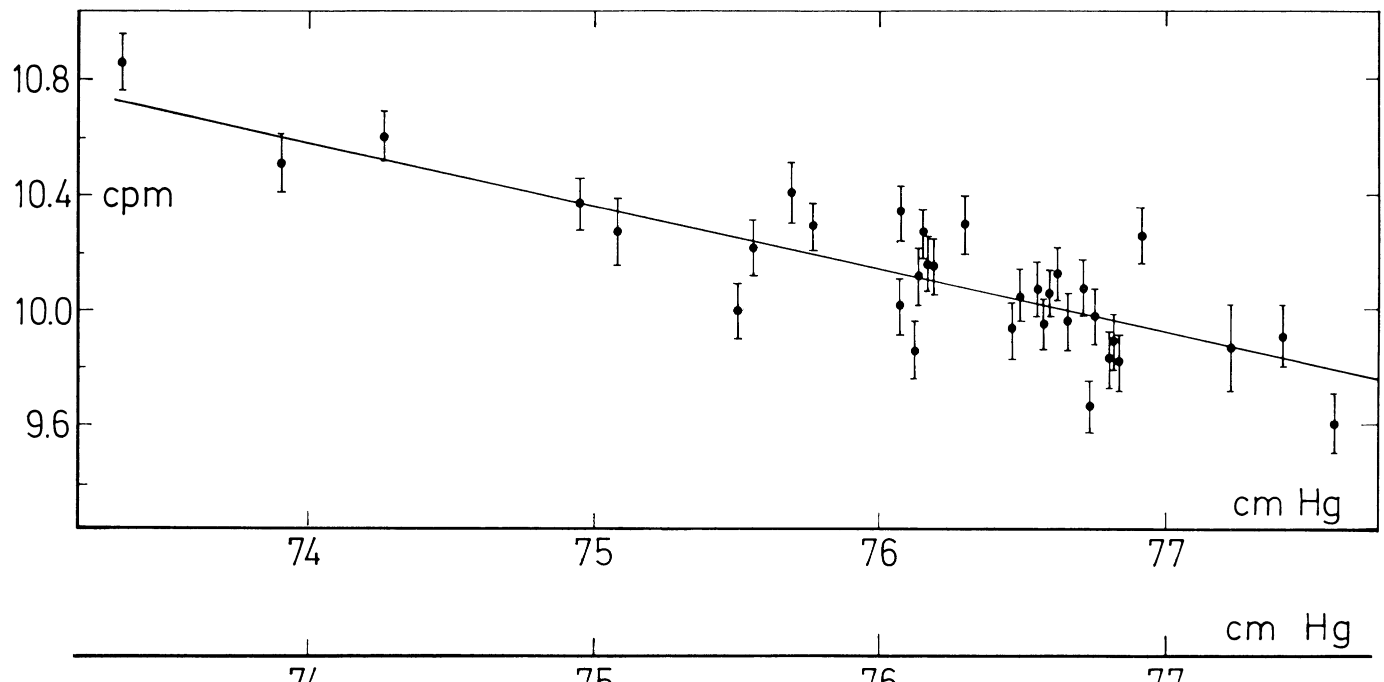

Fig. 11. Background counting rate as a function of atmospheric pressure. The values are corrected for a memory effect (see fig. 13) of 0.2‰ and for a change of the shielding on 9/8/77; they are all normalized to the counting rate of mid June 1977, on which date the anthracite sample used for these measurements already was contaminated by modern carbon to an amount of 0.7 to 0.8 cpm.

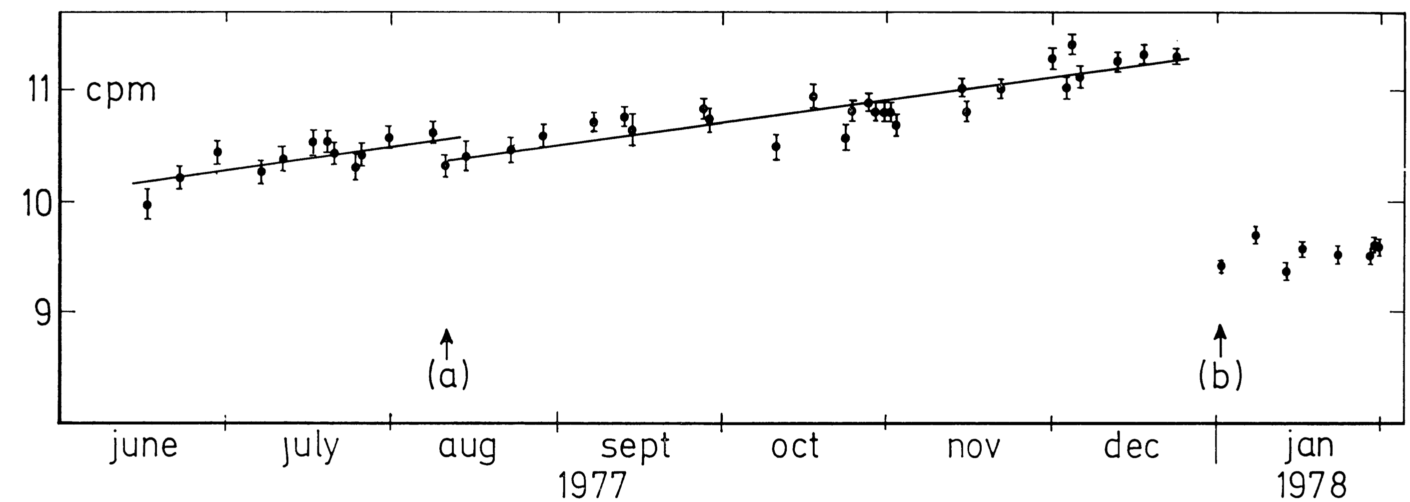

Fig. 12. The counter memory effect. The measurements were all obtained from the same anthracite sample until January 1978. They have been normalized to a barometric pressure of 76 cm Hg. On August 9, 1977 the shielding has been slightly improved (arrow (a)); a new anthracite sample has been introduced on 1/1/78 (arrow (b)).

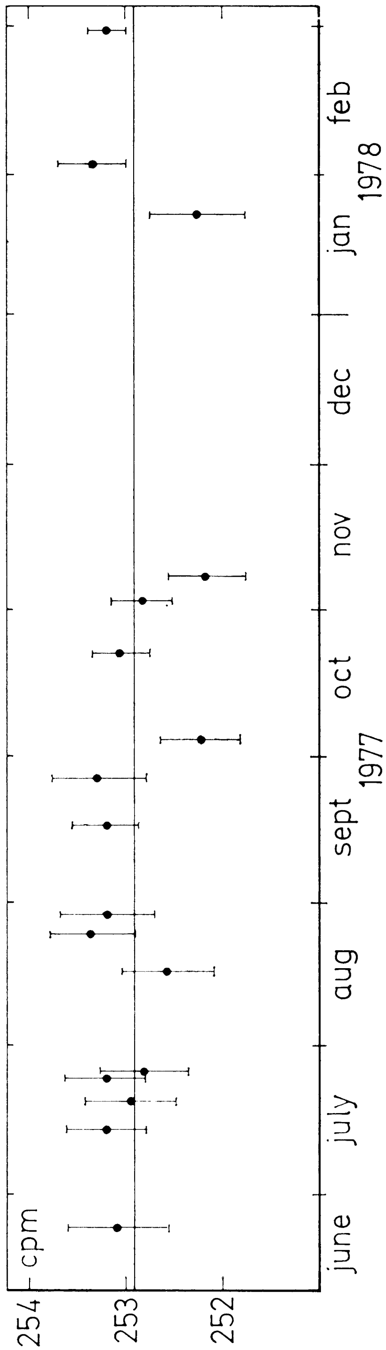

Fig. 13. Counting rate of NBS oxalic acid.

Summary of corrections applied to the measured activity.—The raw counting rate is first normalized to a "gas purity" zero (fig. 10). The background that is to be subtracted from the counting rate is corrected for a deviation from 76cm Hg of the average barometric pressure prevailing during the measurement (fig. 11).

After the GM counters and the proportional counters have been triggered, the system is inaccessible to a new pulse for some time (fig. 7). The total dead time is about 4 percent. The GM counting rate varies with the barometric pressure. As a result the dead time is not constant but depends both on the specific ^{14}C activity of the sample and on the barometric pressure. Corrections for this variable dead time are applied.

The ^{14}C counting rate is then normalized to a standard density of the filling gas of 0.2381 mole/l. The density correction is calculated from the temperature and pressure of the filling gas, treating CO_2 as a Van der Waals gas.

All samples are corrected for fractionation by normalization to a $\delta^{13}C_{PDB}$ value of $-25‰$, except oxalic acid which is normalized to $\delta^{13}C = -19‰$. In addition, the measured activity of oxalic acid is age-corrected to 1950, using $T_{1/2} = 5730$ yrs.

System performance.—The operating characteristics of the system are summarized in table 1. Although it has been designed for accurate measurements of modern samples, the conventional (2σ) age limit of the set-up is 61,500 yrs, if care is taken to measure an uninterrupted series of old samples. A memory effect of 0.2‰ gives an apparent age of 57,000 yrs to anthracite measured once following a modern sample. Although it is of no importance for very old samples, the purity correction is not correct in those cases, because it applies only to the total pulse height spectrum of modern samples (mainly ^{14}C). After having applied all corrections mentioned above, the overall accuracy for modern carbon in two counting periods of 22 hrs each, is 1.3(5) ‰, including the maximum error due to the uncertainty in the purity correction (0.4‰).

TABLE 1

System characteristics

Net recent counting rate (A_o) (0.95 × activity NBS oxalic acid)	240.28 ± 0.11	cpm
Background (76cm Hg)	9.40 ± 0.05	cpm
dependence on barometric pressure	0.22	cpm/cm Hg
Active length of each counter	74	cm
Diameter of counter	41	mm
Diameter of anode wire	25	μm
Total active volume	6840	ml
Volume gas handling system	630	ml
Working pressure at 24°C	4303	torr
Working voltage	6750	volt
Gas amplification	9500	
Figure of merit	78.4	
Age limit of detection (2 days)	61500	yr
Overall accuracy (2 days)	1.3	‰
Capacity	125	samples/yr

The final test for the stability of operation of the system is the repeated measurement of NBS oxalic acid. From Figure 11, it is seen to be satisfactory.

In addition, the new set-up has been compared by making several cross checks on the same NBS oxalic acid sample with three other ^{14}C counters currently in operation in our laboratory, providing an average result of 100.06 ± 0.28 percent. Several measurements of ANU sucrose in the high-precision set up produced a final result of $\Delta^{14}C = 500.6 \pm 0.8‰$.

With a background and an oxalic acid measurement once a week, the theoretical capacity of the system is 125 samples per year.

ACKNOWLEDGMENTS

The operation of the small high-pressure counter has thoroughly been discussed with C A M Brenninkmeyer. Additional technical details, included in this paper, have been provided by A F M de Jong, after the first author published his thesis. The oxalic acid cross crecks with other ^{14}C counters were performed by H J Streurman. The project has been supported financially by the Netherlands Organization for Pure Scientific Research (ZWO).

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[RADIOCARBON, VOL. 21, NO. 1, 1979, P. 41-47]

BRITISH MUSEUM NATURAL RADIOCARBON MEASUREMENTS X

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The following list consists entirely of dates for archaeologic samples from the prehistoric flint mining site of Grime's Graves, Weeting, Thetford, Norfolk, England (52° 30′ N, 0° 40′ E, Natl Grid Ref TL 816898), measured over the period from August 1973 to December 1977,* all the samples having been excavated between 1972 and 1976. The dates were obtained by liquid scintillation counting of benzene using a Model 3315 Packard Tricarb Liquid Scintillation Spectrometer linked to a Hewlett Packard 2100A computer system for on-line processing of counting data (Hall & Hewson, 1977). The laboratory procedures used were those outlined in the two previous lists (R, 1976, v 18, p 16; 1977, v 19, p 143).

Antler and bone samples were demineralized with 1 N hydrochloric acid at about 20°C to provide pure collagen for ^{14}C age measurement; charcoal samples were pretreated by prolonged boiling in dilute hydrochloric acid. The highly calcareous environment in which these materials had been buried precluded contamination by humic acids and no pretreatment with alkali was needed.

The dates are expressed in radiocarbon years relative to AD 1950, based on the Libby half-life for ^{14}C of 5570 years, and are corrected for isotopic fractionation ($\delta^{13}C$ values are relative to PDB). No corrections have been made for natural ^{14}C variations. The modern reference standard was NBS oxalic acid. Errors are based on counting statistics alone and are equivalent to $\pm$ 1 standard deviation ($\pm 1\sigma$).

The British Museum excavation at Grime's Graves from 1972-1976 has provided a unique opportunity for interdisciplinary study of the problems of dating a large prehistoric industrial site by the radiocarbon method. Previous excavations (Clarke, 1915; Greenwell, 1871) had shown that picks made from the antlers of red deer (*Cervus elaphus*) were used by the prehistoric miners at Grime's Graves as at other flint mines in S England. The picks were preserved in large numbers in the chalk fill of galleries, shafts and other workings. A number of picks from the excavations of A L Armstrong, who worked at Grime's Graves between ca 1920 and the mid-1930's, were held in the Museum's collections. These and well-provenanced specimens from other archaeologic excavations had already been used to provide a general framework of 17 radiocarbon dates for Grime's Graves and flint mines on the S coast of England

* Dates obtained over part of the same period for archaeologic sites other than Grime's Graves formed the previous two lists, British Museum VIII and IX; further dates for other sites obtained during this time will form the next two lists, British Museum XI and XII.

and on Salisbury Plain (R, 1961, v 3, p 41; 1963, v 5, p 106; 1969, v 11, p 285; Burleigh, 1975). Excavation of a shaft at Grime's Graves in 1971-1972 yielded 7 more samples of antler and charcoal which provided dates in good general agreement with those for the material from the earlier excavations (R, 1976, v 18, p 32; Mercer, 1976; Sieveking *et al*, 1973). The radiocarbon determinations suggested that flint mining at Grime's Graves dated to the period around 4000 yr BP, confirming the accepted view that exploitation of the site did not pre-date the Neolithic period (Clark & Piggott, 1933; Piggott, 1954). The other British flint mines appeared to be up to 1000 yr earlier, suggesting that mining had moved to E Anglia after the mines on the S coast and perhaps those on Salisbury Plain had been abandoned. Questions which still remained unanswered were the extent to which the available dates represented the total period of mining at Grime's Graves and the possibility that mining had been renewed at a later period as the presence of pottery and other occupation debris of recognizably later date suggested.

The scale of the excavation and dating problems at Grime's Graves may be judged from a brief description of the site. Over the area of some 37 ha which the site occupies many different methods of exploitation of flint are represented. More than 350 infilled large-scale shaft and gallery mines have been located although only ca 20 of these have been explored to any extent. Typically, the shafts of these mines are 4 to 8m in diam at the surface and 5 to 14m in depth. Low horizontal galleries radiate from the base of each shaft, often interconnecting with the galleries of adjacent shafts. Open-cast mining in the form of smaller pits, 2 to 4m in diam and 2 to 3m in depth, also now infilled, occupies a large area, and different parts of the site may have been exploited sequentially. Accompanying and sometimes overlying the underground workings are surface layers, some containing the abundant debris of flint workshops and some containing habitation debris, not necessarily related to industrial activity. To gain an overall picture of the sequence and intensity of mining and industrial activity at Grime's Graves, radiocarbon samples were taken from every type of underground and surface working investigated and from workshop and habitation areas on different parts of the site.

For the purposes of this date list the radiocarbon determinations have been grouped into broad classes as follows:

I. Early occupation sites. Pits containing occupation debris unrelated to and antedating flint mining and workshop activity.

II. Galleried mines. Shafts cut into solid chalk to reach deep layers of tabular flint.

III. Open-cast mines. Workings of two main types comprising small pits cut into cryoturbated chalk and till, and trial pits cut into undisturbed chalk, both in search of localized supplies of nodular flint.

IV. Industrial debris. Flint workshops, both small and large-scale.

I. EARLY OCCUPATION SITES

Lab no.	Grid ref	Feature	Material	Date BP	Date BC	$\delta^{13}C$ ‰
BM-990	880/910	1b	Charcoal	7614 ± 80	5664	–24.90
BM-989	900/870	5c	Charcoal	8519 ± 309	6569	–21.60

II. GALLERIED MINES

Lab no.	Shaft	Gallery	Material	Date BP	Date BC	$\delta^{13}C$ ‰
BM-973	15A	31-32	Antler	3827 ± 45	1877	–24.20
BM-997	15A	57-58	Antler	3960 ± 56	2010	–24.90
BM-975	15B	19-20	Antler	3940 ± 41	1990	–24.10
BM-1051	15B	19-20	Antler	3887 ± 56	1937	–23.20
BM-1003	15B	31-32	Antler	3949 ± 42	1999	–22.50
BM-1052a	15B	31-32	Antler	4114 ± 45	2164	–22.90
BM-1052b	15B	31-32	Antler	3954 ± 43	2004	–22.90
BM-996	15B	57-58	Antler	3890 ± 42	1940	–23.60
BM-1053	15B	57-58	Antler	3834 ± 50	1884	–23.30
BM-974	15C	57-70	Antler	3887 ± 47	1937	–24.10
BM-1054	15C	57-70	Antler	3904 ± 36	1954	–22.20
BM-980	15D	37-38	Antler	3736 ± 58	1786	–24.80
BM-1056a	15D	37-38	Antler	3838 ± 42	1888	–23.80
BM-1056b	15D	37-38	Antler	3740 ± 48	1790	–23.80
BM-978	15D	79-80	Antler	3865 ± 44	1915	–25.00
BM-1011	15D	79-80	Antler	3952 ± 44	2002	–22.50
BM-1057	15D	79-80	Antler	3924 ± 47	1974	–23.00
BM-972	15D	79-80	Charcoal	3071 ± 209	1121	–27.40
BM-1260	15D	516-517	Antler	4037 ± 62	2087	–22.50
BM-1262	15D	516-517	Charcoal	3900 ± 54	1950	–24.70
BM-1002	15E	59-60	Antler	3882 ± 45	1932	–21.20
BM-1058	15E	59-60	Antler	3876 ± 48	1926	–22.90
BM-998	15E	61-62	Antler	3992 ± 45	2042	–23.00
BM-977	15F	59-60	Antler	4015 ± 61	2065	–24.50
BM-1059	15F	59-60	Antler	3977 ± 47	2027	–22.60
BM-1000a	15G shaft	—	Antler	4051 ± 109	2101	–23.20
BM-1000b	15G shaft	—	Antler	4022 ± 57	2072	–23.20
BM-976	15G	75-76	Antler	3849 ± 44	1899	–23.00
BM-979	15J	79-80	Antler	3820 ± 46	1870	–25.00
BM-1001	15J	79-80	Antler	3868 ± 56	1918	–23.30
BM-971	15J	79-80	Charcoal	3868 ± 66	1918	–25.80
BM-986	15J	79-80	Charcoal	3845 ± 44	1895	–25.90
BM-1027	Greenwell	101-102	Antler	3855 ± 36	1905	–23.00
BM-1261	Greenwell	101-102	Antler	3853 ± 71	1903	–21.40
BM-1049	Greenwell	104-107	Antler	3884 ± 43	1934	–22.10

II. GALLERIED MINES (continued)

Lab no.	Shaft	Gallery	Material	Date BP	Date BC	$\delta^{13}C$ ‰
BM-1028	Greenwell	108-109	Antler	3922 ± 38	1972	–19.50
BM-1044	Greenwell	108-109	Antler	3922 ± 86	1972	–22.30
BM-1048	Greenwell	108-109	Antler	3880 ± 38	1930	–21.60
BM-1050	Greenwell A	200-201	Antler	3893 ± 44	1943	–21.70
BM-1068	Greenwell A	200-201	Antler	3784 ± 50	1834	–22.10
BM-1029	Greenwell C	105-106	Antler	3859 ± 53	1909	–22.40
BM-1045	Greenwell C	105-106	Antler	3949 ± 41	1999	–23.30
BM-1047	Greenwell C	105-106	Antler	3974 ± 45	2024	–22.60
BM-1046	Greenwell C	in gallery	Antler	3797 ± 52	1847	–20.30
BM-981	11A	in gallery	Antler	3874 ± 47	1924	–22.80
BM-982	11B/E	in gallery	Antler	4090 ± 58	2140	–21.00
BM-987	11B/E	in gallery	Charcoal	3671 ± 75	1721	–26.00
BM-983	11D	in gallery	Antler	3761 ± 48	1811	–21.70
BM-984	11E	in gallery	Antler	3902 ± 58	1952	–23.10
BM-985	11F	in gallery	Antler	4010 ± 59	2060	–23.00
BM-1020	2	in gallery	Antler	3844 ± 221	1894	–23.00
BM-1069	2	in gallery	Antler	3896 ± 141	1946	–22.00

III. OPEN-CAST MINES

Lab no.	Grid ref	Feature	Material	Date BP	Date BC	$\delta^{13}C$ ‰
(a) Small pits						
BM-970	955/820	3	Antler	3767 ± 57	1817	–24.90
BM-1019	950/820	4	Antler	3593 ± 45	1643	–23.20
BM-992	955/820	5	Antler	3727 ± 57	1777	–23.20
BM-993	955/820	6	Antler	3614 ± 67	1664	–23.50
BM-1007	950/820	6	Antler	3825 ± 54	1875	–23.30
BM-1016	950/820	11	Antler	3797 ± 49	1847	–20.60
BM-1005	950/820	12	Charcoal	3948 ± 37	1998	–24.70
BM-1015	950/820	14	Antler	3851 ± 34	1901	–22.20
BM-1017	950/820	16	Antler	3710 ± 39	1760	–23.10
BM-1063	953/850	28	Antler	3874 ± 55	1924	–22.10
BM-1062	961/861	34	Antler	3695 ± 49	1745	–22.90
(b) Trial pits and mines						
BM-1060	—	Pit 3A	Antler	3863 ± 86	1913	–23.50
BM-1009	950/820	7	Antler	3825 ± 41	1875	–20.60
BM-1010	950/820	14	Antler	3770 ± 66	1820	–21.50
BM-1008	950/820	24	Antler	3764 ± 39	1814	–23.10
BM-1061	952/964	105	Antler	3666 ± 55	1716	–22.00

IV. INDUSTRIAL DEBRIS

Lab no.	Grid ref	Feature	Material	Date BP	Date BC	$\delta^{13}C$ ‰
(a) Small scale						
(i) Early group						
BM-1023	950/820	18	Charcoal	4061 ± 52	2111	–24.30
BM-1012	950/820	19	Antler	3695 ± 33	1745	–22.90
BM-1064	950/860	32	Antler	3748 ± 59	1798	–22.80
BM-1024	950/820	36	Charcoal	3904 ± 38	1954	–18.60
BM-1006	950/820	38	Charcoal	4017 ± 60	2067	–25.10
BM-1066	1195/945	Trench 2	Charcoal	4224 ± 74	2274	–24.70
(ii) Late group						
BM-812	1000/910	(1972)	Antler	3380 ± 55	1430	–26.60
BM-1030	950/950	106	Charcoal	2953 ± 36	1003	–25.80
BM-1032	940/940	112	Charcoal	3286 ± 67	1336	–20.10
(b) Large scale						
BM-995	1267/906	—	Charcoal	3947 ± 66	1997	–25.30
BM-988	1255/905	—	Charcoal	3755 ± 259	1805	–25.00
BM-1013	1255/905	L6 baulk	Charcoal	3929 ± 49	1979	–27.00
BM-1014	1266/900	—	Charcoal	3813 ± 43	1863	–25.80

V. OCCUPATION DEBRIS

Lab no.	Grid ref	Feature	Material	Date BP	Date BC	$\delta^{13}C$ ‰
(a) Minor features						
BM-811	1000/905	(1972)	Charcoal	3607 ± 300	1657	–27.20
BM-991	900/870	2	Charcoal	3414 ± 46	1464	–24.10
BM-994	955/820	7	Charcoal	3535 ± 90	1585	–25.10
BM-1022	950/820	13	Charcoal	3559 ± 39	1609	–24.90
BM-1018	950/820	23	Antler	3593 ± 37	1643	–21.70
BM-1033	940/950	121	Charcoal	2881 ± 49	931	–25.60
BM-1034	960/940	124	Charcoal	3763 ± 47	1813	–25.80
BM-1065	1274/1022	Trench 3	Charcoal	3941 ± 89	1991	–24.60
(b) Occupation debris with Bronze Age pottery						
(i) Minor features						
BM-1031	950/950	108	Charcoal	3386 ± 41	1436	–24.90
(ii) Shaft X, 1270/900 (1270/905, 1275/900, 1275/905)						
BM-1035	L14 m.sq.G		Charcoal	2994 ± 40	1044	–25.50
BM-1039	L20 m.sq.M		Charcoal	2806 ± 54	856	–25.00
BM-1040	L20a m.sq.D		Charcoal	2905 ± 54	955	–25.00
BM-1036	L19 m.sq.G		Charcoal	2995 ± 39	1045	–25.50
BM-1041	L19a m.sq.C		Charcoal	3573 ± 57	1623	–25.20
BM-1042	L19b m.sq.H		Charcoal	2919 ± 53	969	–24.70

V. OCCUPATION DEBRIS (continued)

Lab no.	Grid ref	Feature	Material	Date BP	Date BC	$\delta^{13}C$ ‰
BM-1043	L19c	m.sq.H	Charcoal	2838 ± 53	888	−24.80
BM-1265	L4	m.sq.BCDFGH	Charcoal	2800 ± 79	850	−24.20
BM-1038	L5	m.sq.A	Charcoal	2936 ± 43	986	−24.80
BM-1266	L6	m.sq.K	Charcoal	2834 ± 53	884	−24.70
BM-1037	L9	m.sq.JMN	Charcoal	3003 ± 49	1053	−21.40
BM-1263	L4	m.sq.L	Charcoal	3443 ± 53	1493	−24.80
BM-1264	L10	—	Charcoal	3154 ± 64	1204	−24.90

VI. BONE ANALYSIS

Lab no.	Grid ref	Feature	Material	Date BP	Date BC	$\delta^{13}C$ ‰
BM-1067	940/950	123	Bone	2559 ± 80	609	−21.90

V. Occupation debris. Hearth material, either *in situ* or redeposited in rubbish pits, with assoc fragments of pottery, stone tools or in some instances with metal tools, but not assoc with workshop debris.

VI. Bone analysis.

The ordering of dates within these classes is as follows: For the deep mines (Pit 15, Greenwell's pit, Pit 11 and Pit 2, respectively) dates are listed in shaft and gallery order. In the other 5 classes, the dates are listed in Feature no. order, with the exception of dates for Shaft X (V, Occupation debris) which are listed in stratigraphic order. In all classes dates for antler precede dates for charcoal from the same provenance. The point of origin of the grid system used for the Grime's Graves excavation is Base Reference Peg 1000/1000 (Sieveking *et al*, 1973, fig 6, p 194).

In summary, the evidence newly available from Grime's Graves suggests that the large-scale exploitation of flint by means of galleried mines dates to a relatively short period between ca 2100 to 1800 BC, while open-cast quarrying continued until ca 1650 BC. There is some evidence for intermittent occupation on the site, with tool manufacture, between this date and the intensive Bronze Age occupation, not related to flint extraction, beginning ca 1000 BC. No evidence was found for an early mining period antedating the galleried mines.

A full discussion and interpretation of the dates will appear as one of the fascicles (Burleigh & Sieveking, ms in preparation) in a series to be published by the British Museum on the recent excavations at Grime's Graves. Finally, brief reference should be made to 2 other aspects of the radiocarbon dating relating to Grime's Graves. These are, firstly, the evidence for very short-term natural ^{14}C variations provided by radiocarbon dates for antlers from the deep mines (Burleigh & Hewson, 1976;

1978), and secondly, the dating of the skull and skeleton of a domestic dog found in gallery 104-107 of Greenwell's pit, 1 of only 3 complete examples known from the Neolithic period in Britain (Burleigh *et al*, 1977).

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UNIVERSITY OF SASKATCHEWAN RADIOCARBON DATES VIII

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This series reports some of the measurements made since publication of the previous list. Methods essentially remain as described in Saskatchewan II (R, 1960, v 2, p 73). The laboratory now joins operation with the National Museum of Canada, Ottawa. The prime purpose is to provide radiocarbon dating service for Canadian archaeologists through the National Museum, although commercial services are available to others as analytical capacity permits.

SAMPLE DESCRIPTIONS

I. GEOLOGIC SAMPLES

Scrimbit series, Saskatchewan

Wood from buried forest, 3.6 to 5.2m below surface in glacial kettle, J Scrimbit farm near Kayville (49° 46′ N, 105° 11′ W). Found in layer of gyttja (Dew, 1959). Coll and subm 1958 by B A McCorquodale, Sask Mus Nat Hist, Regina (now Prov Mus Alberta, Edmonton).

S-80. **11,500 ± 300**

10cm diam conifer trunk in horizontal orientation 3.9m below surface.

S-81. **10,000 ± 250**

Root of stump 1.2m high, preserved in upright position. Sample from level of cones and needles 4.6m below surface.

S-83. **11,700 ± 300**

Wood from cones and needles horizon, 5.2m below surface.

S-85. **10,400 ± 250**

Wood from limbs in horizontal orientation, 3.6m below surface.

General Comment (BAM): S-80 poorly preserved, date anomalous. Time span correlates with gyttja laminae count (Bard, 1959).

S-685. Sutherland, Saskatchewan **14,040 ± 465**

Bone from 4.6m gravel bed below 0.6m boulders and overlying Floral Formation till, near Saskatoon (52° 12′ N, 106° 35′ W). Coll 1972 by C R Harington; subm 1972 by E A Christiansen. *Comment* (EAC): date and field evidence indicate gravel deposited by glacier which deposited Battleford Formation. Boulder layer interpreted as lag concentrate from erosion of latter till formation.

S-793. Camp Mackay, Saskatchewan **11,120 ± 150**

Wood from testhole in Qu'Appelle Valley 43.6 to 44.2m below valley bottom in Qu'Appelle Alluvium (50° 31′ N, 102° 18′ W). Coll 1973 by C Higgins and E A Christiansen; subm 1973 by E A Christiansen. *Comment* (EAC): dates early deposition of Qu'Appelle Alluvium.

S-794. Esterhazy, Saskatchewan **11,260 ± 150**

Wood from testhole in Qu'Appelle Valley near Esterhazy (50° 31′ N, 102° 09′ W). From brecciated shale overlain by 21.3m till and 2.4m sand, underlain by 29.9m till. Coll 1973 by C Higgins and E A Christiansen; subm 1973 by E A Christiansen. *Comment* (EAC): till cover interpreted as landslide since glacier position 160km NW of site at this time (Christiansen, 1978).

Fort Qu'Appelle series, Saskatchewan

Shells from testhole in Qu'Appelle Alluvium near Fort Qu'Appelle (50° 46′ N, 103° 48′ W). Coll 1973 by C Higgins and E A Christiansen; subm 1973 by E A Christiansen.

S-795. **6445 ± 135**

Shells 3.4 to 4m below valley bottom.

S-796. **8395 ± 115**

Shells 12.2 to 12.8m below valley bottom.

General Comment (EAC): dates part of Qu'Appelle alluvium deposit.

S-804. Weed Creek, Alberta **2765 ± 90**

Bison bone from 1.1m below surface, in lower terrace sand deposits, 3.9m above present bed of Weed Creek, near Thorsby (53° 17′ N, 113° 57′ W). Coll and subm by R C Shelford, Univ Alberta, Edmonton. *Comment* (RCS): date younger than other dates on terrace for N Saskatchewan R of 6600 yr (Shelford, 1975).

S-950. Waterhen River, Saskatchewan **1855 ±75**

Peat from base of 2.1m deposit covering Waterhen R valley bottom (54° 25′ N, 108° 38′ W). Coll and subm 1974 by E A Christiansen. *Comment* (EAC): dates beginning of peat formation at this valley location.

Beaver River series, Saskatchewan

Peat and wood fragments from augerhole in alluvium under 2.7m road fill in Beaver R valley (54° 15′ N, 108° 58′ W). Coll and subm 1974 by E A Christiansen.

S-960. **1600 ± 100**

From 0.3m below top of peat bed.

S-961. **3205 ± 65**

From 0.6m below top of peat bed.

S-962. **3140 ± 105**

From 0.9m below top of peat bed.

General Comment (EAC): dates peat accumulation for site location in Beaver R valley.

Waterhen River series, Saskatchewan

Peat from augerhole 6.4m below road fill surface in depression near the Waterhen R (54° 27′ N, 109° 12′ W). Coll and subm 1974 by E A Christiansen.

S-963. **490 ± 65**

From 0.3m below top of peat bed.

S-964. **9935 ± 170**

From 3.0m below top of peat bed.

General Comment (EAC): dates beginning and present state of peat accumulation for site location.

Eagle Creek series, Saskatchewan

Bone fragments from fresh exposure by redeposition and bluff slump caused by 1973 creek channel diversion, Eagle Creek valley, NW of Tessier (51° 47′ N, 107° 30′ W). Coll and subm 1975 by T S Woolf, Geol Sci, Univ Saskatchewan.

S-1073. **850 ± 60**

From redeposition exposure, on creek bed surface.

S-1074. **2365 ± 70**

From 2m below surface, in clay matrix, bluff slump.

General Comment (TSW): secondarily deposited bison bones, post Wisconsin age. For geology of area, see Scott (1962).

S-1075. Park Valley, Saskatchewan **4210 ± 75**

Charcoal from 1cm bed 1.2m below surface in flood plain deposit, exposed in alluvium E bank of S Saskatchewan R (51° 49′ N, 106° 43′ W). Coll and subm 1975 by E A Christiansen. *Comment* (EAC): date implies only 1.2m of sediment deposition during last 4000 yr.

Mission Lake series, Saskatchewan

Carbonaceous silt from augerhole in slough bottom (50° 43′ N, 103° 46′ W). Coll and subm 1976 by E A Christiansen.

S-1169. **2950 ± 80**

0.30m below surface.

S-1170. **4980 ± 85**

0.91m below surface.

S-1171. **7040 ± 115**

1.52m below surface.

S-1172. **9735 ± 120**

2.13m below surface.

General Comment (EAC): rate of recent sedimentation over dated internal constant at 2.54cm/100 yr.

Goodale Farm 026 series, Saskatchewan

Gyttja and mollusk shells from augerhole in slough bottom (52° 03′ N, 106° 30′ W). Coll and subm 1976 by E A Christiansen.

S-1173. **1355 ± 80**

Gyttja 1.83m below surface.

S-1174. **3225 ± 50**

Gyttja 2.13m below surface.

S-1175. **4815 ± 70**

Gyttja 2.74m below surface.

S-1176. **5480 ± 75**

Mollusk shells 2.74m below surface.

S-1177. **7160 ± 110**

Gyttja 3.66m below surface.

Goodale Farm 029 series, Saskatchewan

Carbonaceous silt from augerhole in slough bottom (52° 03′ N, 106° 30′ W). Coll and subm 1976 by E A Christiansen.

S-1178. **6705 ± 180**

From 1.52m below surface.

S-1179. **9290 ± 155**

From 2.13m below surface.

S-1180. **10,730 ± 280**

From 2.74m below surface.

Horseshoe Lake Core series, Alberta

Gyttja core from 1.22m to 7.47m below lake level, 657 amsl, Horseshoe Lake, 6.4km SW of Metiskow (52° 21′ N, 110° 45′ W). Coll and subm 1976 by E I Wallick, Alberta Research Council, Edmonton.

S-1181. **2000 ± 100**

1.22 to 1.26m depth.

S-1182. **2200 ± 85**

1.59 to 1.63m depth.

S-1183. **2750 ± 70**

1.95 to 1.99m depth.

S-1184. **3345 ± 155**
2.30 to 2.34m depth.

S-1185. **3365 ± 85**
2.65 to 2.69m depth.

S-1186. **3960 ± 165**
3.05 to 3.09m depth.

S-1187. **4625 ± 105**
3.50 to 3.54m depth.

S-1188. **5160 ± 80**
3.96 to 4.00m depth.

S-1189. **8600 ± 435**
5.49 to 5.52m depth.

S-1190. **10,180 ± 160**
7.42 to 7.45m depth.

General Comment (EIW): sedimentation rate 0.1cm/yr, similar to Lake Wabamun, 32.2km W of Edmonton. S-1190 indicates sedimentation post glacial.

Agar Slough 01 series, Saskatchewan

Carbonaceous silt from augerhole in slough bottom, near Saskatoon (52° 03′ N, 106° 30° W). Coll and subm 1976 by E A Christiansen.

S-1191. **3295 ± 125**
0.61m below surface.

S-1192. **9300 ± 220**
4.27m below surface.

S-1193. **9630 ± 230**
4.57m below surface.

S-1194. **10,560 ± 255**
4.88m below surface.

Agar Slough 02 series, Saskatchewan

Carbonaceous silt from augerhole in slough bottom, near Saskatoon (52° 02′ N, 106° 29′ W). Coll and subm 1976 by E A Christiansen.

S-1195. **1570 ± 115**
1.22m below surface.

S-1196. **9620 ± 210**
4.27m below surface.

Martens Slough 01 series, Saskatchewan

Carbonaceous silt from augerhole in slough bottom, near Saskatoon (52° 02′ N, 106° 29′ W).

S-1197. **8350 ± 200**

2.74m below surface.

S-1198. **10,240 ± 250**

4.57m below surface.

S-1199. **11,070 ± 245**

6.40m below surface.

General Comment (EAC): sedimentation post-glacial.

Lebret series, Saskatchewan

Wood from testhole, Qu'Appelle Valley bottom (50° 45′ N, 103° 41′ W). Coll and subm 1976 by C Higgins and E A Christiansen.

S-1224. **5740 ± 85**

Wood from 6.4m below valley bottom.

S-1225. **7380 ± 110**

Wood from 22.6m below valley bottom.

General Comment (EAC): deposition of Qu'Appelle Alluvium started before 7380 yr with sedimentation rate diminishing with time.

Lake View Beach series, Saskatchewan

Wood from testhole, Qu'Appelle Valley bottom (50° 42′ N, 103° 38′ W). Coll and subm 1976 by C Higgins and E A Christiansen.

S-1228. **4260 ± 90**

Wood from 5.5m below valley bottom.

S-1229. **4730 ± 85**

Wood from 6.4m below valley bottom.

S-1230. **4965 ± 80**

Wood from 10.1m below valley bottom.

General Comment (EAC): dates indicate diminishing sedimentation rate of Qu'Appelle Alluvium.

S-1231. Reindeer Lake, Saskatchewan **6420 ± 115**

Peat from base of deposit, 1.8m below surface on topographic high, Site DA-631, Reindeer Lake (56° 15′ N, 103° 35′ W). Coll and subm 1976 by D Alley, Saskatchewan Research Council, Saskatoon. *Comment* (DA): date agrees with other basal peat ages for area.

Grande Cache series, Alberta

Peat from fen and bog area, unglaciated plateau Mine Pit 8, Grande Cache (53° 49′ N, 119° 09′ W). Coll and subm 1977 by J D Campbell, Alberta Research Council, Edmonton.

S-1277. **5320 ± 95**

Peat from Crescent Lake fen, from 2.38 to 2.44m below surface.

S-1278. **4510 ± 145**

Peat from bog, 4.42 to 4.57m below surface.

S-1279. **7705 ± 75**

Peat from bog, 5.33 to 5.49m below surface.

General Comment (JDC): post Wisconsin peat accumulations.

S-1280. Blairmore, Alberta **4790 ± 90**

Peat from 1.73m to 1.80m below surface, large fen W branch of Gold Creek near Chaudron Peak, Blairmore (49° 35′ N, 114° 27′ W). Coll and subm 1977 by J D Campbell. *Comment* (JDC): date indicates post Wisconsin age, deposit believed in part to be older.

S-1304. Sioux Crossing, Saskatchewan **10,110 ± 185**

Wod from testhole, Qu'Appelle Valley bottom (50° 48′ N, 103° 54′ W). Coll 1974 by C Higgins and E A Christiansen; subm 1976 by E A Christiansen. *Comment* (EAC): deposition of Qu'Appelle Alluvium started before 10,110 yr.

Riddell series, Saskatchewan

Bone from gravel pit exposure of Floral-Battleford Formations (Christiansen, 1978), 4.8km N of Sutherland (52° 09′ N, 106° 36′ W). Coll and subm 1975 by T S Woolf.

S-1305. **15,340 ± 500**

Metapodial bone (*Equus*) from sands 1.5m below Floral-Battleford Formation contact.

S-1306. **4560 ± 115**

Bison bone fragments from Battleford Formation, 30cm below surface.

General Comment (TSW): date S-1305 within expected range for Pleistocene sequence, S-1306 post Wisconsin age may indicate human activity.

S-1308. Edson, Alberta **9560 ± 190**

Calcareous tefra deposit in spring discharge area near Edson (53° 59′ N, 117° 28′ W). Coll and subm by R Voguiell, Alberta Research Council, Edmonton. *Comment* (RV): date indicates deposit post Pleistocene.

II. ARCHAEOLOGIC SAMPLES

S-141. Constable Property site, British Columbia **450 ± 60**

Charcoal from Constable Property site (DkSf-3), Comox Bay, Vancouver I. (49° 40′ N, 124° 55′ W). From Sq 2, depth 45.7cm, shell midden, Coll and subm 1960 by K Capes, Natl Mus Canada. *Comment* (KC): artifacts similar to Millard Creek site, date too recent, possible intrusive charcoal from late culture marked by shell and slate fragments.

S-143. Mansfield Property site, British Columbia 2370 ± 70

Charcoal from Mansfield Property site (DkSf-1), Sec 66, outside city limits Courteney, Comox Valley (49° 41′ N, 124° 59′ W). From Sq 1, depth 0.9 to 1.2m, midden of alternate shell and gravelly sand layers. Coll and subm 1960 by K Capes. *Comment* (KC): certain artifacts suggests San Juan phase relationship, id with late phase on Fraser delta (Carlson, 1960). Chipped stone and ground slate points deviate and date implies older lower levels than late Fraser delta complex.

S-144. Campbell River site, British Columbia 810 ± 80

Charcoal from Campbell River site (EaSh-1), W side of mouth of Campbell R, opposite Spit Reserve (50° 02′ 40″ N, 125° 15′ W). From Level 3, fire evident zone, assoc with 2 chipped stone points, obsidian and quartz pieces, depth 33cm. Coll and subm 1960 by K Capes. *Comment* (KC): relationship of site unknown.

S-145. Fort Rupert site, British Columbia 5275 ± 110

Charcoal from Fort Rupert site (EeSu-1), Beaver Harbour, E coast Vancouver I. (50° 42′ N, 127° 24′ W), 0.8km E of Hudson Bay Co fort founded AD 1849. From Layer 3, stratified shell midden over 3m deep. Coll and subm 1960 by K Capes. *Comment* (KC): unexpectedly early date since bone points and wood-working tools are traits of late San Juan phase (Carlson, 1960). Two resemblances to artifacts from early Straits of Georgia—Juan de Fuca sites were noted.

S-168. Dunn site, Saskatchewan 5000 ± 120

Charred bone from Dunn site (DgNf-1), NE1/4-8-22W2, near Amulet (49° 38′ 06″ N, 104° 56′ 40″ W). From undisturbed area below plow zone, over 30 Scottsbluff-Eden points and fragments coll from surface of cultivated field. Coll and subm 1961 by T F Kehoe, Saskatchewan Mus Nat Hist (now Milwaukee Pub Mus). *Comment* (TFK): relatively late date for Scottsbluff-Eden as this Cody complex material from a Wyoming site dated 6650 ± 600 BC (I-245: R, 1964, v 6, p 269-279). Site also included Oxbow occupation dated 3250 ± 130 BC at Oxbow Dam site (S-44: R, 1960, v 2, p 80).

S-211. LeVesconte Mound, Ontario 1170 ± 95

Charcoal from LeVesconte Mound, Concession 1, Seymour Twp, Northumberland, Ontario (44° 11′ 05″ N, 77° 40′ 18″ W). From Sq 6D, 53cm depth. Accretion mound constructed by Point Peninsula peoples, containing rich assortment of Hopewellian grave goods. Should date latest period of Hopewellian influence in Ontario ca AD 500. Coll and subm 1962 by W A Kenyon, Royal Ontario Mus. *Comment* (WAK): date 300 yr too recent, no other evidence to support such a late Hopewellian influence in Trent Valley; however, no reason to suspect sample contamination.

S-469. Ouimet site, Ontario **1070 ± 260**

Charcoal (NMC-318) from Ouimet site, W end of Oblate Mission I., opposite Lansdowne House, Attawapiskat Lake (52° 13′ 30″ N, 87° 53′ 30″ W). From Test Pit 1, clearly demarcated Laurel component. Stratified site Late Woodland (Blackduck), Laurel and possible Archaic components. Date should resolve temporal position of Laurel Tradition and represents first Laurel date on the Hudson Bay drainage. Coll and subm 1968 by J V Wright, Nat Mus Canada. *Comment* (JVW): date too recent. An earlier date, AD 250 (S-464: R, v 15, p 199) is regarded as dating occupation.

S-508. Dougall site, Ontario **2185 ± 220**

Charcoal (NMC-358) from Dougall site (BdGu-2), side Couchiching Narrows, Simcoe Co (44° 37′ N, 79° 23′ W). From Sq B, 20cm depth, below Point Peninsula material. Site has continuous occupation from Middle Woodland to historic period. Should date earliest component, early Point Peninsula, Middle Woodland period as 2000 yr. Coll and subm 1969 by J V Wright. *Comment* (JVW): date agrees with AD 170 ± 110 (S-507: R, v 15, p 206) for Point Peninsula occupation of site (Wright, 1972).

Steeprock Lake site series, Manitoba

Charcoal from Steeprock Lake site (C2-UN-55), Prov Govt Campground, Porcupine Forest Reserve, NE1/4-12-42-28-W1, Manitoba (52° 36′ 05″ N, 101° 21′ 30″ W). Non-ceramic site with late Paleo-Indian, Early Archaic and Late Archaic tool assemblages. Early component dominated by Early Archaic tool forms with Simonsen-Logan Creek affiliations. Coll by A A Simpson for W M Hlady, Manitoba Archaeol Soc; subm 1970 by R Wilmeth, Natl Mus Canada.

S-615. Steeprock Lake site, Level 5 **2480 ± 120**

Charcoal (NMC-457) from apparent hearth, depth 20.3 to 30.5cm, in dark red sand level of Sq 205N10W, upper terrace, Level 5 Early Archaic component. Assoc with chopper blade and lithic debris.

S-616. Steeprock Lake site, Level 3 **3950 ± 130**

Charcoal (NMC-458) from Floor Level 3, depth 15.2 to 20.3cm, in dark red sand, Sq 225N20W, upper terrace, Early Archaic component. Assoc with early tool assemblage, including side-notched point.

General Comment (AAS): dates more recent than estimate ca 6000 yr but consistent with site dark red sand strata overlying light red sands.

Gray Burial site series, Saskatchewan

Human bone fragments from burial site (EcNx-1a), situated above glacial drainage channel, NW of Swift Current, (50° 21′ N, 107° 54′ W). Large burial site on relatively homogeneous sand deposit. No stratigraphic sequence observed, assoc with Oxbow projectile points. Coll 1970 and 1971 by J Wilson, T Foster and B Clark; subm 1971 by J F V Millar, Univ of Saskatchewan.

S-619. Burial 23 **4955 ± 165**

S-646. Burial 42 **3755 ± 100**

S-647. Burial 46 **5100 ± 390**

S-693. Burial 59 **3550 ± 295**

S-706. Burial 30 **3485 ± 195**

S-707. Burial 65 **3750 ± 180**

General Comment (JFVM): dates seem to cluster into groupings, no stratigraphic or cultural evidence for this observation.

East Pasture site series, Saskatchewan

Bone fragments from East Pasture site (EcNx-4), NW of Swift Current (50° 21′ N, 107° 52′ W). From Test Pit 18, lowermost horizon assoc with Oxbow culture artifacts. Coll 1970 and 1971 by J Wilson; subm 1971 by J V F Millar.

S-638. Unit 77/114 **265 ± 80**

Assoc with unid. pottery, 70 to 80cm below surface.

S-639. Unit 70/143 **2405 ± 80**

Horizon immediately above Oxbow level.

S-637. Unit 70/143 **4235 ± 55**

Oxbow horizon 60 to 100cm below surface.

General Comment (JFVM): dates consistent with cultural affiliation and stratigraphy.

Sibbetson Lake site series, Northwest Territories

Charcoal from Sibbetson Lake site, 80.5km W of Fort Simpson, NWT (61° 50′ N, 121° 10′ W) on point, NW end of Sibbetson Lake. From hearth 1 to 8cm below surface, 18.3m from lake shore in silt, assoc with artifact assemblage termed Mackenzie Complex. Coll 1972 by K Dice and L Korotopetz; subm 1972 by J F V Millar.

S-691. **2225 ± 170**

1 to 8cm depth.

S-703. **2265 ± 385**

1 to 8cm depth.

General Comment (JFVM): dates correlate well with the cultural assoc, represents transitional stage between middle and late period of Déné prehistory of W Mackenzie Basin.

Bell site series, British Columbia

Charcoal from Bell site (EeRk-4), 16km NE of Lillooet, British Columbia, on E bank of Fraser R at 700m asl (50° 44′ 35″ N, 121° 49′ 30″ W). 23 prehistoric housepits of various ages, most cultural material attributed to Kamloops phase, ca AD 1250 to 1800. Oldest occupation coincides with use of microblades ca 2550 to 550 BC. Good organic preservation and high artifact yield have added to knowledge of late prehistoric life of area. Coll 1971 by J Hubbard, R Torrens, J Bade, D Best, M Freisinger, S Lawhead and J Levitt for A H Stryd, Cariboo Coll, Kamloops, British Columbia; subm 1972-1974 by R Wilmeth.

S-659. Housepit 22a **1930 ± 70**

Charcoal (NMC-502), depth 75cm below surface on bottom, oldest floor. Assoc cultural material assigned to Component 3, 2nd oldest at site, containing atlatl points, no evidence of bow and arrow use, and no microblades, ca 500 BC to AD 1.

S-660. Housepit 22b **1215 ± 90**

Charcoal (NMC-503), depth 35cm below surface. Assoc with dark-colored stratigraphic zone containing Kamloops phase cultural material, youngest occupation of House 22 and site, ca AD 1300 to 1700.

S-661. Housepit 23 **1560 ± 90**

Charcoal (NMC-504), depth 45cm below surface, overlying only living floor in house. Assoc cultural material Kamloops phase, one of largest artifact samples of site, ca AD 1300 to 1700.

S-662. Housepit 2 **1305 ± 80**

Charcoal (NMC-505), depth 20cm below surface, from charred and burned wood overlying only living floor in house. Floor assoc with material Component 1, Kamloops phase, ca AD 1100 to 1300.

S-709. Housepit 13 **1380 ± 65**

Charcoal (NMC-506), depth 28cm below surface, above only living floor in house. Assoc Component I, Kamloops phase, ca AD 1100 to 1600.

S-763. Housepit 19 **1430 ± 60**

Charcoal (NMC-507), depth 40cm below surface. Single living floor assoc with developed form of Kamloops phase. House almost fully excavated yielded nearly 3000 tools. Good organic preservation resulted in recovery of carvings in bone and antler, also wide range of tools, ca AD 1300 to 1700.

S-764. Housepit 1 **2965 ± 95**

Charcoal (NMC-508), bottom of large post hole, 102cm below surface and 72cm below only living floor. One of larger assemblages of site but no diagnostic artifacts, ca AD 1000 to 1800.

S-765. Housepit 21 **1470 ± 40**

Charcoal (NMC-509), depth 118cm below surface, assoc with oldest floor. Directly overlying sample was stratigraphic zone containing 1% volcanic ash, presumably Bridge River ash dated to late 1st millennium BC, ca 500 BC to AD 500.

S-937. Housepit 5 **1380 ± 65**

Charcoal (NMC-728), timber feature overlying only floor in house, presumably part of house superstructure. Single component occupation, early Kamloops phase.

S-938. Housepit 14 **1575 ± 145**

Charcoal (NMC-729), depth 40 to 50cm below surface, probable roof fill directly overlying bottom floor. Adequate diagnostic material lacking, probably belongs to Lillooet phase.

General Comment (AHS): dates part of 24 dates on Bell site and part of 50 radiocarbon ages of archaeol assemblages from Lillooet area, interior British Columbia. One, possibly 2 pre-housepit occupations, one with microblades, were uncovered but assemblages are small and not yet dated. Bell site housepits span 3 tentative archaeol phases a) poorly represented, unnamed phase prior to Lillooet phase but not assoc with microblades termed Nicola phase (Stryd, 1973), b) Lillooet, and c) early Kamloops phase. S-659 and S-764 provide min and max dates for pre-Lillooet phase, supported by dates from housepit 1, Mitchell site (S-580-582: R, 1975, v 17, p 335). These demonstrate that housepits are almost as old as 3000 yr and are not assoc with microblades, contrary to findings of Lochmore-Nesikep locality just S of Lillooet (Sanger, 1970). S-938 provides an age estimate of Lillooet phase which terminates ca AD 450, S-662 unacceptably young for this phase. Other dates acceptable for earliest manifestations of the Kamloops phase, except S-661 is somewhat too old. Distinction between Lillooet and Kamlops phases not always certain, considerable continuity and overlap exists between these 2 archaeol units. Dates also exhibit overlap, period 1560 ± 90 to 1305 ± 80 BP. Rejection of oldest Kamloops phase dates, S-661 and I-6067 (R, 1976, v 18, p 184) and youngest Lillooet phase dates, S-662 and I-6077C, unpub, suggest AD 450 for boundary between these 2 phases, but more complex overlapping may exist.

Junction site series, Northwest Territories

Charcoal (KjNb-6), ca 200m from Thelon Game Sanctuary (63° 39′ 30″ N, 104° 28′ 20″ W). Site 200 by 400m subject to erosion of blowout side walls, central portion destroyed by aeolian action, result materials from all 7 levels on common level suitable for cluster analyses. Coll 1971 by B Yorga, S Burger, P Kettles, J Hunston and 1972 by B C Gordon; subm 1972 and 1973 by B C Gordon, Natl Mus Canada.

S-663. Junction site, Level 3 **1915 ± 140**

Charcoal-sand mix (NMC-512) assoc with quartzite basally-ground point, quartzite microblade and blade-core fragment, a sidescraper-unifacial knife fragment, bifacial knives and tubular end scraper, ca AD 1000.

S-710. Junction site, Keewatin level **5060 ± 310**

Charcoal-sand mix (NMC-513) from lowest or Keewatin level, Sq 55, 4S2E. Should date initial occupants of region, ca 2000 to 2500 BC.

S-664. Junction site, Keewatin level **3085 ± 70**

Charcoal-sand mix (NMC-514).

S-718. Junction site, Level 3 **1600 ± 65**

Charcoal (NMC-575) assoc with side and end scrapers, tabular end-scraper, blades, biface and uniface fragments.

S-719. Junction site, Thelon II or Keewatin level **Modern**

Charcoal (NMC-576). Should date Thelon I or II, ca 2500 yr BP or older.

S-720. Junction site, Level 3 **1085 ± 80**

Charcoal (NMC-577) assoc with quartzite sideblades.

S-732. Junction site, below Level 5 **1775 ± 100**

Charcoal (NMC-578) from below Levels 5, 4 and 3 and above Arctic Small Tool tradition level. Assoc with keeled endscraper and combination side-endscraper, ca AD 200 to 500.

S-733. Junction site, Level 2 **1515 ± 110**

Charcoal (NMC-579) Area C, assoc with crude lanceolate point.

S-734. Junction site, Level 3 **1780 ± 215**

Charcoal (NMC-580).

General Comment (BCG): 1st complex stratified site in barrenlands, few Shield Archaic, Pre-Dorset and Taltheilei dates prior to Junction site, hence narrow age-range initial estimates. Additional barrenland excavations suggest the following cultural assignments; S-710 Shield Archaic, S-664 Arctic Small Tool, S-663, S-718, S-734 Middle Taltheilei, S-720 Late Taltheilei. Area C, Level 2 and Area B below Level 5, S-733 and S-732 date Middle Taltheilei. S-719 coll a few cm below surface, near center of blowout where old cultural floors emerge apparently contaminated by more recent campfires.

Tezli site series, British Columbia

Charcoal from Tezli site (FgSd-2), W end of Kluskus creek on both shores, 1067m asl (53° 04′ 30″ N, 124° 30′ 05″ W). Large pit house village site, multiple occupations both within and between houses. Upper levels may represent Carrier Indians, lower levels may pre-date Carrier occupation. Coll 1971 by K Dedecker, A Lewicki, A Scholz, T Lorenz and P F

Donahue; subm 1972, 1973, 1975 by P F Donahue, Univ Wisconsin (now Archaeol Survey of Alberta, Edmonton, Alta).

S-666. Tezli site, Housepit B, hearth **240 ± 155**

Charcoal (NMC-525) from central hearth, ca AD 500 to 1800.

S-667. Tezli site, Housepit B, Feature 20-71 **3275 ± 405**

Charcoal (NMC-526) from rock concentration with charcoal 20 to 30cm below surface, Sq N2/E1. Should date most recent occupation ca AD 500 to 1800.

S-768. Tezli site, Housepit D, hearth **335 ± 135**

Charcoal (NMC-527) from central hearth ca AD 500 to 1800.

S-769. Tezli site, Housepit D, E wall **3850 ± 140**

Charcoal (NMC-528) 80cm below surface, N1.3m/E0. Should date oldest occupation ca AD 500 to 1500.

S-770. Tezli site, Housepit F **2335 ± 120**

Charcoal (NMC-529) at base of hole above river gravel. Should date 2nd house row, ca AD 500.

S-771. Tezli site, Housepit J **1920 ± 190**

Charcoal (NMC-530) at base above river gravel. 2nd row of parallel housepits, ca AD 500.

S-1035. Tezli site, Housepit Q **100 ± 60**

Wood (NMC-792) from Feature 12-71, post remains in B horizon of House Q. Post dug into C horizon and did not extend up through A horizon. Should date summer surface occupations rather than pithouses, cluster of 3 structures different than others of site, assoc 3 microblades, ca AD 1.

General Comment (PFD): dates agree with interpretation of cultural history. S-667 and S-769 date earliest known construction of pithouses, older than original estimate. S-1035 regarded as recent intrusion, *ie,* fence post.

Blind Bay Rock Shelter series, British Columbia

Charcoal from Blind Bay Rock Shelter (EfQu-10), Shuswap Lake (50° 54′ 04″ N, 119° 22′ 55″ W). Small rock shelter under schist outcrop overhang. Cultural affiliation uncertain, assoc with one crudely fashioned stemmed point and one lanceolate shaped point. Coll 1972 by S Johnson, J D Stewart, Univ Calgary, and K Fladmark, Simon Fraser Univ; subm 1973 by R Wilmeth.

S-725. Blind Bay Rock Shelter, Zone I **3290 ± 140**

Charcoal (NMC-563) from concentration within thin layer of charcoal-stained beach gravel. Lowest part of earliest cultural zone, 0.47 to 0.49m below surface.

S-726. Blind Bay Rock Shelter, Zone I **1695 ± 165**

Charcoal (NMC-564) from base of lowest cultural zone, 0.30m below surface.

S-727. Blind Bay Rock Shelter, Zone IV **1485 ± 90**

Charcoal (NMC-565) from concentration of charcoal beneath fallen schist slab in middle cultural zone, 0.25m below surface. Assoc with much tiny flakes showing signs of heat treatment.

S-728. Blind Bay Rock Shelter, Zone V **430 ± 65**

Charcoal (NMC-566) from highest charcoal-stained layer, below fallen schist slab, 0.17m below surface.

General Comment (JDS): earliest occupation to date of Shuswap Lake sites (Fladmark, 1973), contrary to original expectation of Paleo-Indian occupation suggested by geology and meager artifacts (Stewart, 1973). S-725 and -726 date difference possibly from disturbance during prehistoric occupation due to loose gravel deposits; Zone I probably represents long depositional period rather than single component of short period. Rock shelter intermittently occuppied during dated period.

S-742. Carruthers site, Saskatchewan **3050 ± 80**

Charred bone from Carruthers site (FbNs-3), near N edge of Dunfermline Sand Hills (52° 12′ 10″ N, 107° 02′ 46″ W). Assoc with Oxbow projectile points in cultural layer 35 to 50cm below surface. Coll 1972 and subm 1973 by I G Dyck, Sask Mus Nat History, Regina. *Comment* (IGD): minimum age for Oxbow complex, site marked by abundant small end scrapers and sparse animal bones indicating special activity area.

Saatut site series, Northwest Territories

Caribou bones from Saatut site (PeHa-1), Borden Peninsula, W coast of Eclipse Sound, on S shore of flat point, S end of Navy Board Inlet, Baffin I. (72° 43′ 45″ N, 80° 13′ W). Small artifact rich Dorset site, Saatut I 2.7m asl, Saatut II 5cm asl, however artifacts suggest contemporary occupations. Coll and subm 1973 by Fr G Mary-Rousselière, Catholic Mission, Pond Inlet.

S-755. Saatut I, Caribou bone (NMC-594) **1530 ± 80**

From Sq 7, Dorset midden, should date local phase of culture characterized by specialized industry ca AD 100.

S-881. Saatut I, Caribou bone (NMC-657) **1325 ± 90**

From Sq 41 and 42, lower level of midden.

S-756. Saatut II, Caribou bone (NMC-595) **1925 ± 70**

From Saatut II house.

S-850. Saatut II, Caribou bone (NMC-654) **1180 ± 90**

From Sq 5, House 1.

General Comment (GM): previous dates on seal bones Saatut I AD 440 and Saatut II 445 BC were too far apart for typologically similar sites (S-590, -671: R, 1975, v 17, p 337, 342). S-755 and -756 still too far apart to support contemporary occupations. S-850 and -881 both too recent.

Stendall site series, Manitoba

Bone from Stendall site, Pipestone Creek, SE Sec 3 Twp 10 R 29W1 (49° 48′ 10″ N, 101° 19′ 53″ W). Large buffalo kill-processing site. Coll 1972 by A Gerth; subm 1973 by W M Hlady, Manitoba Archaeol Soc.

S-785. Stendall site, Level 2 **755 ± 60**

Bone, probably bison (NMC-604) from 5.1 to 10.2cm below surface.

S-786. Stendall site, Level 3 **965 ± 70**

Bone, probably bison (NMC-605) from 10.2 to 15.2cm below surface. *General Comment* (WMH): dates indicate occupation period of 2 centuries although assoc artifacts suggest a shorter period.

White site series, Ontario

Carbonized wood and charcoal from White site, Lot 34, Conc 6, Pickering Twp (44° N, 79° W). Site ca 207m asl, ca 0.8 to 1.2 ha, on secondary R Terrace and yet undetermined area of main terrace above small branch of W Duffin Creek. Shallow cultural deposits, apparent difference in carbonized seed remains and scarcity of faunal remains are in sharp contrast to nearby Drapper site, suggest site was large seasonal camp with structures for specialized economic activities. Ceramics extremely varied and include Huron Incised, Black Neck, and basket-impressed types. Coll 1973 by P G Cook, S Sawford and R Naras; subm 1973 by B Hayden, Virginia Commonwealth Univ (now Simon Fraser Univ).

S-791. White site, Sq 42-44N, 5-7E **320 ± 70**

Carbonized cedar stump (NMC-616) from W wall of Sq, depth 15cm below surface, in midden deposit which extends to 30cm depth, assoc with carbonized corn kernels, fish and animal bones, and ceramics. Rich midden in vicinity of hearth and several pits.

S-792. White site, Sq 20-22S, 10-12W **435 ± 85**

Charcoal (NMC-617) from Feature 2, depth 12cm below surface, basin-shaped depression between 2 gravel bars, refuse filled. Sample from 3cm below light gray ash lens and 5cm above river gravels. Midden yielded much vegetal material, carbonized corn kernels, fish and animal bone but little ceramics.

S-858. White site, Sq 18-20S, 4-6W **1070 ± 105**

Charcoal (NMC-618) from Feature 1, refuse filled basin-shaped depression. Poor recovery of cultural and organic material.

S-857. White site, Sq 18-20S, 8-10W **645 ± 105**

Charcoal (NMC-619) from Feature 1 depth 12 to 15cm, assoc with carbonized corn kernels and sherds.

S-859. White site, Sq 42-44N, 5-7E **225 ± 90**

Charcoal (NMC-620), depth 30 to 33cm, lower portion of midden containing abundant pottery, fish, animal, and human bone.

General Comment (BH): dates are from various locations on site hence may represent more than 1 component. S-858 appears anomalous but may represent early Iroquoian occupation, excluding S-858 mean value compatible with contemporaneous occupation with Draper site.

S-797. Atherly Narrows site, Ontario **4560 ± 115**

Wood from fish weir stake, Atherley Narrows between Simcoe and Couchiching Lakes, N Hwy 12 bridge, Mara Twp (43° 36′ 19″ N, 79° 22′ 05″ W). Id paper birch (*Betula Papyrifera*). Coll 1973 by K Cassavoy; subm 1973 by R B Johnston, Trent Univ. *Comment* (RBJ): date agrees with previous dates on other weir stakes (Johnston & Cassavoy, 1977) slightly older than 2500 BC.

S-798. Constance Bay Site-2, Ontario **1855 ± 110**

Charcoal from Constance Bay Site-2 (BiGa-3), on Constance Creek, 48km W of Ottawa (45° 28′ N, 76° 04′ W). Assoc with Middle Woodland ceramics and lithics. Coll and subm 1973 by G D Watson, Ottawa. *Comment* (GDW): date consistent with Middle Woodland ceramics of site.

Grant Lake site series, Northwest Territories

Charcoal and peat from Grant Lake site (KkLn-2) NE end of Grant Lake, Dubawnt R, Keewatin Dist (63° 43′ 20″ N, 100° 26′ 10″ W). Agate Basin site, probable fall caribou hunt location ca 5550 to 6050 BC. Coll 1973 and subm 1973, 1975, by J V Wright.

S-809. Grant Lake site, Sq C Feature 1 **2025 ± 100**

Charcoal (NMC-666) under firestone of Feature 1. Should date 1st occupation of area.

S-833. Grant Lake site, Sq C Feature 2 **160 ± 50**

Charcoal (NMC-667) from N edge of hearth in Feature 2 on surface of duft.

S-810. Grant Lake site, Sq A Feature 2 **3620 ± 105**

Charcoal (NMC-668) from concentration in duft, 25.4cm below surface.

S-811. Grant Lake site, Trench I **1515 ± 85**

Peat (NMC-669) from trench 6m E of Sq D, 66cm below surface and 35.6cm below occupation level. Non-cultural, should pre-date Agate Basin level and post-glacial plant mat. Geol significance and earliest possible time of man in area.

S-1056. Grant Lake site, Sq A, B and C **7220 ± 850**

Carbonized bone (NMC-808-812) combined sample from Components A, B and C. Should date 1st human occupation of area and period relative to similar materials to S and W.

General Comment (JVW): apparent erratic contamination of samples except S-1056 where max range acceptable date.

S-814. Butte site, Quebec **805 ± 95**

Charcoal (NMC-673) from Butte site (Cb-Fd-7), Becancour municipality, 0.8km E of Laviolette Bridge, 1.6km S of St Lawrence R (42° 18′ N, 72° 32′ W). Site on hill summit, ca 192m N-S, 41 to 180m E-W, 10m above surrounding terrain and river level, W slope sand, E slope clay. Occupation zone irregular and discontinuous, varies in depth relative to surface. From Pit N10, depth 25cm, assoc with Lamoka point. Should compare to Lamoka remains of N Y State and date level of Champlain Sea for this period ca 2000 BC. Coll 1973 by P Gauthier; subm 1974 by R Marois, Nat Mus Canada. *Comment* (RM): Lamoka and Brewerton points indicate earlier period, sample not related to remains.

S-815. Bouvais site, Quebec **2180 ± 140**

Charcoal (NMC-674) from Bouvais site (CbFd-5), on narrow terrace, probable ancient beach, midway S flank of hill below Butte site (CbFd-7), Becancour municipality, 0.8km E of Port Laviolette, 1.6km S of St Lawrence R (42° 18′ N, 72° 32′ 18″ W). Occupation zone rests on gravel S edge and fine sand on N edge of terrace. From Pit N103, 23cm below surface on fine sand, assoc with expanded base drill, base of occupation zone. Same occupation zone in Pit N4 yielded Lamoka point shorter than point of Butte site. Comparison to S-814 should mark possible change of Lamoka points and indicate retreat rate of Champlain Sea. Coll 1973 and subm 1974 by R Marois. *Comment* (RM): date seems too recent as site yielded no potsherds, ceramics in use in area since 800 BC.

Beaumier site series, Quebec

Charcoal from Beaumier site (CcFd-2), St-Odilon on sand terrace with abrupt face 6m high, E bank St Maurice R, 4.8km from mouth (48° 22′ N, 72° 34′ W). Site 130 by 30m, intersected by 3 deep depressions former creek tributaries to St Maurice R. Occupation zone at surface, scattered artifacts, regularity of surface broken by mounds, one containing 20cm charcoal. Site linked to development of St Lawrence Iroquois. Coll 1972 by C Ouayou, P Courbin, J Trudel and A Gérard; subm 1974 by R Marois.

S-816. Beaumier site, Pit N1W9 **145 ± 80**

Charcoal (NMC-675) from Level 1, Zone C, depth 11cm below surface. Assoc with uncollared rim sherd decorated with cord-wrapped stick impressions in vertical above oblique above horizontal bands from lip to shoulder, lip pointed. Interior also bears cord-wrapped impressions ca AD 1000.

S-817. Beaumier site, Pit W6 **280 ± 135**

Charcoal (NMC-676) from Level 1, Zone C, depth 14cm below surface. Assoc with uncollared rim sherd decorated with linear impressions forming a double horizontal row of cross-hatch. Lip also cross-hatch decorated, interior not decorated. Woodland cultural complexes of region not clearly defined or chronologic position certain. Date should give chronologic position and aid evaluation of change evidenced by pottery ca AD 1000.

S-836. Beaumier site, Pit 05 **370 ± 70**

Charcoal (NMC-678) from Level 1, Zone D, 18cm below surface.

S-837. Beaumier site, Pit N, 05 **185 ± 75**

Charcoal (NMC-679) from Pit N, 05, Level 1, Zone D, 20.5cm below surface.

S-838. Beaumier site, Pit S, 08 **375 ± 70**

Charcoal (NMC-680) from Level 1, Zone B, 9cm below surface.

General Comment (RM): S-816 and -837 rejected as too recent since no group of Trois-Rivières region of 17th or 18th centuries, historic period, known to have assoc artifacts. S-817, -836, and -838 are reasonable at lower error range; latter 2 assoc with sherds from a single vessel. Age difference between S-836 and -837 from adjacent pits at same depth unexplained; implies contamination or site disturbance during historic occupations.

Draper site series, Ontario

Charcoal from Draper site (AlGt-2), left bank Duffins Creek, Pickering Twp, 289 asl (43° 56′ 30″ N, 79° 10′ 20″ W). Late Ontario Iroquois site, almost certainly ancestral to Huron. Possibly fortified, located along steep stream terrace. Coll 1973 by M Malberg, M Dawding, P Naras, A Simmons and B Hayden; subm 1974 by B Hayden.

S-818. Draper site, Sq 42-44N, 42-44E **590 ± 75**

Charcoal (NMC-621) assoc with Feature 2, hearth in A3 soil horizon, ca AD 1450.

S-819. Draper site, Sq 28-30N, 66-68E **210 ± 80**

Charcoal (NMC-622) from sub-Sq 4, Feature 2, hearth 24 to 27cm depth. Should date house occupation, ca AD 1450.

S-860. Draper site, Sq 20-22N, 72-74E **405 ± 65**

Charcoal (NMC-623) from sub-Sq 12 and 16, Feature 1. Should date house occupation.

S-861. Draper site, Sq 22-24N, 72-74E **570 ± 95**

Charcoal (NMC-624) from sub-Sq 13 and 14, Features 2 and 3, 30 to 35cm depth. Should date house occupation.

S-862. Draper site, Sq 22-24N, 70-72E **430 ± 85**

Charcoal (NMC-625) from sub-Sq 11 and 15, fill of Posthole 1, 36cm depth. Should date house occupation.

S-863. Draper site, Sq 46-48N, 42-44E **495 ± 65**

Charcoal (NMC-626) from Feature 4, 42 to 5cm depth. Should date house occupation.

General Comment (BH): all samples from interior of Structure 2, average of all samples AD 1500, excluding S-819 average AD 1452, both closely agree with ceramic age estimate AD 1450 to 1500 (Wright, 1966).

Saamis site series, Alberta

Bone and charcoal from Saamis site (EaOp-6), 2.5km upstream from entrance of Seven Persons Creek into S Saskatchewan R, NE 1/4 Sec 24 Twp 12R6W4, 724 asl (50° 1′ N, 110° 42′ W). Coll 1973 by V Gadd, J Stuber and B Burton; subm 1974 by L Brumley, Medicine Hat Coll, Medicine Hat, Alberta.

S-824. Saamis site, Area C **435 ± 125**

Bone (NMC-635) from excavation Unit 73, SE quad and excavation Unit 77, SE quad, 0.9m below surface. Late prehistoric site assoc with meat processing activities. Should date earliest occupation ca AD 1600 to 1700.

S-825. Saamis site, Area E **85 ± 70**

Bone (NMC-636) from excavation Unit 78, NE quad, sparse layer of bone in bank along Creek. Potsherds from single Late Prehistoric vessel recovered. Probable bison butchering-processing site.

S-827. Saamis site, Area B **210 ± 80**

Charcoal (NMC-642) from excavation Unit 116, NE quad, Level 1, Feature 72, depth 7.6 to 66cm below surface. Late prehistoric or protohistoric campsite area. Sample from one of a number of basin hearths, which contained layers of fire-cracked rocks; deer, bison and dog bones; and 2 large duck-stamped rim sherds.

General Comment (LB): S-824 and -827 within expected age range and correspond to stratigraphic sequence. S-825 unacceptable should date close to S-824.

S-826. Stampede Camp, Alberta **3690 ± 95**

Charcoal (NMC-637) from Stampede Camp site (EaOp-4), on Seven Persons Creek, NE1/4 Sec 24 Twp 12R6W4, 661 asl (50° 01′ N, 110° 39′ W). From excavation Unit 17, Feature 5, large rock-filled basin hearth. Late prehistoric campsite based on ceramics and projectile points ca AD 1500 to 1600. Coll and subm 1973 by L Brumley. *Comment* (LB): date 2000 yr older than estimate based on single potsherd and several Plains Side-notched projectile points; no earlier diagnostic artifacts recovered. Sample definitely assoc with hearth fill, no disturbance evident. Multicomponent site is concluded although lack of supporting evidence.

S-828. Point Beazer site, Alberta **430 ± 90**

Charcoal (NMC-643) from Point Beazer site (DhPh-3), on 1st terrace above W side St Mary R (49° 07′ N, 113° 12′ W). From Feature 3, irregular rock-lined hearth, 74 to 79cm below surface, 25N130W, Level 4. Assoc with fire-broken rock, argillite flakes and chopper, butchered bone, canine mandible, and an obsidian flake, dated AD 1590 by obsidian hydration method. Multicomponent campsite in Old Women's phase of late prehistoric period, assoc with kill-site (DhPh-2). Coll 1973 by B Burles; subm 1974 by J M Quigg, Univ Calgary (now Archaeol Survey Alta, Edmonton, Alberta). *Comment* (JMQ): although hearth not directly assoc with major cultural refuse, date in Old Women's phase time range, earliest occupation of site. Obsidian date in reasonable agreement.

S-829. DhPh-13 site, Alberta **1150 ± 120**

Charcoal (NMC-644) from DhPh-13 site, W side St Mary R, on 2nd terrace (49° 12′ 45″ N, 113° 15′ 05″ W). From irregular rock-lined hearth, Test 3, Level 4, 58cm below surface, assoc with side-notched projectile point and potsherd. Single component occupation level in Old Women's phase, in buried Ah horizon within Chernozemic soil profile. Debris included fire-cracked rock, butchered bison bone, ceramics and flakes dispersed over large area with concentrations in activity areas, ca AD 1200. Coll 1973 by J Thompson; subm 1974 by J M Quigg. *Comment* (JMQ): 1 of few early dates for Old Women's phase in S Alberta; similar artifacts from Belly R valley DgPk-75 site dated AD 750 (S-724; R, 1975, v 17, p 348). Sample provides evidence that Old Women's phase spread across S Alberta during this time.

Cape Freels-1 site series, Newfoundland

Charcoal from Cape Freels-1 site (DhAi-1), on high ridge along Cape Cove between S Bill and Cape Island, Bonavista Bay (49° 14′ 10″ N, 53° 29′ 20″ W). Series of Maritime Archaic seasonal encampments, 1000 to 3000 BC. Coll by P Bishop and P Carignan; subm 1974 by P Carignan, Memorial Univ (now Newfoundland Mus).

S-830. Cape Freels-1 site, Loc 6 **1450 ± 110**

Charcoal (NMC-660) from hearth, S15E0.

S-868. Cape Freels-1 site, Loc 9 **1605 ± 65**

Charcoal (NMC-664) from hearth, S70W25.

S-869. Cape Freels-1 site, Loc 3 **1045 ± 90**

Charcoal (NMC-665) from hearth, S40E5.

General Comment (PC): site initially believed to be late terminal Archaic, however, dates indicate occupation during and slightly later than Dorset period and may alter previous conceptions of cultural sequences of insular Newfoundland.

S-831. Cape Freels-2 site, Newfoundland **1740 ± 100**

Wood charcoal (NMC-661) from Cape Freels-2 site (DhAi-2), Cape Cove beach between S Bill and Cape I., Bonavista Bay (49° 14′ 01″ N, 53° 29′ 07″ W). From hearth in single occupation layer underlying peat deposit. Prehistoric Beothuck ca AD 1000 to 1500. Coll 1973 and subm 1974 by P Carignan. *Comment* (PC): date earlier than expected and, if accepted, establishes Beothuck Indian presence during etxensive Dorset Eskimo occupation of insular Newfoundland. Further site dates will be required to verify Indian-Eskimo cohabitation of island and possible Beothuck descendants from Maritime Archaic inhabitants.

Cape Freels-3 site series, Newfoundland

Charcoal from Cape Freels-3 site (DhAi-3), on high embankment near Cape I., Bonavista Bay (49° 13′ 50″ N, 53° 28′ 55″ W). Terminal Maritime Archaic seasonal encampments ca 1000 to 3000 BC. Coll 1973 and subm 1974 by P Carignan.

S-832. Cape Freels-3 site, Loc II **1205 ± 80**

Charcoal (NMC-662) from Archaic hearth, N20E25, below peat deposit.

S-867. Cape Freels-3 site, Loc 7 **1255 ± 105**

Charcoal (NMC-663) from Archaic hearth, N15E10, below peat deposit.

General Comment (PC): dates later than expected, indicates occupation during late Dorset period.

S-835. Monique site, Quebec **1060 ± 105**

Charcoal (NMC-677) from Monique site, in Becancour Industrial Park, 100m from St Lawrence R, Quebec (46° 26′ 20″ N, 72° 25′ 30″ W). Site on sand beach broken by knolls and marsh areas at bank of St Lawrence R. From Sec A, N trench, 52cm below surface, assoc with body sherds, some decorated with fingernail impressions, others, thick cord-wrapped stick impressions. Should establish chronologic position of site relative Beaumier and Batiscan sites ca AD 900. Coll 1973 and subm 1974 by R Marois. *Comment* (RM): date between Batiscan and Beaumier sites of Trois-Rivières area.

S-844. DgPh-2 site, Alberta **130 ± 85**

Unbutchered bison bone (NMC-627) from DgPh-2 site, W bank St Mary R, E of Atena (49° 07′ N, 133° 12′ W). From lowest level of bone bed at water edge, 4m overburden soil. Buffalo kill in slump block next to river, badly eroded, located between buried campsites DgPh-1 and DgPh-3. Assoc with quantities of unbutchered axial skeletal remains and a few butchered elements. No lithic material discovered. Coll 1972 and subm 1974 by J M Quigg. *Comment* (JMQ): date suggests assoc with Old Women's phase of Late Prehistoric period. Slump more recent covering bone deposit. Point Beazer site upstream containing camp and processing areas probably related to site.

Majorville Cairn series, Alberta

Bone from Majorville Cairn (EdPc-1), S bank of Bow R, 32km S of Bassano (50° 31′ N, 112° 24′ W). Cairn 918.4 asl, 9m diam and 1.6m high, encircled by medicine wheel, 28.8m diam, with 26 to 28 spokes. Coll 1971 and subm 1974 by J Calder, Univ Calgary.

S-854. Majorville Cairn, Layer 16 **2090 ± 210**

Bone (NMC-584) from Level 1, excavation Unit 1-7.

S-855. Majorville Cairn, Layer 12 **2655 ± 85**

Bone (NMC-585) from Levels 1 to 3, excavation Unit 1-5.

S-856. Majorville Cairn, Layer 14 **3845 ± 160**

Bone (NMC-586) from Levels 1 to 2, excavation Unit 2 × 1-7.

General Comment (JC): dates verify early antiquity for cairn bldg on NW plains.

Baldwin site series, British Columbia

Charcoal from Baldwin site (GbTo-36), W side Kaien Island, Prince Rupert Harbour (54° 17′ 03″ N, 130° 21′ 22″ W). Coast Tsimshian village site, destroyed 1974 by harbour construction. Coll 1973 and 1974 and subm 1974 by R Inglis, Nat Mus Canada.

S-871. Baldwin site, Trench 1 **2655 ± 65**

Charcoal (NMC-691) from Area A, Level 16, 3.63m below surface; lower level of site ca 4000 to 4500 yr BP.

S-872. Baldwin site, Trench 7 **3285 ± 110**

Charcoal (NMC-692) from Area A, N wall of hearth feature excavated into basal sands. Should date 1st occupation ca 4000 to 4500 yr BP.

S-873. Baldwin site, Trench 5 **1830 ± 105**

Charcoal (NMC-693) from Area A, Level 12, SW quad, 2.77m below surface. Will date lower level and significant zoomorphic carving ca 3000 to 3500 yr BP.

S-990. Baldwin site, gravel pit profile **2740 ± 110**

Charcoal (NMC-776) from 1.9cm burnt wood lens in gravel pit profile, extending from edge of pit feature 1.4m towards harbor. From 1.1m below surface, basal layer on band of decomposed rock 3.8cm thick, overlying thin band of clay on sterile matrix.

S-991. Baldwin site, Trench 5 **1525 ± 55**

Charcoal (NMC-777) from Area A, Level 3, 0.97m below surface in hearth feature in matrix of crushed clam and gray gravel. Will date burials and artifacts from upper horizon.

General Comment (RI): site badly disturbed by railroad construction AD 1910, World War II defense encampments and recent small cabins, leaving only back platform area intact. As with other sites in area, inland area dates later than front probably a result of population pressure forcing expansion inland. Start of this behavior was Middle period, 1500 BC to AD 500; S-872, -871, and -990 acceptable dates. S-873 somewhat later than 500 BC estimate but acceptable. S-991 indicates degree of midden disturbance.

S-874. Flach site, Alberta **3260 ± 320**

Charcoal (NMC-447) from Flach site (FjPh-101), on 1 of upper terraces of Old Man Creek, 3.2km from confluence with N Saskatchewan R, NE of Edmonton (53° 30′ N, 113° W). From NW corner of NE test block at bottom of fossil *Bison* level. Excavation uncovered remains of at least 2 bison larger than contemporary forms, with many long bones placed in piles. Assoc flake and non-diagnostic triangular point on quartzite flake. Should date terminal phase of terrace construction related to N Saskatchewan R terrace sequence, ca 5000 to 11,000 yr BP. Coll 1970 by R Bonnichsen, Univ Maine, Orono; subm 1974 by R Wilmeth, Nat Mus Canada. *Comment* (RB): charcoal assoc with remains of large bison, horn core spread greater than 91cm, considerably larger than *Bison bison*. Date younger than expected, no reason to doubt validity, probably 1 of youngest dated *Bison occidentalis* skeletons yet recovered in N Plains.

Bird's Eye Cove Shelter series, British Columbia

Charcoal from Bird's Eye Cove Shelter (DeRu-15), 1.2km S of Bird's Eye Cove, Range 5, Sec 17, Vancouver I. (48° 46′ 50″ N, 123° 35′ 50″ W). Rock shelter 13 by 5m, open N and S ends. Stratigraphy unclear, ash lenses and larger shell midden layers difficult to trace from 1 pit to next. Coll 1971 by D N Abbott; subm 1974 by B Kennedy, Prov Mus British Columbia.

S-875. Bird's Eye Cove Shelter, 3.22m depth **2000 ± 70**

Charcoal (NMC-556) from loose shell midden, N8.60, E0-0.10, 3.22m below Datum A, 0.5m below surface. Assoc with bone chisel and 2 shell ornaments.

S-876. Bird's Eye Cove Shelter, 2.75m depth **1310 ± 70**

Charcoal (NMC-557) from N4.90-6.00, ca W2.60-2.90, at edge of hearth between dark soil and shell midden, 0.10 to 0.15m below surface. Same assoc as S-875.

S-877. Bird's Eye Cove Shelter, 3.10 to 3.30 depth **1900 ± 75**

Charcoal (NMC-558) from loose shell midden with occasional black streaks in excavation unit, N7-9, W1-3, 3.10 to 3.30m below Datum A, 0.45 to 0.65m below surface. Lowest sample recovered; with S-875 and -876, should date range of occupation ca AD 1450.

S-878. Bird's Eye Cove Shelter, 2.88m depth **1205 ± 80**

Charcoal (NMC-559) from among fire-cracked rocks, N7-9, E0, 2.88m below Datum A, 0.10 to 0.15m below surface. Same assoc as S-875 and -876.

General Comment (DNA): dates older than estimate, however, material recovered applicable to 300 BC to historic contact. Oldest dates S-875 and -877 from shell midden, 0.5m depth, and youngest dates S-876 and -878, from immediately above complex deposits of soil and ash with less shell, consistent with stratigraphy and implies 2 components of occupation.

S-893. East Sugar Island site, Ontario **2540 ± 130**

Bone (NMC-602) from East Sugar Island site, on small plateau, NW corner of East Sugar I. in Rice Lake, 190.5 asl (44° 14′ N, 78° 8′ W). From pit in Sq A-1, Area 1, depth 35.6 to 73.7cm. Layer of artifact and bone-bearing soil lining pit distinct from sterile fill. Site apparently series of camp sites occupied from late Archaic to historic period. During Archaic village site. Should date manufacture and use of ground slate points ca 4500 to 5000 yr BP. Coll 1972 by J Prideaux; subm 1974 by W A Kenyon, Royal Ontario Mus. *Comment* (WAK): date unexplainably too recent for mid-Archaic in Ontario.

S-894. Hungry Hall Mound 1, Ontario **820 ± 65**

Oak charcoal (NMC-603), NW1/4 Sec 16, Atwood Twp, Rainy R Dist (48° 49′ 15″ N, 94° 41′ 15″ W). Site 324 asl, 1 of 2 Blackduck burial mounds near mouth of Rainy R, Mound 2, upstream, dated AD 1190 ± 60 (S-109: R, 1962, v 4, p 77). Sample from 0.82m below subsoil surface around center of sub-mound pit and overlying stratum of multiple secondary burials and grave furniture, where sample was thrown with ash, bone fragments from crematorium. Will date construction of feature and assoc colln of 18 complete ceramic vessels and other cultural material ca AD 1000. Coll 1969 and subm 1974 by W A Kenyon. *Comment* (WAK): excellent agreement.

S-918. Lindsay Mammoth site, Montana **11,925 ± 350**

Mammoth tibia (NMC-710) from Lindsay Mammoth site, SE Sec 6 and NE Sec 7 Twp 17NR52E Dawson County, 35.4km NE of Glendive (47° 15′ N, 105° 08′ W). From undisturbed surface in lower member of 1.2m loess unit overlying a Paleocene formation. Asymmetrical distribution of bony elements, suggestions of butchering, rearrangement of certain bony parts to facilitate butchering and presence of 8 angular but irregular shaped sandstone blocks suggest assoc with man. Should indirectly date loess unit and estimate onset of stabilized conditions preceding its accumulation ca 11,000 yr BP. Coll 1967 by L B Davis, Montana State Univ; subm 1974 by R Wilmeth. *Comment* (LBD): 2 previous dates 10,700 ± 290 BP (WSU-652: unpub) and 9490 ± 135 BP (I-7028: unpub).

S-919. Crossing site, Northwest Territories **Modern**

Calcined bone fragments (NMC-711) from Crossing site (MiRi-2), S shore Horton Lake, N of Great Bear Lake, Dist Mackenzie (67° 27′ 30″ N, 122° 42′ W) at 349m asl. Scattered over excavation units within occupation horizon, 0 to 15cm below turf or exposed at ground surface. Caribou crossing site, yielded assemblage with microblades, microcores, side-notched points, tine end scrapers and a copper ulo blade. Certain aspects suggest Arctic Small Tool Tradition but burins, tine side-blades and end-blades lacking. Should date occupation, possible diverse occupations represented ca 2000 to 4000 yr BP. Coll 1972 and subm 1974 by D W Clark, Nat Mus Canada. *Comment* (DWC): although campsites around Horton Lake have been occupied within past 100 yr, no evidence of modern occupation observed at site. Date not applicable to implements recovered (Clark, 1975b).

S-920. RlIg-52 site, Alaska **885 ± 80**

Calcined bone, almost exclusively of medium to large mammals (NMC-712) from RlIg-52 site, shore of small lake 98.7 asl, Batza Tena loc, Indian R/Little Indian R, Koyukuk R region, W interior Alaska (65° 51′ N, 154° 11′ W). Sample from thin scatter over 1/3 area of small encampment complex based upon points, knives, scrapers made from large obsidian flakes and numerous blade-like flakes. Microblades, burins and ceramics absent. Stone pestle and tabular hide-working stones present. Complex presently unique, possibly early Athapaskin ca 200 to 1200 yr BP, but could be 2500 yr BP. Coll 1971 and subm 1974 by D W Clark. *Comment* (DWC): date compatible with interpretations of Koyukuk R prehistory (Clark, 1974, 1975b) although bone fragments and artifacts recovered from surface and a few cm depth, unsealed context.

S-922. MiRh-5 site, Northwest Territories **1610 ± 110**

Calcined bone, predominantly from medium and large mammals (NMC-714) from MiRh-5 site, on glacial moraine on S shore of Horton Lake, Dist Mackenzie (67° 26′ N, 122° 37′ W). Sample at 359.7 asl, exposed on denuded area, semi-concentrated probably originating in hearth of which no ash or charcoal remain, Area C, assoc with rough quartzite tools. Cultural affiliation uncertain, ca 200 to 5000 yr BP. Coll 1972 and subm 1974 by D W Clark. *Comment* (DWC): site appears to be cobble-quarry flaking sta (Clark, 1975b). Tentative date until regional archaeol sequence established.

Potlatch site series, British Columbia

Charcoal and charred wood from Potlatch site (FcSi-2, formerly FcSi-201), S shore of Little Anahim Lake, 4.8km W of Anahim settlement, central interior British Columbia (52° 29′ 30″ N, 125° 20′ 30″ W). Site includes 1 large rectangular surface structure and 4 semi-subterranean circular houses of 2 distinct forms. There appear to be 3 components, prehistoric, protohistoric, and historic; latter 2 attributed to Chilcotin Indians. Coll 1968 by R Wilmeth and B Wilmeth, 1969 by J Andelson; subm 1974, 1975 by R Wilmeth.

S-923. Potlatch site, Potlatch House **130 ± 80**

Charred wood (NMC-725) from Sq N19W18, E wall trench, 49cm depth. House known to have been abandoned between AD 1865 and 1875, but contains trade items dated to 1st half of 18th century; construction possible ca AD 1700.

S-945. Potlatch site, Spalyan Bat'o House **1695 ± 90**

Charcoal (NMC-308) from floor of NE quad of Spalyan Bat'o House, traditional Chilcotin winter lodge. One European item, copper bead, recovered ca AD 1750 to 1860.

S-1036. Potlatch site, Midden 4 **Modern**

Charcoal (NMC-793) from ash-filled depression at base of Midden 4, trash accumulation of historic period partially overlapping prehistoric house pit. Sample assumed to predate midden and assoc with house.

General Comment (RW): dates acceptable, Potlatch House could be as early as AD 1740, thus overlapping with age of some European material. Midden 4 historic, not related to adjacent house pit. Early date for Spalyan Bat'o House difficult to explain, clearly not assoc with house structure, presence of microblade suggests disturbance of earlier occupation; evidence of disturbance in other units of site. Previous dates, AD 80 and AD 335 bracket S-945 (S-501 & -500: R, 1973, v 15, p 204).

Arnarnitung site, Northwest Territories **930 ± 95**

Seal bone (NMC-708) from Arnarnitung site (MbDj-1), island located 0.8km SE Bon Accord, Cumberland Sound, Baffin I. (66° 16′ N, 67° 07′ W). From Test Area 1, Sq ID, 50 to 55cm depth. Comparatively large Thule culture winter site on small island, almost completely destroyed but originally contained 15 large sod-stone and whale bone houses. Should date earliest major Thule period occupation in Sound. Coll 1973 and subm 1974 by P Schledermann, Univ Calgary. *Comment* (PS): analysis of assoc harpoon head material suggests AD 1220.

S-929. Niutang site, Northwest Territories **510 ± 65**

Seal bone (NMC-709) from Niutang site (MbDc-1), SE shore of Kingnait Fjord, 56km from fjord entrance into Cumberland Sound, Baffin I., Dist Franklin (66° 12′ N, 64° 42′ W). From Test Sq W, 45cm level. Large Thule winter site and caribou hunting sta, now badly destroyed. Contained 16 house ruins, tent rings, several quarmats, caches and large burial ground. Sample from proximity of eroding bank suggesting earlier occupation than test of house structure. Coll 1973 and subm 1974 by P Schledermann. *Comment* (PS): harpoon head typology indicate ringed seal bone dates should be more recent by ca 200 yr.

S-934. Council site, British Columbia **1425 ± 70**

Wood charcoal (NMC-731) from Council site (GaUb-7), SE of Mission Hill in village of Haida, on E shore of Masset Harbour, Queen Charlotte I. (54° 02′ 05″ N, 132° 10′ 30″ W) ca 5.29m above high tide. From Unit C, Level 3, 60cm below surface, in shell midden. Deposit to 100cm depth. Prehistoric to protohistoric, now destroyed. Coll 1973 and subm 1974 by P Severs, Univ Alberta. *Comment* (PS): site elev slightly above 2 historic sites of Ut-te-was and Ka-Yung, seems too old, 10m sites date ca 2000 to 3000 yr BP. Four non-diagnostic artifacts recovered.

Blue Jackets Creek site series, British Columbia

Wood charcoal from Blue Jackets Creek site (FlUa-4), S of Skaga Point on E shore of Masset Sound, Queen Charlotte I. (53° 59′ 35″ N, 132° 08′ 22″ W), 3.5m above high tide. Prehistoric shell midden deposits to 270cm depth. Multicomponent, some artifact assemblages similar to those of Skoglund's Landing site (FlUa-1). Graham tradition defined by K Fladmark also present. Coll 1972, 1973 and subm 1974 by P Severs.

S-935. Blue Jackets Creek site, Level VII **3815 ± 115**

Wood charcoal (NMC-732) from N1W2, 125cm depth, NE quad Feature 16, possible hearth. Undisturbed burials at this level ca 3000 yr BP.

S-936. Blue Jackets Creek site, Level XI **4150 ± 90**

Wood charcoal (NMC-732) from S2E2, 200cm depth, SW quad, lens of charcoal and fire-cracked rock in midden ca 4500 yr BP.

General Comment (PS): earliest site date, Level XIV, 3310 BC (Gak-5093: unpub) and most recent date, Level 14, 320 BC (Gak-4883: unpub). Level IX dated 2340 BC (GSC-1554: unpub). Dates agree with previous dates.

Manyfingers site series, Alberta

Charcoal and bone from Manyfingers site (DhPj-31), 1st and 2nd terrace of E side Belly $, S Alberta (49° 16′ 40″ N, 113° 33′ 15″ W). Stratified processing and campsite, with 3 occupation levels (Quigg, 1973; 1974). Coll 1973 by J T Thompson, P Perry, and J M Quigg; subm 1974 by J M Quigg.

S-947. Manyfingers site, 2S4E **465 ± 70**

Charcoal (NMC-645) from Level 6, 56 to 66cm below datum, in ash lens. Level contains fire-cracked rock, bone, flakeage, and ceramics assoc with Old Women's phase of Late Prehistoric ca AD 900.

S-864. Manyfingers site, 6S6E **640 ± 105**

Butchered bison bone (NMC-646) from Level 4, 42 to 44cm below datum. Old Women's phase assoc with ceramics, flakeage, fire-cracked rock, bone and side-notched points ca AD 1400.

S-865. Manyfingers site, 6S10E **1100 ± 85**

Bison bone (NMC-647) from Level 6, 62 to 66cm below datum. Avonlea phase, assoc points lithics, choppers, bone, fire-cracked rock and ceramics ca AD 400.

S-866. Manyfingers site, 2S4E **1075 ± 90**

Bone (NMC-648) from Level 7, 74 to 81cm below datum, in dense processing area. Avonlea phase containing butchered bone, lithics, fire-cracked rock and ceramics.

General Comment (JMQ): dates correlate with known age range of the 2 cultural phases as indicated by projectile points and ceramics. 2nd terrace dates Avonlea pottery in S Alberta.

S-971. Crawford site, Ontario **515 ± 75**

Charcoal (NMC-743) from Crawford site (AgHa-23), Six Nations Reserve, Grand R, near Brantford, Ontario (43° 08′ N, 80° 10′ W). From Sq C-3, 20.3cm below surface. Transitional Middleport-Pound site ca AD 1450. Coll 1974 by D Stothers; subm 1974 by D L Keenlyside, Nat Mus Canada. *Comment* (DLK): date agrees with previous date, AD 1370 ± 40 (DIC-258: unpub) from same excavation, 20.3 to 40.6cm below surface. Average of these dates, AD 1400, closely agrees with seriational estimate, AD 1450, and clarifies terminal placement of Middleport substage of Ontario Iroquois tradition and subsequent Pound phase.

S-972. Schaeffer site, Ontario **450 ± 55**

Human bone (NMC-744) from Schaeffer site (Pelee Island-4), SW corner Pelee I., Essex Co (41° 45′ 30″ N, 82° 38′ W). From Test Excavation 1, 30cm below surface, assoc with artifactual remains. Bone fragmented by plow disturbance but burial context reliable. Single component site several hundred m from lake shore, probably heavy vegetation in prehistory. Evidence of cultural relation to McGraw site, S Ohio, late Hopewellian manifestation. Mounds similar to site observed on other islands in W basin, Lake Erie probably related, ca AD 200 to 500. Coll 1969 and subm 1974 by D L Keenlyside. *Comment* (DLK): cultural context of human bone and assoc diagnostic lithics clearly not related to such a late date.

S-973. McDonald Farm site, Nova Scotia **180 ± 55**

Moose bone (NMC-745) from McDonald Farm site (BjCo-5) on shoreline SW end of Olding I., Pictou Co (45° 38′ N, 62° 29′ W). From Area D, shell midden 30.5 by 15.3m, max depth 43.2cm, along beach S bay of island. Single component, Maritime, adapted culture, possible antecedents of ethno-historic Micmac ca AD 800 to 1000. Coll 1913 by H I Smith and W J Wintemberg, Nat Mus Canada; subm 1974 by D L Keenlyside. *Comment* (DLK): date too recent, possible historic intrusion.

S-974. Eisenhauer Shell Heap, Nova Scotia **610 ± 95**

Charcoal (NMC-746) from Eisenhauer Shell Heap, shore of Mahone Bay, Lunenburg Co, 2.4km W of Indian Point (44° 29′ N, 64° 40′ W). Shell Heap 24.4 by 7.6m on small knoll on narrow beach, Andrew Cove. Sample from 4.6 by 1.5m area beneath undisturbed shell accumulation underlain by black soil and ash 5 to 15cm depth. Single component, possible antecedents of ethnohistoric Micmac (Smith & Wintemberg, 1929). Coll 1913 by J I Smith and W J Wintemberg; subm 1974 by D L Keenlyside. *Comment* (DLK): date acceptable to present understanding of prehistory of coastal Nova Scotia. Assoc ceramics and lithic assemblages show parallels to coastal New Brunswick with sites dating approx same period.

S-976. RkIh-36 site, Alaska **1324 ± 260**

Calcined bone (NMC-748) from RkIh-36 site, E bank of Koyukuk R, Batza Tena loc, Batztega sublocality, NW interior Alaska (65° 04′ 30″ N, 154° 27′ W) 79.2m asl. From 40-50N, 4.5-7W, concentration of calcined bone, soil and obsidian flakes occurring in frost starting at base of organic litter but mostly under brown soil layer and above green-brown soil horizon. Assemblage included end-scrapers, side-notched points, sparse microblade assemblage, copper awl, notched cobbles, rough bifaces, somewhat comparable to Tuktu complex. Should date complex although possibly more than 1 component ca 3000 to 6500 yr BP. Coll 1971 and subm 1974 by D W Clark. *Comment* (DWC): date unacceptable compared to W Alaska dates for assemblages with side-notched points including Tuktu site type. However, date may apply for central and E Alaska to assemblages characterized by both side-notched points and microblades as well as certain other attributes of Tuktu complex.

Boardwalk site series, British Columbia

Shell from Boardwalk site (GbTo-31), NW side of Elizabeth Point, Digby I., Prince Rupert Harbour (54° 17′ 20″ N, 130° 22′ 46″ W). Prehistoric winter village of Gispakloats tribe of Tsimshian shell midden containing ca 310,000 cu m cultural material. Coll and subm 1974 by R I Inglis.

S-983. Boardwalk site, Area A, E70S20 **2735 ± 65**

Shell (NMC-769) from E wall, 88.9cm from top of cultural deposit in matrix of intact, fragmented and crushed shells, winkles, barnacle, and mussel. Should date burials from middle horizon ca 1500 yr BP.

S-984. Boardwalk site, Area A, E70S20 **2310 ± 60**

Shell (NMC-770) from E wall, S end of profile, 63.5cm below surface, in matrix of intact and broken clam, some blue mussel and sea urchin. Should date burials from upper horizon ca 500 to 1000 yr BP.

S-985. Boardwalk site, Area C, N3S3S **2175 ± 65**

Shell (NMC-771) from N Wall, 61cm below top of cultural deposit in matrix intact and broken butter clam, mussel and sea urchin. Should date upper horizon burials ca 1000 yr BP.

S-986. Boardwalk site, Area C, N35E5 **2385 ± 105**

Shell (NMC-772) from N wall in matrix intact and broken clam, mussel and sea urchin. Should date middle horizon burials ca 1500 yr BP.

S-987. Boardwalk site, Area C, Trench B **2230 ± 60**

Shell (NMC-773) from N wall, 2.5cm below surface and 91.4 to 101.6cm above black lens in matrix of intact and broken shell, loose organic soil. Should date last occupation of house pits.

General Comment (RII): S-983, -984, and -986 burials on back ridge of shell dump earlier than expected, indicating rear platform no longer used long before village site abandoned. Box burials, some with grave goods such as copper, amber, dentalia, shell beads and sea otter teeth, and a cache of warrior weapons assoc with dates, suggests ranked society was established in Middle Horizon. S-987 from top of a ridge between 2 house pits in front of S-986 location supports interpretation of abandoned back area for house sites some 2000 yr BP.

Grassy Bay site series, British Columbia

Charcoal from Grassy Bay site (GbTn-1), Fern Passage Indian Reserve No. 3, Metlakatla Band (54° 18′ 52″ N, 130° 15′ 48″ W). Coast Tsimshian camp and village. Coll 1968 by B Simonsen for G F MacDonald, Nat Mus Canada; subm 1974 by R I Inglis.

S-992. Grassy Bay site, Pit C, Level 7 **1620 ± 55**

Charcoal (NMC-778) from 1.45m below datum. From hearth feature in matrix of crushed mussel and clam shells, brown soil and ash.

S-933. Grassy Bay site, Pit C, basal level **1700 ± 60**

Charcoal (NMC-779) from 1.78m below datum, in matrix of charcoal-stained soil with decomposed schist, overlying beach gravel.

S-994. Grassy Bay site, Pit A, Level 4 **620 ± 55**

Charcoal (NMC-780) from 0.58m below datum, in matrix of dark soil, gravel and some crushed shell.

S-995. Grassy Bay site, Pit A, Level 10 **1615 ± 60**

Charcoal (NMC-781) from 1.88m below datum in matrix of dense shell, intrusive cultural deposit on beach gravel.

General Comment (RII): AD 250 to 1500 acceptable period for seasonal camp for exploitation of fish resources of inner Prince Rupert Harbour area, especially Shawatlans.

Lucy Island site series, British Columbia

Charcoal from Lucy Island site (GbTp-1), SW end of Lucy I. (54° 17′ 39″ N, 130° 37′ 02″ W). Coast Tsimshian shellfish processing campsite. Coll 1968 by B Simonsen for G F MacDonald; subm 1974 by R I Inglis.

S-996. Lucy Island site, 1.83m depth **2070 ± 60**

Charcoal (NMC-782) from Test Area 2, Unit A, 1.83m below surface, in matrix of crushed shell assoc with hearth feature.

S-997. Lucy Island site, 2.93m depth **2500 ± 60**

Charcoal (NMC-783) from Test Area 2, Unit A, 2.93m below datum, just above base of deposit, in matrix of crushed clam, sand and brown soil.

General Comment (RII): seasonal campsite 16km offshore from Prince Rubert Harbour indicates prehistoric exploitation of outer island shellfish and seabird resources as early as ca 500 BC; dates from base of shellfish deposit.

S-998. Brown's Beach site, Newfoundland **1100 ± 60**

Charcoal (NMC-736) from Brown's Beach site (DeAl-2), on terrace 4.6 to 7.1m asl, S shore of Bloody Reach, Bonavista Bay (48° 42′ 14″ N, 53° 55′ 22″ W). From concentration in SE corner of Sq S20E25, and NE corner of Sq S25E20. Maritime Archaic site ca 1000 BC. Coll 1974 and subm 1975 by P Carignan. *Comment* (PC): stone tool inventory thought to reflect Late Maritime Archaic occupation, however date indicates Beothuck. If correct, site suggests possible continuity of Maritime Archaic styles till late prehistoric time.

S-999. Bloody Bay Cove site, Newfoundland **1020 ± 55**

Charcoal (NMC-737) from Bloody Bay Cove site (DeAl-1), SE side of cove, E side of Bloody Point, Bonavista Bay (48° 44′ 58″ N, 53° 50′ 55″ W). From Feature 1, S25W65, hearth assoc with Maritime Archaic tools ca 1000 to 1500 BC. Multicomponent site, Maritime Archaic, Dorset and Beothuck. Coll 1974 by W Oldford; subm 1975 by P Carignan. *Comment* (PC): hearth features of multicomponent sites, Bonavista Bay difficult to identify in spite of close proximity of diagnostic tool forms. Date may apply to Beothuck occupation which is in assemblage.

S-1000. Sailor's site, Newfoundland **375 ± 75**

Charcoal (NMC-738) from Sailor's site (DeAj-1), SW edge of gravel pit in Sailor's Harbour, near community of Salvage, Bonavista Bay, (48° 41′ 21″ N, 53° 40′ 27″ W). From Feature 1, N35E15, hearth assoc with Beothuck artifacts ca AD 1000. Multicomponent site, Dorset and Beothuck. Coll 1974 by P Lane; subm 1975 by P Carignan. *Comment* (PC): date indicates Beothuck occupation also reflected in artifact inventory.

S-1001. Fox Bar site, Newfoundland **1255 ± 65**

Charcoal (NMC-739) from Fox Bar site (DeAk-3), low lying bar near Beaches Head, Bonavista Bay, Newfoundland (48° 48′ 55″ N, 53° 48′ 50″ W). From Feature 1, S10W0, hearth probably assoc with Maritime Archaic tools. Stratified site, multicomponent, Maritime Archaic, Dorset and Beothuck, upper cultural level mixed. Coll 1974 and subm 1975 by P Carignan. *Comment* (PC): multicomponent upper cultural level made positive id of hearth impossible, appeared more closely assoc with Maritime Archaic tools. Date indicates late Dorset or Beothuck occupation, both represented in assemblage.

Moosehide site series, Yukon

Charcoal and bone from Moosehide site (LaVk-2), Moosehide village, on highest bench 21.3m, at junction of Yukon R and Moosehide Creek, W central Yukon (64° 05′ N, 139° 26′ W). Seasonal campsite with post-1900 historic material in humus layer and separate underlying Little Arm component (MacNeish, 1964) containing wedge-shaped cores, transverse burins, microblades, and other artifacts ca 5000 to 7000 yr BP. Coll 1974 and subm 1975 by J R Hunston, Univ Calgary.

S-1002. Moosehide site, Pit 4, Level 2 **5625 ± 80**

Charcoal (NMC-740) from 4N4W, assoc with microblades and flakes in brown loess soil matrix.

S-1003. Moosehide site, Pit 6, Level 2 1405 ± 60

Charcoal (NMC-741) from 6N4W, 15 to 20cm below surface, assoc with fragmented bone and flakes.

S-1004. Moosehide site, Pit 6, 7N4W, Level 2 Modern

Bone (NMC-742) from 6N4W, assoc with microblades and a wedge-shaped microcore.

General Comment (JRH): S-1002 agrees with dated Little Arm manifestations SW Yukon at Otter Falls and Canyon sites and stratigraphic position of this component at Gladstone site. S-1003 and -1004 too recent; possible disturbance of site SW portion Pit 6.

S-1014. See-Everywhere site, Alberta 160 ± 60

Bison bone (NMC-787) from See-Everywhere site (EcOr-34), SE Sec 21 Twp 16 R7W4 (50° 21′ 47″ N, 110° 54′ W). Found near base of Cairn 1 in Sq 0N1W and 1N1W, medium size cairn on commanding view knoll along edge of large coulee. Large quantity of stone debitage and a few lost or discarded tools present in vicinity of cairn. Excavation of cairn yielded cultural material characteristic of Middle and Late Prehistoric and Historic periods. Coll 1972 by R Heitzman; subm 1975 by J Brumley, Univ Calgary. *Comment* (JB): definite date for construction of cairn as bison vertebrae at base of cairn, no other bases for evaluating date.

Ramillies site series, Alberta

Bison bone from Ramillies site (EcOr-35), N side of W end of Chaisson Ridge, SE Sec 21 Twp 16 R7W4 (50° 21′ 03″ N, 110° 54′ 10″ W). Multicomponent kill-camp site composed of trap-kill area, XV-3 on top edge of coulee, large natural hollow with manmade earth stone wall, 2nd kill area, XV-2 jump or snow-bank type below XV-3 on upper slope of coulee. Campsite related to 1 or both kill areas, 2 components id, Avonlea and Old Women's phase. Coll 1974 by V Maltin; subm 1975 by J Brumley.

S-1015. Ramillies site, Feature A1 965 ± 65

Bison bone (NMC-788) from SE 4S2W, XV-3, Level 12 at 134.5cm below datum. Assoc with Feature A1, stone construction forming part of bison trap. Bone on original ground surface of cultural layer upon which wall built, found under collapsed wall.

S-1016. Ramillies site, Feature A2 660 ± 115

Bison bone (NMC-789) from NE 6S0W, XV-3 at 80cm below surface, assoc with man-made buried rock alignment, apparently part of drive line. Bone from original ground surface upon which rock alignment built, from a few cm S of base rocks. Should give max age of feature and post-date trap-kill situation S-1015, ca AD 800 to 1200.

General Comment (JB): acceptable dates.

S-1017. Shaw Burial site, Alberta **1390 ± 90**

Bison bone (NMC-790) from Shaw Burial site (EdOn-7), E Sec 10, Twp 19 R2W4 (50° 35′ 47″ N, 110° 11′ 20″ W). Assoc with single burial, body located within or beneath medium-sized stone cairn constructed on ground surface now 45cm below present surface. Site discovered and destroyed during gas pipeline construction. Few stone tools, bison and human bone coll. Coll 1974 by B Shaw; subm 1975 by J Brumley. *Comment* (JB): no basis for evaluating date, probably Besant or Avonlea phase.

S-1018. Horne site, Nova Scotia **540 ± 55**

Charcoal (NMC-735) from Horne site (BfCv-3), N side Shubenacadie R, 1.2km NE from Grand Lake outlet (44° 66′ N, 63° 31′ W). From Unit D2, Quad I 2.8m and Quad IV 3.5m, depth below datum 0.88m. Disturbed multicomponent site, spring to fall occupation assoc with aceramic to ceramic assemblages. Should date small hearth, Feature 5, late ceramic period with broad corner-notched projectile points ca 1000 yr BP. Coll 1974 and subm 1975 by S Davis, St Mary's Univ, Halifax. *Comment* (SD): date too recent for projectile points, possible contamination by recent brush burning of area.

S-1028. McIntyre site, Ontario **4715 ± 270**

Carbonized wood from McIntyre site, N shore Rice Lake, Otonabee Twp, Peterborough Co, Ontario (44° 11′ 55″ N, 78° 11′ 11″ W). From Feature 1, hearth pit, assoc with broken deer mandible bone, bear, canine bone, and chert fragments. Coll 1974 and subm 1975 by R B Johnston. *Comment* (RBJ): date ca 100 yr older than 5 other dates that cluster around 3670 yr (I-9068, -9312-9315: unpub) on material from other pits.

Goose Point site series, British Columbia

Charcoal from Goose Point site (FeSi-1), W bank Dean R between Little Bay and Big Anahim Lakes (52° 29′ 40″ N, 125° 20′ 30″ W). Site includes 2 semi-subterranean houses, one historic Chilcotin winter lodge, the other a prehistoric type dated AD 1240 ± 80 (S-502: R, 1973, v 15, p 205). Coll 1969 by P F Donahue, J Hall, and R Wilmeth; subm 1975 by R Wilmeth.

S-1037. Goose Point site, Bes Ico House, Zone II **170 ± 55**

Charcoal (NMC-794) from Bes Ico House, SE quad 1.78N1.25E, 57cm below datum, ca 14cm below surface, assoc with heavy bone concentration in Zone II ca AD 1600 to 1800.

S-1038. Goose Point site, Bes Ico House floor **245 ± 75**

Charcoal (NMC-795) from Bes Ico House, SE quad N 2.00 to 3.20, E 0.24 to 1.00, 86 to 88cm below datum, 28 to 30cm below surface, floor level, ca AD 1600 to 1800.

S-1039. Goose Point site, Bes Ico House Posthole 790 ± 205

Charcoal (NMC-796) from Bes Ico House Posthole 3; should date house construction AD 1600 to 1800.

General Comment (RW): dates S-1037 and -1038 agree with age estimate of house form and presence of European trade item. S-1039 earlier than house construction, may be derived from earlier component. Posthole contained charcoal, but may not be from post used in construction. Date close to that of nearby Suzchet House (S-502: R, 1973, v 15, p 205).

Radiant Lake—3 site series, Ontario

Charcoal from Radiant Lake—3 site (CaGn-1), at exit of North R into Radiant Lake (46° 00′ 07″ N, 78° 17′ 58″ W). Multicomponent site. Coll 1966 and 1967 and subm 1975 and 1976 by B M Mitchel, Deep River, Ontario.

S-1044. Radiant Lake—3 site, Sq L21 2165 ± 75

Charcoal (NMC-286) from 45.7cm depth in roasting pit containing thick coiled potsherds decorated with dragged dentate or pseudo-scallop shell at 17.8 to 33cm. Probably oldest pottery producing component at site ca 2000 yr BP.

S-1045. Radiant Lake—3 site, Sq K24 1520 ± 60

Charcoal (NMC-288) from 15.2 to 22.9cm depth among rims and body sherds with external punctations and internal nodes above horizontal rows of cord-wrapped stick. Most sherds occurred at 15.2 to 16.5cm. Sample believed to be Middle Woodland and should date use of cord-wrapped paddle edge ca 1800 yr BP.

S-1161. Radiant Lake—3 site, Sq I22 Modern

Charcoal (NMC-814) from 43.2cm below surface on hilltop 13m above lake level, should date Archaic component with ground slate points ca 3000 yr.

S-1162. Radiant Lake—3 site, Sq L24 4815 ± 45

Charcoal (NMC-815) from 41 to 48cm below surface, assoc with slate chips at 28 to 41cm and ground slate point at 37cm. Should date Archaic component.

S-1163. Radiant Lake—3 site, Sq E22 4150 ± 135

Charcoal (NMC-816) from 43 to 56cm below surface, assoc with massive quartz chips at 46 to 48cm. Should date Archaic component.

General Comment (BMM): S-1044 dates occupation using Vinette 2 techniques (Ritchie & MacNeish, 1949) particularly pseudo-scallop shell and banded rocker or drag stamped zones. Date fits range 490 BC to AD 90 (GaK-1891, -1892: R, 1973, v 15, p 57) for similar components along Petawawa R (Mitchell, 1969) and equates with range between lower Ottawa R site, 490 BC (S-578: R, 1975, v 17, p 334) (Watson, 1972) and middle Ottawa R site, 80 BC to AD 130 (I-2084, -2083: R, 1968, v 10, p 283-

284) (Wilmeth, 1969). Stratigraphically S-1045 follows peak Middle Woodland zone, 215 BC (S-1044) and precedes cord malleated exterior punctated pottery zone, AD 710 (GSC-1351: unpub). Date for ceramic manifestation of late Middle Woodland in E central Ontario and confirms temporal position indicated by stratigraphy. S-1161-1163 expected to date Archaic component, median date of S-1162 and -1163 compares to Whitson Lake—2 site (Hurley *et al*, 1972) dated 2590 BC (GSC-2181: unpub), Petawawa R site 50km E where much quartz was used.

S-1053. Near site, Yukon **615 ± 85**

Charcoal and charred wood from single timber (NMC-641) from Near site (JeVq-2), E shore Kluane Lake, midway between Gladstone Bay and entrance to Talbot Arm (61° 21′ N, 138° 42′ W) at 793m asl. From 010, Level 4 in 1st reddish buried soil in Neoglacial loess, 3rd or 4th buried soil in unit, 1st one widely burned. 2nd burned soil ca 5cm below 1st soil, contact with top of White R ash. Only 1st burned soil horizon produced cultural material. Sparse, small site with limited evidence of small component stratigraphically above one assoc with sample. Neither component clearly id but possibly related to Aishikik complex. Should date component and one of several cessations of loess deposition that have occurred since eruption of White R ash ca 1000 yr BP. Coll 1973 and subm 1975 by R E Morlan, Nat Mus Canada. *Comment* (REM): satisfactory date.

S-1061. Hind site, Ontario **2875 ± 75**

Human bones, 11 ribs, 3 vertebrae and sternum, copper-stained (NMC-813) from Hind site (AdHk-1), lower Thames Valley, Mosa Twp, Middlesex County (42° 32′ N, 81° 35′ W). From Burial 15, complete except foot bones disturbed by burrowing animal. Red Ochre, Glacial Kame site, although other components may be present. Previous dates using 3 techniques range from 4570 ± 120 to 1790 ± 100 yr BP. Age of burial of interest because of preserved soft tissue of neck area; preservation possibly aided by copper impregnation and dry sandy soil. Coll 1970 by S Wortner and W Donaldson; subm 1975 by H Savage, Univ Toronto. *Comment* (HS): microscopic sects of black organic material from cranial cavity and at foramen magnum of skull showed preserved collagen fibers and nerve tissue. Stylolid process of base of skull showed preserved osteocytes in Haversian systems. Archaeol context and date would indicate earliest preserved human tissue in N America (Gak-3794a, -3794b, -3944c: unpub).

S-1067. Katepwa Beach site, Saskatchewan **4780 ± 195**

Comminuted bison bones from cottage well, Katepwa Beach site (EaMv-1) (50° 41′ 52″ N, 103° 37′ 30″ W). Coll *in situ* from occupation layer 5 to 15cm thick at 2.3m below surface. Assoc with chipped stone flakes and a biface. Coll and subm 1975 by I G Dyck. *Comment* (IGD): dates bison butchering site.

JjNd-1 site series, Northwest Territories

Charcoal from JjNd-1 site, central N shore of large i., NE bay of Firedrake Lake, Mackenzie Dist (61° 33′ 40″ N, 104° 34′ 00″ W). Surface material Middle Taltheilei, included small chert point, 2 chert scrapers, quartz scraper, hammerstone, chi-tho fragment, retouched and unmodified chert flakes. 4 sq m test pit in area of surface material exposed 2 charcoal lenses separated by charcoal-streaked white sand. Coll 1975 by H von Krogh; subm 1975 by B C Gordon.

S-1136. JjNd-1 site, upper charcoal band 715 ± 60

Charcoal (NMC-820) from upper charcoal band beneath 100cm sand, 200cm inward from bank exposure. Should post-date occupation and, with S-1137, bracket this occupation ca post-AD 400.

S-1137. JjNd-2 site, lower charcoal band 1740 ± 110

Charcoal (NMC-821) from lower charcoal band below 100cm sand, 200cm inward from bank, assoc with pentagonal and fishtailed points, ca pre-AD 400.

General Comment (BCG): dates bracket Middle Taltheilei period, AD 0 to 600, more closely related to lower charcoal date.

S-1138. KaNp-1 site, Northwest Territories 1775 ± 60

Charcoal (NMC-822) from KaNp-1 site, E ridge of i., N arm of upper Nonache Lake, 16km NE of Sparrow Bay, SE Mackenzie Dist (62° 06′ 30″ N, 109° 17′ 00″ W). Small sand blowout, 1931 asl, shallow single buried component containing Taltheilei Chipewyan material ca AD 1200 to 1700. Coll 1975 by M Wright; subm 1975 by B C Gordon. *Comment* (BCG): estimated age based on 2 shallow side-notched projectile points similar to Late Taltheilei points. If date correct, it represents previous unknown emanation of shallow notching in Great Slave Lake region, possible Plains affiliations.

JkNf-1 site series, Northwest Territories

Charcoal from JkNf-1 site, NE Jarvis Lake, SE Mackenzie Dist, NWT (61° 42′ 00″ N, 104° 51′ 00″ W). Favorable camp location E narrows, 2092 asl, 65 by 110m site almost totally destroyed by wind erosion. Two cultural levels below 40 to 50cm of sterile overburden, separated by brown sand layer. Below a pink-white layer yielding a few flakes possibly related to Shield Archaic material found on surface. Arctic Small Tool and Taltheilei tradition materials also represented. Coll 1975 by H von Krogh; subm 1975 by B C Gordon.

S-1139. JkNf-1 site, upper level 535 ± 60

Charcoal (NMC-823) from upper level, Test Pit 2, probably Early to Middle Taltheilei as reflected by surface materials ca 300 BC to AD 600.

S-1140. JkNf-1 site, lower level 1340 ± 50

Charcoal (NMC-824) from lower level, Test Pit 2, assoc with chert microblade attributed to Arctic Small Tool tradition ca 700 to 1000 BC.

General Comment (BCG): buried material single component of Middle to Late Taltheilei rather than Shield Archaic or Arctic Small Tool, latter found only on surface. Buried chert microblade, only Arctic Small Tool artifact in horizon probably intrusive.

S-1141. JiNf-7 site, Northwest Territories **1030 ± 65**

Charcoal in sand (NMC-825) from JiNf-7 site, on peninsula, N shore of Firedrake Lake, SE Mackenzie Dist (61° 28′ 40″ N, 104° 51′ 30″ W). From single buried component, quartzite artifacts in deposit and on surface, including stemmed and unstemmed pentagonal projectile points. Coll 1975 by H von Krogh; subm 1975 by B C Gordon. *Comment* (BCG): lanceolate stemmed points common in Middle Taltheilei AD 150 to 600, date places pentagonal points in early phase of Late Taltheilei, probable evolvement out of Middle Taltheilei.

S-1142. JiNc-3 site, Northwest Territories **940 ± 50**

Charcoal in sand (NMC-826) from JiNc-3 site, E end of E bay of Firedrake Lake, E of main caribou crossing, SE Mackenzie Dist (61° 26′ 30″ N, 104° 24′ 50″ W). From buried burned soil, 40cm below surface. Cultural material in white sand zone below burned soil, included quartzite concave-based ground-notched point. Surface material largely historic with thin veneer of prehistoric remains. Coll 1975 by H von Krogh; subm 1975 by B C Gordon. *Comment* (BCG): date acceptable for projectile point, similar to other Late Taltheilei specimens dated AD 800 to 1750.

S-1143. JjNe-6 site, Northwest Territories **1390 ± 50**

Charcoal in sand (NMC-827) from JjNe-6 site, SW shore of narrows of Jarvis Lake, at caribou crossing, SE Mackenzie Dist (61° 39′ 20″ N, 103° 48′ 30″ W). From Area B2 in charcoal band just below layer containing Middle Taltheilei artifacts. Should pre-date occupation, AD 1 to 600. Coll 1975 by H von Krogh; subm 1975 by B C Gordon. *Comment* (BCG): acceptable date.

Réal site series, Quebec

Charcoal from Réal site, (DdGt-9) ca 2km from mouth of Duparquet R, Palmarolle Twp, Abitibi (48° 39′ 10″ N, 70° 19′ 30″ W). From Sector B, 0.25km NW of Bérubé site (DdGt-5), on point relative to Bérubé, closes bay which separates sites. Occupation zone rested directly on bedrock, cultural affiliation to be determined. Coll 1975 by N d'Entremont and D Turgeon; subm 1975 by R Marois.

S-1149. Réal site, Pit S2E1 **1635 ± 150**

Charcoal (NMC-839) from Zone 2, SE quad, 9cm below surface. Level 2 represents occupation zone which varies from 8 to 15cm in thickness.

S-1150. Réal site, Pit S3E4 **2760 ± 70**

Charcoal (NMC-840) from Level 3, Zones 5 and 6, NW quad, 25 to 35cm below surface. Level 3 is below occupation zone and composed of fine compact brown soil. From charcoal pocket 10cm thick over almost all NW quad, 15 to 25cm below top of Level 3 and 25 to 36cm below surface. Should determine if artifacts of Level 3 at DdGt-9 and DdGt-5 belong to an occupation earlier than that of Level 2, ca 1 BC.

General Comment (RM): S-1149 indicates at least 2 occupations that are not stratigraphically distinguishable and are represented and probably overlap in deposit of Level 2. Both scraper and gun flint recovered from zone above Level 2. Many artifacts recovered from surface probably Archaic, supported by S-1150 date.

S-1153. DdGt-4 site, Quebec **465 ± 115**

Charcoal (NMC-843) from DdGt-4 site, E shore of Lake Abitibi on 6m cliff, Palmarolle Municipality (48° 39′ 30″ N, 79° 19′ 45″ W). From Pit S1, Level 2, Zone A, SE quad, 7cm depth. Occupation zone 2 to 7cm thick, produced flakes only, other pits yielded some crudely made stone artifacts and a glass bead. Coll 1974 by R Dubois; subm 1973 by R Marois. *Comment* (RM): site appears to be seasonal camp, dates younger than artifacts suggest, bead regarded as intrusive.

JjNk-2 site series, Northwest Territories

Charcoal from JjNk-2 site, extreme NW bay of Rennie Lake, S shore, SE Mackenzie Dist (61° 34′ 45″ N, 105° 45′ 40″ W). 405 asl on sandy ridge next to spruce grove, blowout exposure. 2 charcoal bands in sand below which a bone layer, possibly 3 occupations, variety of projectile points and other artifacts were recovered. Coll 1975 by M Wright; subm 1975 by B C Gordon.

S-1155. JjNk-2 site, upper level **390 ± 65**

Charcoal (NMC-828) from upper band with bone, ca AD 1200 to 1600.

S-1156. JjNk-2 site, lower level **1320 ± 90**

Charcoal (NMC-829) from lower level band overlying sand containing bone and 10.2 to 15.2cm below upper charcoal band.

General Comment (BCG): S-1155 correlated with Late Taltheilei tools in surface of blowout, excavation produced only stone flakes. S-1156 dates between Middle and Late Taltheilei, between stemmed and side-notched points recovered from site surface.

S-1160. Midge's Tent Ring site, Northwest Territories **Modern**

Charcoal in sand (NMC-833) from Midge's Tent Ring site (KkLn-14), N end of Grant Lake, Dubawnt R, Keewatin Dist (63° 43′ 20″ N, 100° 26′ 15″ W). Three large tent rings 15.2m above lake. From shallow excavation just below surface vegetation, probably recent Eskimo. Few artifacts but considerable butchered caribou bone. Coll 1974 by M Gordon; subm 1975 by B C Gordon. *Comment* (BCG): modern date acceptable, site early historic occupation of barrenland interior by Caribou Inuit, represents one of deepest penetrations.

Cartier site series, Quebec

Charcoal from Cartier site, Payne Lake, Ungava Peninsula, on terrace 3.2km W of lake outlet, S shore, Quebec (59° 17′ N, 73° 24′ W). Site 152m long, 4.6 to 36.6m wide, 2.1m above lake at 122 asl. Cultural features confined to several stone foundations, cache piles, tent rings, a dam and causeway, include European, Thule and modern Eskimo in varying degrees. Cover mainly lichens and moss, limited grass. Coll 1974 by P Bidard and M Jacques; subm 1976 by T E Lee, Centre D'Etudes Nordique.

S-1200. Cartier site, House Foundation 2 **555 ± 80**

Charcoal (NMC-860) from 3.8m E 1m N, Level 1, 0 to 2.5cm below sod on house floor. Should date House 2 or Thule occupation unknown as yet for interior region.

S-1201. Cartier site, Tent Ring 1 **220 ± 60**

Charcoal (NMC-861) from central fireplace, 4.3m W 3m N, 0 to 5cm below sod. Should date early appearance of historic Eskimo inland and place large oval tent ring in early time as indicated by wrought iron.

General Comment (TEL): S-1200, if Thule, is remarkably early for area, alternately date with deviation within 47 yr of expected European occupation of house. S-1201 is early date, since trade goods in general from Fort Chimo, AD 1832. If date is correct, it implies trading contact with St Lawrence or James Bay. Nails appear English, but this is not certain.

S-1208. Arnakadlak site, Northwest Territories **1830 ± 80**

Caribou bone (NMC-851) from Arnakadlak site (PgHb-3), W coast of Navy Board Inlet, Borden Peninsula, Baffin I. (73° N, 80° 38′ W). From old tent ring, 6.5m asl. Site of a few Thule houses and several tent rings, one of which yielded early Dorset or late pre-Dorset assemblage with high proportion of burins. Previous date on marine bone, 775 BC (S-591: R, 1975, v 17, p 337). Coll 1975 and subm 1976 by Fr G Mary-Rousseliere. *Comment* (GM-R): date too recent.

S-1211. EbOp-14 site, Alberta **4245 ± 125**

Charcoal (NMC-854) from face of R bank, W side of S Saskatchewan R (50° 13′ 56″ N, 110° 36′ 23″ W). From small surface hearth, Sq 4S0W, 1.75m below surface. Single occupation, cultural affiliation unknown. Coll 1973 by R Freeman; subm 1976 by J Brumley. *Comment* (JB): date suggests contemporary occupation with McKean phase occupation of nearby Cactus Flower site (EbOp-16).

S-1212. EbOp-42 site, Alberta **2030 ± 100**

Bone (NMC-855) from slope of S Saskatchewan R valley (50° 18′ 58″ N, 110° 37′ 58″ W). Unidentifiable bone fragment from XU-1, Sq 6S4W. Cultural material recovered from buried campsite indicate single occupation related to Besant phase ca AD 200 to 750. Coll 1975 by L Bitz; subm 1976 by J Brumley. *Comment* (JB): date acceptable and with date for occupation II of nearby EbOp-44, 60 BC (S-1213) suggests contemporary Besant components.

EbOp-44 site series, Alberta

Bone from EbOp-44 site, small knoll on slope of S Saskatchewan R valley (50° 18′ 59″ N, 110° 38′ 03″ W). Probable camp and primary processing area for bison kills. 3 occupations: Occupation I—Old Women's phase, Occupation II—Besant phase, and Occupation III—Pelican Lake phase. Coll 1975 by C Meyer; subm 1976 by J Brumley.

S-1213. EbOp-14 site, Occupation II **2010 ± 55**

Bone (NMC-856) from XU-1, Sq 18S16W, and 18S18W. Unidentifiable bone fragment, should give 1st Besant component date for SE Alberta ca AD 200 to 750.

S-1214. EbOp-14 site, Occupation I **210 ± 110**

Bone (NMC-857) from all Sq's XU-1, Old Women's phase ca AD 1400 to 1700.

General Comment (JB): dates acceptable, contemporary with nearby EbOp-42 site.

Trade Lake site series, Saskatchewan

Bone from Trade Lake site (GiMw-18), SW corner of Trade Lake (55° 21′ N, 103° 49′ W). Appears to be single component temporary campsite with late prehistoric Selkirk or Clearwater Lake phase cultural affiliation. Coll 1974 by J Light and S J Smailes; subm 1976 by S J Smailes, Saskatchewan Mus Nat Hist.

S-1215. Trade Lake site, Sq 4S0E **Modern**

Bone (NMC-858) from Level 1, 64N10E, 6cm below datum and from Levels 2 and 3, B horizon of podzolic soil.

S-1216. Trade Lake site, Sq 4S3E **265 ± 65**

Bone (NMC-859) from 25-33N 57-66E, 5.7 to 8.3cm below datum, in B horizon of podzolic soil, a few cm under moss.

General Comment (SJS): S-1216 1st positive date for Clearwater Lake phase in N Saskatchewan.

S-1220. Blumenhof site, Saskatchewan **4235 ± 100**

Human bone (NMC-554) from Blumenhof site (EaNw-1), 4.8km NE of Blumenhof village (50° 10′ N, 107° 40′ W). Skeleton discovered at 2.4m depth in tertiary sands beneath ca 1.2m of boulder clay. No evidence of intrusion through clay till. Bison skull of modern size found in back-hoe pit at about same level. If not intrusive, would predate last glacial advance in area. Coll 1961 by T F Kehoe and B McCorquodale; subm 1976 by A L Bryan, Univ Alberta. *Comment* (ALB): date proves skeleton intrusive, skull in excellent condition, one of oldest known for Plains Indian. Racemization date on skeletal sample less than 6000 yr (J Bada, pers commun, 1976) (Bryan & Steels, 1976).

S-1241. Moose Mountain Medicine Wheel, Saskatchewan **2650 ± 245**

Charcoal (NMC-880) from Moose Mountain Medicine Wheel (DkMq-2), 12.9km N of Kisbey (49° 46′ N, 102° 42′ W) from highest dome-shaped hill of area at 785m asl. Combined sample from W of center of central cairn from datum to 30cm above datum. Site stone configuration in form of medicine wheel consisting of central cairn, 9.1m diam, surrounded by stone circle, 15.2 to 18.3m diam, with 5 lines of stones extending in several directions terminating in stone cairns, 0.9m diam. Cultural affiliation unknown. Charcoal in black earth indicates site burned over before central cairn and rock feature built. Astronomy interpretation estimates age 2000 yr BP, Prairie side-notched points suggest 1000 to 1300 yr BP. Coll and subm 1976 by T F Kehoe. *Comment* (TFK): date acceptable to astronomy implications (J A Eddy, pers commun). Prairie side-notched points lay directly above basal rocks of central cairn and may date later than basal configuration.

S-1257. KbNg-6 site, Northwest Territories **2020 ± 110**

Charcoal in sand (NMC-882) from 366m asl and 10.4m above Lynx Lake, SE Mackenzie Dist (62° 19′ 30″ N, 106° 03′ 00″ W). From lower of 2 levels. Site on exposed W island in beaded esker chain running E to W across S lobe of Lynx Lake. Surface artifacts Middle Taltheilei, AD 150 to 600, excavated tools diagnostic of Taltheilei tradition but not of specific period. Coll 1976 by R Blacklaws; subm 1976 by B C Gordon. *Comment* (BCG): date indicates Early Taltheilei occupation, 500 to 100 BC or initial stage of Middle Taltheilei, 100 BC to AD 500 (Gordon, 1976).

S-1258. KjNb-7 site, Northwest Territories **6120 ± 110**

Charcoal in sand (NMC-883) from KjNb-7 site, on right bank of Upper Thelon R, 9.7km downstream from Hanbury R, Mackenzie Dist (63° 39′ 34″ N, 104° 28′ 30″ W). From bottom level, sub 56 Sq 39, of main excavation. Esker remnant site at prominent caribou crossing. Multicomponent with Arctic Small Tool and Taltheilei traditions above bottom level of Shield Archaic, ca 2500 to 3500 BC. Coll 1976 by M Barlow; subm 1976 by B C Gordon. *Comment* (BCG): previous dates for Shield Archaic from KjNb-7 and close adjacent KjNb-6 span period 2800 to 3200 BC. Oldest date for this tradition in Canada, predating by 600 yr Migod site dates on Dubaunt R, 210km E. Supports hypotheses by J V Wright that this tradition developed from Northern Plano Agate Basin, dated Migod site 5200 to 6000 BC. High percentage of plano-convex cross-section, uniface knives and a large triangular well-finished end scraper resemble Northern Plano. Oldest date on upper Thelon R.

KeNi-4 site series, Northwest Territories

Charcoal from KeNi-4 site, NW bay of Whitefish Lake close to Snowdrift R, headwaters to Sandy Lake, SE Mackenzie Dist (62° 46′ 25″ N, 106° 58′ 00″ W). Large blowout site 0.8km in length, 366 asl and 10.4m above Whitefish Lake, adjacent to caribou water-crossing of Beverly population. 3 distinct levels visible, probably all Taltheilei Chipewyan. 4 basal levels found 0.4km NE but not tested, surface materials Arctic Small Tool and Taltheilei traditions. Coll 1976 by R Blacklaws; subm 1976 by B C Gordon.

S-1259. KeNi-4 site, top level **405 ± 40**

Charcoal in sand (NMC-884) from top level, test bank SW end of site adjacent to water-crossing and combined with charcoal from upper level of 2nd test bank across gully, assoc flakes. Should date late Indian hunter occupation of buried horizon ca AD 1200 to 1600.

S-1260. KeNi-4 site, middle level **2545 ± 160**

Charcoal in sand (NMC-885) from middle level of 2 test banks described S-1259. Should date occupation containing chi-tho, quartzite biface knife and flakes ca AD 800 to 1400.

S-1261. KeNi-4 site, lowest level **3620 ± 125**

Charcoal in sand (NMC-886) from lowest of 3 buried occupation floors, assoc with quartzite biface knife and flakes ca AD 1 to 800.

General Comment (BCG): S-1259 late Taltheilei period, S-1260 suggests earliest Taltheilei occupation despite Early and Middle Taltheilei artifacts on surface but not found in buried horizons. S-1261 may represent early pre-Dorset or Late Shield Archaic, pre-Dorset artifacts on surface. Site appears to be hunting area for a considerable period.

S-1307. Walter Moser site, Saskatchewan **1710 ± 90**

Powdered charcoal from fire pit, Walter Moser site (EeOk-1) (50° 40′ 19″ N, 109° 47′ 34″ W). From 30cm below surface, assoc with dwelling floors, cache pits, and other habitation features in 2nd of possible 4 cultural zones. Coll 1976 by O L Malory, Paleo Sci Integrated, Winnipeg; subm 1977 by I G Dyck. *Comment* (OLM): dates 2nd occupation layer. Evidence site occupied from Oxbow and McKean periods to historic.

Meliadine—1 site, Northwest Territories

Bone from Meliadine—1 site (KfJm-3), W coast Hudson Bay (62° 53′ N, 92° 09′ W). Thule occupation ca AD 1200 to 1600. Coll 1975 and subm 1976 by U Linnamae, Univ Saskatchewan.

S-1309. Interior House 2 **410 ± 55**

Bone (caribou) from floor level.

S-1310. Interior House 1 **570 ± 55**

Bone mostly caribou from occupation layer under E wall.

General Comment (UL): acceptable dates for Late Thule.

S-1317. Meliadine—2 site, Northwest Territories **675 ± 65**

Caribou bone from Meliadine—2 site (KfJm-3), W coast Hudson Bay (62° 53′ N, 92° 09′ W). From floor level of entrance passage, House 2, Thule occupation. Coll 1975 by B Clark; subm 1976 by U Linnamae. *Comment* (UL): acceptable Thule date.

Daylight site series, Northwest Territories

Caribou bone from Daylight site (KgJm-7), W coast Hudson Bay (63° 03′ N, 92° 15′ W). Thule occupation. Coll and subm 1976 by U Linnamae.

S-1311. Interior House 3 **345 ± 85**

Bone from occupation layer.

S-1312. Interior House 3 **425 ± 225**

Bone from above occupation layer.

General Comment (UL): acceptable dates for Late Thule.

Ahmai site series, Northwest Territories

Caribou bone, some burned, from Ahmai site (KgJm-8), W coast Hudson Bay (63° 03′ N, 92° 15′ W). Thule occupation. Coll and subm 1976 by U Linnamae.

S-1313. Interior House 1 **825 ± 100**

Bone from occupation layer.

S-1314. Exterior House 1 **745 ± 90**

Bone from below sod, beside entrance passage.

General Comment (UL): acceptable dates for Thule.

Rainbow site series, Northwest Territories

Caribou bone from Rainbow site (KgJm-9), W coast Hudson Bay, NWT (63° 03′ N, 92° 15′ W). Thule occupation. Coll and subm 1976 by U Linnamae.

S-1315. Interior House 1 **285 ± 100**

Bone from occupation layer at floor level.

S-1316. Interior House 1 **345 ± 85**

Bone from below floor flags.

General Comment (UL): acceptable dates for Thule.

S-1329. Woodlawn site, Saskatchewan **875 ± 70**

Bone fragments from Woodlawn site (DgMn-6) (49° 07′ 00″ N, 102° 58′ 45″ W). From burial pit, 12cm depth, on top of prominent hill, N of Souris R. Remains of 3 individuals assoc with large conch columella (*Busycon*) pendant. Coll 1976 by P C P Hartney and E G Walker; subm 1977 by I G Dyck. *Comment* (EGW): date consistent with Woodland affiliation.

S-1330. Eastcott Flat site, Saskatchewan **2490 ± 90**

Bone fragments from Eastcott Flat site (FhNa-69) (53 18′ 30″ N, 104° 06′ W). Prehistoric occupation level at 80cm depth, deepest site of area. Coll 1976 and subm 1977 by D Meyer, Saskatchewan Research Council. *Comment* (DM): appears to be acceptable date for such a deeply buried site.

S-1331. Bushfield East site, Saskatchewan **335 ± 60**

Bone fragments from Bushfield East site (FhNa-13), near Nipawin (53° 19′ N, 104° 03′ W). From occupation level 38 to 48cm below surface. Material id as Clearwater Lake phase, widespread archaeol entity in boreal forest, N Manitoba and Saskatchewan. Coll 1976 and subm 1977 by D Meyer. *Comment* (DM): date within range of previous Clearwater Lake Phase dates of region.

III. TROPOSPHERIC RADIOCARBON SAMPLES

The ^{14}C content of wheat grown since those previously reported (R, 1962, v 4, p 78-79) and (R, 1965, v 7, p 234-235) have been determined, covering period AD 1952 to 1977. Samples grown at (1) Research Branch, Dominion Experimental Farm, Scott, Saskatchewan (52° 23′ N, 108° 50′ W) and (2) Crop Sci Dept, Univ Saskatchewan, Saskatoon (52° 27′ N, 106° 38′ W). Due to similar results, samples from Scott location discontinued after 1968 season. Changes in ^{14}C content are expressed in terms of quantity Δ (Broecker & Olson, 1961) assuming the δC^{13} value to be $-25‰$.

Sample no.	Year	Location	Δ
S-323	1964	Saskatoon	981 ± 10
S-324	1964	Scott	968 ± 10
S-325	1965	Saskatoon	776 ± 13
S-326	1965	Scott	796 ± 9
S-327	1966	Saskatoon	747 ± 9
S-328	1966	Scott	730 ± 9
S-329	1967	Saskatoon	657 ± 9
S-331	1967	Scott	713 ± 10
S-330	1968	Saskatoon	604 ± 10
S-332	1968	Scott	593 ± 11
S-333	1969	Saskatoon	543 ± 11
S-334	1970	Saskatoon	545 ± 12
S-335	1971	Saskatoon	530 ± 12
S-336	1972	Saskatoon	480 ± 12
S-337	1973	Saskatoon	455 ± 13
S-338	1974	Saskatoon	427 ± 12
S-339	1975	Saskatoon	384 ± 11
S-340	1976	Saskatoon	381 ± 6
S-341	1977	Saskatoon	341 ± 6

Comment (AR): continued decline in tropospheric ^{14}C following peak yr 1963-64 induced by nuclear tests, indicates more uniform mixing toward an equilibrium level.

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[RADIOCARBON, VOL. 21, NO. 1, 1979, P. 95-106]

SYDNEY UNIVERSITY NATURAL RADIOCARBON MEASUREMENTS V

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Experimental procedures and methods of age calculation are as previously described (Gillespie & Temple, 1976), except that BC/AD ages are not reported (resolution of 9th Radiocarbon Conference, 1976).

Interlaboratory cross checks and duplicates

Lab no.	SUA date	Other no.	Other date	Ref
SUA-191/3	860 ± 85	ANU-2007	600 ± 70	Polach (pers commun)
SUA-354/3	380 ± 80	ANU-2008	340 ± 70	Polach (pers commun)
SUA-MS24	157.0 ± 1.6% Mod	ANU-2006	154.5 ± 0.6% Mod	Polach (pers commun)

SAMPLE DESCRIPTIONS

I. GEOLOGIC SAMPLES

A. Australia

Shoalhaven Valley series

Samples coll by M A J Williams, School Earth Sci, Macquarie Univ, Australia, from late Holocene granitic colluvial slope mantles in Upper Shoalhaven catchment (35° 55′ S, 149° 37′ E).

SUA-77. 1/M101 **2110 ± 205**

Charcoal from dicotyledons, 57 ± 7cm below surface.

SUA-78. 2/M106 **3080 ± 100**

Charcoal from dicotyledons, 40 ± 5cm below surface.

SUA-79. 3/M107 **255 ± 110**

Charcoal from dicotyledons, 5 ± 2cm below surface.

General Comment (MAJW): these dates and others from same area (Gak-1627, 1628, 2022) suggest that hillslopes in S Tablelands of NSW were unstable and streams aggrading between 4000 and 1500 yr BP. Preliminary ages for these samples pub by Williams (1978).

Point Stuart series

Samples coll by M A J Williams from chenier sequence at Point Stuart, Northern Territory (12° 13′ S, 131° 52′ E).

SUA-80. D1/1 **3020 ± 85**

Littoral shell from base of sandy beach ridge overlying littoral clays, 12 to 26cm below surface.

SUA-81. D1/3 **4490 ± 90**

As above, 35 to 85cm below surface.

SUA-82. D1/5 **1725 ± 80**

As above, 35 to 65cm below surface.

SUA-82/2. D1/5 **3195 ± 85**

Individual non-cemented shells from SUA-82.

SUA-83. D1/7 **1030 ± 80**

Littoral shell from surface of active beach.

General Comment (MAJW): these chenier ridges all within 1m of present spring tide level. Dates show a late Holocene shoreline progradation of >1.4km since innermost chenier developed, and at least 0.88km since 4450 ± 85 yr BP. There is no evidence that sea level exceeded its present level in this area during last 4500 yr.

Broad Sound series

Samples coll 1972 by P J Cook, Bur Min Resources, Canberra, Australia, from Broad Sound, Queensland.

SUA-110. 71636146 **30,700 ± 1200**

Dead colonial coral from mouth of Styx R (22° 23′ S, 149° 47′ E) coll in sea water where corals no longer grow. Sample partly buried in intertidal mud, extensively recrystallized. Age regarded as minimum.

SUA-127. 71636039(S) **2950 ± 80**

Oyster shell from chenier on E side of Herbert Creek (22° 28′ S, 149° 57′ E). Ages does not fit with chenier sequence on W side of Broad Sound (Cook & Polach, 1973); significance uncertain.

SUA-128. 71636147(S) **2430 ± 80**

Shells from drill hole 7.9 to 8.5m below top of sandbank on Crocodile Banks (22° 20′ S, 149° 53′ E). Age indicates rapid offshore sedimentation in Broad Sound.

SUA-129. 7063611 **16,190 ± 225**

Carbonate nodules from sea bottom, depth 12m (22° 17′ S, 149° 44′ E.)

SUA-130. 71636147(N) **16,180 ± 440**

Re-collection of carbonate nodules from same area as SUA-129. *Comment* (PJC): carbonate nodules cover much of sea floor at N end of Broad Sound, believed to have formed within soil profile and indicate that sea level was much lower than present ca 16,000 yr BP.

SUA-126. 71636059(E) **1720 ± 80**

Wood from dead mangrove stump, partly buried in saline mud, Torilla Plain (22° 23′ S, 149° 58′ E).

SUA-131. 71636206 **1335 ± 115**

Mangrove wood, 1.8m below surface in Hoogly-Waverley Creek area (22° 21′ S, 149° 40′ E), from auger hole.

SUA-132. 71636207 **1100 ± 110**

Wood, as above, 1.8m below intertidal surface mean.

SUA-133. 71636208 **4125 ± 310**

Wood as above, 1.6 to 2m below surface, Torilla Plain (22° 25′ S, 149° 59′ E).

SUA-134. 71646209 **1110 ± 250**

Wood as above, 0.9 to 1.5m below surface.

SUA-136. 71636211 **2450 ± 210**

Wood as above, 1.8 to 2.1m below surface.

SUA-137. 71636212 **5850 ± 155**

Wood as above, 2.5m below surface (22° 25′ S, 149° 54′ E).

SUA-138. 71636213 **5785 ± 550**

Wood as above, 2.5 to 2.8 m below surface (22° 25′ S, 150° 07′ E).

SUA-139. 71636214 **6000 ± 400**

Wood from diamond drill hole (22° 28′ S, 150° 00′ E).

General Comment (PJC): samples of wood were pretreated to remove humic acids. Ages suggest that sea level stabilized ca 6000 yr BP, and since then there has been rapid seaward progradation of shoreline with varied sedimentation rates in Broad Sound.

Lake Curlip series

Organic mud samples coll by P G Ladd, Botany Dept, Univ Melbourne, Australia, from sediments in Lake Curlip, near Orbost, Victoria (37° 45′ S, 148° 35′ E).

SUA-159. LC200 **1685 ± 150**

Sample 2m below surface of swamp surrounding lake, near level of change from open water to swamp vegetation conditions according to sedimentation and pollen evidence.

SUA-160. LC1000 **5200 ± 210**

Sample from base of peat and estuarine mud core below swamp. Details of site pub (Ladd, in press).

Gulf of Carpentaria series

Marine shell samples coll by K Grimes, S Needham, and J Smart, Bur Min Resources, Canberra, Australia, from sites near Gulf of Carpentaria, N Australia. Subm by H F Doutch, same address.

SUA-183. 70795047 **5345 ± 155**

Sample from beach ridge N of Snake Creek, ca 5km inland from coast (16° 42′ S, 141° 15′ E).

SUA-184. 70795050 **850 ± 80**

Sample from beach rock anterior to youngest beach ridge, 300m from coast (16° 42′ S, 141° 12′ E).

SUA-185. 72797020 **4170 ± 90**

Sample from youngest beach ridge, W bank of Kirke R (13° 53′ S, 141° 23′ E).

SUA-197A. 72796243 **1380 ± 80**

Gasteropod shells from top of beach at Edward River Mission (14° 54′ S, 141° 37′ E).

SUA-197B. 72796243 **500 ± 75**

Bivalve shells, same site as SUA-197A.

SUA-198. 72796244 **860 ± 80**

Sample from beach ridge E of airstrip near Mission.

SUA-199. 72796245 **1030 ± 75**

Sample from beach ridge W of Mission.

SUA-200. 72796246 **3970 ± 90**

Sample from beach ridge E of Mission.

SUA-201A. 72797011 **5335 ± 85**

Gasteropod shell from oldest beach ridge on W bank of Archer R (13° 25′ 30″ S, 141° 41′ E).

SUA-201B. 72797011 **4430 ± 85**

Bivalve shell, same site as SUA-201A.

SUA-202. 72797025 **1035 ± 95**

Fragmented shell from youngest beach ridge S of Archer R mouth (13° 23′ S, 141° 38′ E).

SUA-203. 72797026 **945 ± 70**

Sample close to site of SUA-202.

General Comment (HFD): dates are acceptable in that seaward sites younger than inland beach ridges. Gasteropod and bivalve ages from same site differ for unknown reasons, with gasteropods giving ages in better agreement with other data. Sampling does not provide sufficient evidence for truncation of beach ridge sets. All ages so far $<$6000 BP, a possible date for beginning of progradation of coastline.

Mallacoota Inlet series

Anadara trapezia shells coll by P J Cook from Mallacoota Inlet, Victoria (37° 32′ S, 149° 44′ E).

SUA-231. 71636001 **1420 ± 80**

Sample from near Rangers house.

SUA-232. 71636004 **1500 ± 70**

Sample from 1.5m above present sea level.

SUA-233. 71636006 **710 ± 80**

Sample from 3m above present sea level.

General Comment (PJC): all 3 samples probably from aboriginal middens not directly related to sea level.

SUA-408. CL3/3 **2410 ± 125**

Sample of compacted organic mud with high silt content, exposed in stream entering Club Lake, Kosciusko Natl Park, N S W, (36° 25′ S, 148° 18′ 15″ E). Coll by A R H Martin, Botany Dept, Univ Sydney, Australia. *Comment* (ARHM): age expected to be >6800 yr BP date on similar material coll 20m N of present site (Gak-393). Young date possibly explained by erosion of older sediments and deposition of deltaic stream beds during last 3000 yr. Agrees reasonably with similar material dated at 1800 ± 100 (Gak-2790) from another stream entering lake at 3m higher alt.

SUA-451. Belarah 1 **130 ± 2% modern**

Peat coll by A R H Martin from 62 to 71cm below surface on Kanangra-Boyd Plateau, N S W (33° 54′ S, 180° 30′ 40″ E). *Comment* (ARHM): modern date, needs more detailed sampling for possible explanation.

SUA-433. Triangle Cliffs **3880 ± 105**

Charcoal coll by K Grimes, Geol Survey Queensland, Brisbane, Australia, from buried soil on Fraser I., Queensland (25° 02′ S, 153° 12′ E). Dates transgression of sand dunes at Triangle Cliffs which may be related to slight lowering of sea level. Relatively young age suggests tentative chronology based on correlations with Gippsland, Victoria, is in error. Provides calibration point for correlation between soil depth and age of parent sand.

SUA-505. North Pine **5200 ± 110**

Charcoal coll by D Tresize, Geol Survey Queensland, from cross-bedded sand and gravel deposits overlain by 1.2m gradational clay soil at mouth of One Mile Creek, tributary of N Pine R, S E Queensland (27° 16′ 45″ S, 152° 56′ 56″ E). Date represents lower limit for age of Strathpine terrace assoc with Pine R.

SUA-561. B12 **3890 ± 100**

Shell (*Cymbiola magnifica*) coll by A Stephens, Geol Survey Queensland, from humic sandrock outcropping 0.63m below mean sea level on W side of Bribie I., Queensland (26° 49′ 15″ S, 153° 07′ 45″ E). Date is maximum for sandrock formation at this level.

Victorian coast series

Marine shell coll by E D Gill, Natl Mus Victoria, Melbourne, as part of continuing study of coastal processes.

SUA-87. 1972/7 **1350 ± 80**

Opercula of *Subninella undulata* shells from midden on Cape Reamur (38° 23′ S, 142° 08′ E).

SUA-88. 1972/8 **3115 ± 85**

Limpet shells from midden on beach W of Goose Lagoon, near Port Fairy (38° 24′ S, 142° 11′ E).

SUA-89. 1972/9 **2650 ± 85**

Limpet shells from midden on Cape Reamur (38° 23′ S, 142° 09′ E).

SUA-90. 1972/10 **1075 ± 80**

Shells from midden overlying boulder bed near Apollo Bay (38° 27′ S, 144° 05′ E).

SUA-191. 1973/7 **1020 ± 80**

Shell from midden in small cave at E end of boulder bed at Point Castries (38° 30′ S, 144° 02′ E).

General Comment (EDG): dates from middens fall into several groups thought to be related to coastal processes rather than intermittent occupation.

SUA-186. 1973/2 **5525 ± 100**

Marine still-water facies shells from black silt 1.7m above low water level, near Spring Creek, Torquay (38° 21′ S, 144° 20′ E). Dates Flandrian transgression at this site.

SUA-187. 1973/3 **2920 ± 80**

Shell *Subninella undulata* from slightly emerged boulder bed, same site as SUA-191. Other evidence of this emergence at Port Fairy dated 2840 BP (Gak-3917).

SUA-188. 1973/4 **1275 ± 89**

Shell from vegetated shell grit flat, W side of Cape Reamur (38° 24′ S, 147° 05′ E).

SUA-189. 1973/5 **1495 ± 80**

Shell from vegetated shell grit flat, E side of Cape Reamur, as for SUA-188, 100 to 112cm below surface.

SUA-190. 1973/6 **995 ± 80**

Shell, 15 to 24cm below surface, same site as SUA-189. Although result of high energy beach, these flat, slightly emerged terraces increase in age with depth.

Western Victoria volcanic series

Samples coll by E D Gill, Natl Mus Victoria, Melbourne, from volcanic sequence near Lake Weeranganuck (38° 12′ S, 143° 17′ E).

SUA-266. 1973/8 **11,980 ± 200**

Pedogenic carbonate modules from soil on top of clay dune.

SUA-267C. 1973/9 **4915 ± 105**

Carbonate from bones of extinct marsupials in lacustrine sediments underlying dune of SUA-266 (*cf* GS-152, 6435 BP).

SUA-267P. 1973/10 **11,160 ± 380**

Acid insoluble residue from bones of extinct marsupials, same as SUA-267C.

General Comment (EDG): dating of this sequence still unresolved, since *Coxiella* sp shells from same bed as bones gave date, 25,300 BP (Gak-986).

SUA-268. 1973/11 **7810 ± 115**

Pedogenic carbonate in ejectamenta from Red Rock volcanic complex near Albie (38° 15′ S, 143° 30′ E). *Comment* (EDG): date agrees with geomorphologic estimate, may be compared with similar volcanics at Tower Hill (7500 BP) and Lake Condah (6240 BP).

Western N S W series

Samples coll by R J Wasson, Dept Biogeog & Geomorphol, ANU, Canberra, as part of study on alluvial fan stratigraphy.

SUA-166. Dillon Creek **4560 ± 95**

Charcoal fragments embedded in youngest alluvium on surface of small alluvial fan on W side of Belarabon Range, SW of Cobar (31° 59′ S, 144° 53′ E).

SUA-279. Belarabon 2 **27,900 ± 1100**

Soil carbonate nodules from palaeosol developed in top of small alluvial fan, same site as SUA-166.

SUA-282. Eldee 1 **5080 ± 1060**

Charcoal fragments in base of youngest alluvium on Eldee fan, W side of Barrier Range (31° 40′ S, 141° 08′ E).

SUA-284. U Fan 2 **16,500 ± 260**

Carbonate nodules from palaeosol developed in upper part of oldest alluvium exposed in Umberumberka Fan, W side of Barrier Range (31° 49′ S, 141° 06′ E).

Naracoorte series

Samples coll by F S Aslin and N S Pledge, South Australian Mus, Adelaide, from Henschke's Cave, near Naracoorte (36° 59′ S, 140° 46′ E).

SUA-140. A3 **>35,000**

Dispersed charcoal fragments from silt deposit containing bones of living and extinct species, 105 to 120cm below surface near base of deposit in Area A3.

SUA-234. A1 **$33{,}800^{+2400}_{-1850}$**

Charcoal from 30 to 75cm below surface in Area A1, assoc with extinct fauna, including new species of giant mallee fowl (*Progura naracoortensis*) (van Tets, 1974).

General Comment (NSP): dates correspond to apparent transitional climatic episode as indicated by fossil assemblage, which shows combination of humid/forest and arid environment animals. Excavations continuing to identify faunal changes related to climate.

Skull Cave series

Samples coll by J K Porta, subm by A Baynes, Western Australian Mus, Perth, from cave in dune limestone near Augusta, W A (34° 17′ S, 115° 06′ E).

SUA-227. **2885 ± 85**

Charcoal from 21 to 28cm below surface.

SUA-228. **7865 ± 115**

Charcoal from 100 to 115cm below surface.

General Comment (AB): dates show deposit spans large proportion of Holocene, SUA-227 dates last survival of *Pseudomys albocinereus* in this district and arrival of *Rattus tunneyi*.

B. Irian Jaya

Carstenz series

Samples coll by J A Peterson, Dept Geog, Monash Univ, from basins below glaciers in Carstenz region (4° 04′ 58″ S, 137° 09′ 48″ E), to check for limestone dilution effect.

SUA-287A. CGE12A **102.5 ± 1.0% modern**

Living algae from pond in granite rock basin.

SUA-287B. CGE12B **112.4 ± 0.9% modern**

Living wood from stems of *Caprosma* sp, same site as SUA-287A.

SUA-289A. CGE14A **133 ± 2% modern**

Living algae from limestone basin pond.

SUA-289B. CGE14B **155 ± 2% modern**

Living wood from stems of *Caprosma* sp.

General Comment (JAP): samples all show bomb effect so that incorporation of limestone carbonate should not be a problem. Spread of activities probably related to biologic age of samples. Supports dates obtained on these materials (Gillespie & Temple, 1976; Gillespie, 1976).

II. ARCHAEOLOGIC SAMPLES

A. Australia

Ord Valley series

Samples coll by C E Dortch, Western Australian Mus, from Miriwun rock shelter, now permanently inundated by Lake Argyle (16° 18′ S, 128° 42′ E). Other dates in this series SUA-54-58; ANU-1129, 1130; Gak-1767, 1768.

SUA-141. B2084 **1675 ± 185**

Charcoal from depth 28 to 46cm in upper part of shelter, deposit containing diverse faunal remains and point and blade artifact assemblage typical of Ord Valley late stone industrial phase.

SUA-142. B2087 **2980 ± 95**

Charcoal from depth 50 to 70cm in central part of deposit, containing stratigraphically uppermost assemblage of Ord Valley early phase artifacts and diverse food remains. Date regarded as minimal for early phase assemblage, which is similar to that of basal layer dated at 17,980 ± 1370 yr BP (ANU-1008).

Macleay River series

Samples coll by G Connah, Dept Prehistory, Univ New England, Armidale, from aboriginal midden "Clybucca 3" in lower Macleay Valley (30° 56′ S, 152° 55′ E).

SUA-274. CLY 3.72.56 **3360 ± 115**

Charcoal 30 to 40cm below modern surface.

SUA-275. CLY 3.72.102 **4260 ± 120**

Charcoal 60 to 70cm below surface.

SUA-276. CLY 3.72.112 **5120 ± 145**

Charcoal 90 to 110cm below surface.

General Comment (GC): midden composed mainly of oyster and cockle shells, formed over sand ridge at head of bay in Pleistocene shoreline, 10km inland from present shoreline. Assoc cultural material comprised backed blade industry with minor worked bone. Dates may be compared with one from "Clybucca 1" midden on same shoreline of 3850 ± 140 (Gak-2457).

Swansea Channel series

Samples coll by L K Dyall, Dept Chemistry, Univ Newcastle, from shell midden between Lake Macquarie and Pacific Ocean (33° 06′ S, 151° 40′ E).

SUA-322. Swanch 3 **2080 ± 100**

Charcoal assoc with cremated skeleton in midden.

SUA-421. Swanch 4 **7530 ± 140**

Charcoal from occupation level 24 to 29cm below modern surface of midden. *Comment* (LKD): surprisingly early date for level containing backed blade industry. Other dates from this site SUA-150 and -238 (Gillespie & Temple, 1976).

Sandstone Point series

Samples coll by L Haglund, Dept Anthropol, Univ Sydney, from complex of middens on Sandstone Point, S E Queensland (27° 05′ S, 153° 07′ E).

SUA-478. 42/G3 **620 ± 95**

Charcoal from black, loose midden deposit containing crushed shell and fish vertebrae, below white layer probably due to lime burning that destroyed upper part of midden.

SUA-479. 42/G3b **780 ± 95**

Charcoal from base of midden, contains whole shells.

General Comment (LH): size and depth of middens with complex stratigraphy unique in this area.

Bribie Island series

Samples coll by Haglund from W beach on Bribie I., S E Queensland (27° 02′ S, 153° 07′ E).

SUA-480. S3/C50b **450 ± 95**

Charcoal from top of midden deposit.

SUA-481. S3/C50d **670 ± 95**

Charcoal from base of midden, 25cm below SUA-480.

General Comment (LH): similar age of formation to Sandstone Point series above, lithic material of pebble tools and working edges with use-polish typical.

Walyunga series

Samples coll by R H Pearce, Dept Anthropol, Univ Western Australia, from partly vegeated dune in Walyunga Natl Park (31° 44′ 20″ S, 116° 03′ 42″ E).

SUA-508. C18-14 **3220 ± 100**

Charcoal from 60cm below surface, postdates end of regular use of Bryozoan chert. Distinct change in technology toward regular use of backed blades.

SUA-509. C18-19 **6135 ± 160**

Charcoal from 90cm below surface, related to conclusion of period with no major technology change, Bryozoan chert readily available.

SUA-510. C18-32 **8000 ± 260**

Charcoal from 160cm below surface, dates 1st occupation at this site.

SUA-632. C18-4-100 **1330 ± 100**

Charcoal from 20cm below surface, predates dense, possibly eroded, artifact horizon.

SUA-633. C18-17-36 **4560 ± 150**

Charcoal from 76 to 79cm below surface, predates regular use of mylonite and introduction of flat adze, latest use of Bryozoan chert.

General Comment (RHP): dates suggest source of chert was cut off by rising sea level (Pearce, 1977).

B. Pacific Islands

Santa Cruz series

Samples coll by R C Green, G Hendron and G Ward, Dept Anthropol, Univ Auckland, N Z, from islands in Santa Cruz group.

SUA-111. BS-Sz-8:C-2 **3250 ± 70**

Shells from 45 to 60cm below surface at Nanggu village, Nendok (10° 45′ S, 166° 10′ E). Date agrees with estimates based on Lapita sites elsewhere in Oceania, pottery thought to be early Lapita tradition.

SUA-112. BS-Sz-8:C-3 **3140 ± 70**

Shells from 40 to 60cm below surface in another part of same deposit as SUA-111, supports above interpretation.

SUA-113. BB-8-1-C-1 **2860 ± 250**

Charcoal from fire pit in coralline sand under rock shelter on Santa Ana I. (10° 50′ S, 162° 31′ E). Very small sample subm in support of SUA-114, below.

SUA-114. BB-8-1, Sq 51, 52 **3050 ± 70**

Shell, same site as SUA-113. Date suggests earlier estimate for pottery-bearing layer on Santa Ana (I-2878) may have represented stratigraphically mixed sample. Charcoal date SUA-113 confirms reliability of this shell date.

SUA-115. BS-DL-1:C-1 **500 ± 65**

Charcoal from 116cm below surface of rock shelter on Kolua (9° 57′ S, 167° 15′ E). Date is reasonable for earlier use of shelter located on only landing beach on this island.

SUA-116. BS-DT-2:VV-53 **530 ± 65**

Charcoal from oven at top of old beach line at Kahula village, Taumoko I. (9° 57′ S, 167° 13′ E). Earth oven 40m from present beach line, covered by waterlaid sand containing pumice.

SUA-117. BB-2-7-C-44 **380 ± 60**

Charcoal from 156 to 158cm below surface in trench near Su'ena, W Ugi I. (10° 15′ S, 162° 45′ E). Unexpectedly late date when compared with I-6175.

SUA-230. BB-2-7-SS-44 **400 ± 80**

Charcoal from 116cm below surface, same site as SUA-117. Check date agrees with SUA-117 and casts doubt on earlier date for stratigraphically higher sample, I-6175.

SUA-118. BS-Uw-1:2 **1200 ± 60**

Charcoal from oven at Haradewi, NE Ulawa (9° 45′ S, 161° 55′ E). Hamlet-type occupation assoc with chert working and shell ornaments.

SUA-119. BS-Uw-1:3 **940 ± 60**

Charcoal from oven rakeout/midden, same location as SUA-118. Evidence for fishing and shell fishing, hamlet is in center of stone-walled garden complex.

SUA-120. BS-Uw-69:5 **170 ± 55**

Charcoal from oven rakeout/midden at Ewewa, W Ulawa (9° 45′ S, 161° 55′ E). Site is low mound on coastal platform, assoc with intensive chert usage.

SUA-121. BS-Uw-69:6 **250 ± 50**

Charcoal from same site as SUA-120, showing faunal evidence suggesting smaller range of exploited environmental zones. Details of these sites pub by Green and Cresswell (1976).

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[RADIOCARBON, VOL. 21, NO. 1, 1979, P. 107-112]

UNIVERSITY OF MIAMI RADIOCARBON DATES XIV

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The following radiocarbon dates are a partial list of samples measured since January 1978. The chemical, counting and calculation procedures are the same as indicated in R, v 20, p 000-000.

SAMPLE DESCRIPTIONS

I. ARCHAEOLOGIC SAMPLES

A. Bahamas

Bimini Atlantis series

Carbonate rock samples, postulated rd bldg material of lost civilization Atlantis (Harrison, 1971; Shinn, 1977) dated as whole rock and in separated components of shell material and cement, to determine maximum age of "road-like" formation. Cores from blocks —4.6m, oriented parallel to and ca 10km from W Bimini shoreline (26° 0′ N, 77° 30′ W). Coll 1977 by E Shinn, USGS, Fisher Island Sta, Miami, Florida, and subm 1978 by D Drevitson, Univ Miami. Samples id by depth in core.

UM-1359. F(a) 4 to 6 cm, whole rock **2780 ± 70**

UM-1360. F(b) 15.5 to 17cm, whole rock **3500 ± 80**

UM-1361. F(c) 27.5 to 29cm, whole rock **3350 ± 90**

UM-1362. H, shells **3510 ± 70**

UM-1363. B 0 to 5cm, cement **2750 ± 80**

UM-1364. B 12.9 to 16.8cm, cement **2770 ± 80**

UM-1365. B 24.7 to 29.8cm, cement **2840 ± 70**

B. United States

Granada series

Shell and charcoal from prehistoric Indian midden at mouth of Miami R on N bank (25° 46′ 37″ N, 80° 11′ 32″ W) dated site. Coll 1978 by C Martinez, Bur Hist Sites & Properties, Tallahassee, Florida and subm by J Mattes, Univ Miami. *Comment* (P Calvert): external and internal portions of shells (*strombus gigas*) processed separately in conjunction with x-ray defraction analysis to study effects of possible recrystallization in samples.

UM-1366. FS-198-Ch **1740 ± 90**
$\delta^{13}C = -25.56‰$

Charcoal from 60 to 75cm below ground surface.

UM-1367. Duplicate run UM-1366 **1260 ± 70**

UM-1368. FS-198-sh **1600 ± 90**
$\delta^{13}C = +1.41‰$

Internal portion of shell found with UM-1366 and -1367 60 to 75cm below ground surface.

UM-1369. External portion UM-1368 **1590 ± 90**
$\delta^{13}C = +1.89‰$

UM-1371. Duplicate run UM-1369 **1490 ± 250**

UM-1372. Duplicate run UM-1368 **1380 ± 100**

UM-1373. FS-87-sh **1720 ± 70**
$\delta^{13}C = -0.66‰$

External portion of shell 135 to 150cm below ground surface.

UM-1374. Internal portion UM-1373 **1870 ± 90**
$\delta^{13}C = -0.54‰$

UM-1370. FS-87-Ch **1780 ± 100**
$\delta^{13}C = -25.53‰$

Charcoal found with UM-1373 and -1374, 135 to 150cm below ground surface.

Kenan Field series

Three carbonized wood samples and one carbonized marine shell sample from Kenan Field, Sapelo I., Georgia (NGR 473500E, 348000N). Coll 1977 by M R Crook, Florida State Mus and subm 1978 by M R Crook and J T Milanich, Florida State Mus, Gainesville, Florida.

UM-1388. FOA3 r (49) **970 ± 60**
$\delta^{13}C = -25.60‰$

Carbonized wood from probable earth oven that was later used as refuse pit.

UM-1389. Fea. 219 (51) **1660 ± 70**
$\delta^{13}C = -25.52‰$

Carbonized wood from hearth that preceded construction of wall trench assoc with Structure 2.

UM-1390. FEA 108 (53) **790 ± 70**

Carbonized oyster shell from hearth assoc with Structure 1. Sample is from uppermost undisturbed level 25cm below surface.

UM-1391. FEA 109 (54) **1200 ± 60**
$\delta^{13}C = -26.64‰$

Carbonized wood from a probable post hole assoc with construction of Structure 1.

Kings Bay series

Several carbonized wood and oyster samples from Feature 2 and Feature 4 pits located at King's Bay Naval facility, Comden Co, Georgia

(NGR 340600mN, 451000mE). Coll and subm 1978 by R Johnson, Univ Florida, Gainesville. *Comment* (DI): UM-1429 and -1430 are from Feature 4, a trash pit, ca 60 to 62cm below ground surface. UM-1431, -1433 are from Feature 2, hearth 24cm below present ground surface assoc with numerous sherds of fiber-tempered ceramic vessel(s).

UM-1429. Fea. 4 FS #116, KBS 12 **2330 ± 180**
$\delta^{13}C = -26.89‰$

Carbonized wood.

UM-1430. Fea. 4 FS #116a, KBS 12 **980 ± 70**

Oyster shell.

UM-1431. Fea. 2 FS #62, KBS 12 **1330 ± 60**

Oyster shell.

UM-1432. Fea. 2 FS #56, KBS 8 **5000 ± 180**
$\delta^{13}C = -27.99‰$

Carbonized wood.

UM-1433. Fea. 2 FS #60, KBS 8 **4260 ± 100**
$\delta^{13}C = -25.54‰$

Carbonized wood.

Welborn series

Three charred *Pinus* samples from Florida Archeol Site 8 Co 17 in W Columbia Co, Florida, ca 4km E of Welborn, Florida (30° 13′ 26″ N, 82° 46′ 15″ W). Coll and subm 1978 by J T Milanich.

UM-1434. FS 956-A **1460 ± 70**
$\delta^{13}C = -26.04‰$

Dates Mound C and Kolomoki-style pedestaled effigy vessels in N Florida.

UM-1435. FS 1094-A **1720 ± 80**
$\delta^{13}C = -25.80‰$

Dates Mound A and late proto-chiefdom level of social organization at site.

UM-1436. FS 1022-A **1470 ± 70**

Dating required for clarification of Mound C position.

UM-1395. Chaco River **1910 ± 90**
$\delta^{13}C = -23.92‰$

Carbonized wood from Late Basketmaker III pithouse site on Chaco R in NW New Mexico (36° 07′ 03″ N, 108° 11′ 12″ W). Material taken from undisturbed hearth ca 2m below site surface. Coll and subm 1977 by W H Doleman, Mus New Mexico, Santa Fe.

II. GEOLOGIC SAMPLES

A. SE Pacific

E Pacific Rise series

Foram and diatom ooze from E Pacific Rise and Bellinghausen abyssal plain, dated to study sedimentation rate since last glaciation. All samples from SE flank of E Pacific Rise unless stated otherwise and id by depth in core. Coll 1978 by M Dinkelman, Florida State Univ, Tallahassee, and subm 1978 by P Sahler, Univ Miami.

UM-1375. E17-30, 36 to 38cm **15,730 ± 580**

Core from NE Bellinghausen Abyssal Plain (58° 09″ S, 94° 49″ W) from water depth 627m.

UM-1376. PC-E-2, 20 to 22cm **6560 ± 250**

Core (56° 3′ 30″ S, 115° 3′ 42″ W), water depth 518m.

UM-1377. PCE32-22, 13 to 15cm **6920 ± 100**

Core (54° 56′ 12″ S, 120° 00′ W), water depth 457m.

UM-1378. PCE33-22, 27 to 29cm **8380 ± 200**

Core (54° 56′ 12″ S, 120° 00′ W), water depth 457m.

UM-1379. PCE33-22, 66 to 69cm **21,370 ± 420**

Core (54° 56′ 12″ S, 120° 00′ W), water depth 457m.

UM-1380. PCE11-2, 45 to 47cm **10,010 ± 380**

Core (56° 03′ 30″ S, 115° 03′ 42″ W), water depth 518m.

UM-1381. PCE11-3, 18 to 20cm **9570 ± 300**

Core (56° 54′ 12″ S, 115° 14′ 36″ W), water depth 671m.

B. South America

Surinam series

Shell, shell fragment and peat debris from Surinam. Dated to reconstruct Holocene depositional sequence on shoreline. Coll 1977 and subm 1978 by J Rine, Univ Miami, Fisher Island, Miami Beach, Florida.

UM-1406. S-XI: 1139 to 1264cm **7060 ± 100**
$\delta^{13}C = -27.95‰$

Loose peat debris from peaty mud (55° 30′ 15″ W, 05° 49′ 00″ N). Coll from core 15km from present shoreline.

UM-1407. S-Transect: Beach **109.0% mod**

Chione, Crassotrea from active beach (55° 31′ 30″ W, 05° 59′ 40″ N).

UM-1408. P-13: 50 to 95cm **2320 ± 80**

Core containing bivalves from near base of relict beach ridge (55° 12′ 30″ W, 05° 51′ 30″ N).

UM-1409. P-10: 200 to 230cm **1730 ± 120**

Core containing *Chione, Tellin* and unknown shell fragments from base of quartz sand beach sequence on relict beach ridge (55° 11′ 00″ W, 05° 53′ 10″ N).

C. United States

Card Sound series

Peat samples from 30m wide fringing red mangrove stand along Card Sound (25° 20′ 35″ N, 80° 20′ 00″ W), Florida as part of study (R, v 20, no. 3, p 511-512) of effects of peat deposits on underlying limestone. Sample id by depth below ground surface. Coll 1978 by J Meeder, D Introne, and V Skinner, Univ Miami and subm by V Skinner.

UM-1339. Core-1, 19 to 25cm **1630 ± 70**
$\delta^{13}C = -25.02‰$

UM-1340. Core-1, 172 to 187cm **4830 ± 90**
$\delta^{13}C = -25.18‰$

UM-1341. Core-2, 28 to 36cm **900 ± 70**
$\delta^{13}C = -24.71‰$

UM-1342. Core-2, 141 to 147cm **4830 ± 70**
$\delta^{13}C = -26.12‰$

UM-1343. Core-3, 26 to 32cm **500 ± 60**
$\delta^{13}C = -26.44‰$

UM-1344. Core-3, 84 to 90cm **3300 ± 60**
$\delta^{13}C = -26.19‰$

UM-1345. Core-3, 165 to 173cm **5240 ± 80**
$\delta^{13}C = -26.52‰$

Oak Island series

Peat and wood samples dated to study ancient lagoonal environment on North Carolina shoreline, Oak I. (33° 53′ 30″ N, 78° 00′ 07″ W). Coll and subm 1978 by W Cleary, Univ North Carolina, Wilmington.

UM-1354. Oak Island-1 **1440 ± 70**
$\delta^{13}C = -26.82‰$

Peat from exposed face on Yawpow Beach near high tide line.

UM-1355. Oak Island-2 **500 ± 60**
$\delta^{13}C = -28.11‰$

Peat from intertidal zone of beach face below Long Beach pond.

UM-1356. Oak Island-3 **1300 ± 70**
$\delta^{13}C = -26.87‰$

Peat from within Long Beach pond.

UM-1357. Oak Island-4 **1410 ± 80**

Wood from stump forest Caswell beach.

D. Caribbean

UM-1394. Green Cay Boring **4050 ± 90**

Coral boring taken 25m below sea level from Tongue of Ocean in vicinity of Green Cay, Bahamas (24° 04′ N, 77° 10′ W). Sample taken to calibrate facies anatomy on leeward margin of carbonate platform. Coll 1976 by drilling contractor for Univ Miami, Fisher I., Miami Beach, Florida.

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[RADIOCARBON, VOL. 21, No. 1, 1979, P. 113-119]

VIENNA RADIUM INSTITUTE RADIOCARBON DATES VIII

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Measurements have continued with the same proportional counter system, pretreatment procedure, methane preparation and measurement, and calculation, as described previously (R, 1970, v 12, p 298-318). Uncertainties quoted are single standard deviations originating from standard, sample, background counting rates and half-life. No $^{13}C/^{12}C$ ratios were measured.

Sample descriptions have been prepared in cooperation with submitters.

ACKNOWLEDGMENTS

I express my thanks to Ing L Stein for excellent work in sample preparation, and to K Flandorfer for careful operation of the dating equipment.

SAMPLE DESCRIPTIONS

I. GEOLOGIC, GLAZIOLOGIC, LIMNOLOGIC, AND FOREST SAMPLES

A. Austria

Strobl series, OÖ

Clay gyttja, transition from clay to peat development, from base of bogs in Strobl area, Upper Austria. Coll 1974 and subm by D van Husen, Inst Geol, TU Vienna. Clay eliminated by HCl and HF pretreatment; no NaOH pretreatment was given.

General Comment (DvH): date is min for ice retreat in area and dates beginning of organic sedimentation.

VRI-429. Wirling **10,210 ± 150**

Bog between drumlins, W Wirling (47° 43′ 38″ N, 13° 42′ 48″ E).

VRI-431. Moosalm **12,520 ± 180**

Bog in rock depression, W Moosalm (47° 45′ 57″ N, 13° 29′ 07″ E). *Comment* (DvH): dates tundra phase established by palynology.

VRI-430. Plakner **12,410 ± 190**

Bog between drumlins NW farm Plakner (47° 43′ 37″ N, 13° 30′ 42″ E).

VRI-432. Bad Goisern, OÖ **11,970 ± 200**

Clay gyttja, transition from clay to peat development, from base of bog lying within end moraine ramparts NNE farm Sperrer (47° 37′ 12″ N, 13° 37′ 30″ E), near Bad Goisern, Upper Austria (D van Husen, 1973). Coll 1974 and subm by D van Husen. Clay eliminated by HCl and HF pretreatment; no NaOH pretreatment. *Comment* (DvH): dates cold phase established by palynology and min is age for ice retreat in area.

VRI-486. Mt Dachstein, OÖ **11,490 ± 290**

Gyttja from clay/bog transition in depth of 1.70 to 1.75m bog on Gjaidalm (47° 31′ 03″ N, 13° 40′ 05″ E), Mt Dachstein plateau, Upper Austria. Coll 1975 and subm by D van Husen. Clay separation by HCl and HF pretreatment, no humic acids separation. *Comment* (DvH): dates beginning of bog growth and change to warm climate.

VRI-488. Bad Goisern, OÖ **9880 ± 140**

Peat in depth 3.15 to 3.25m of bog near farm Sperrer (47° 37′ 12″ N, 13° 37′ 30″ E), Bad Goisern, Upper Austria. Coll 1975 and subm by D van Husen. No humic acids separation. *Comment* (DvH): dates climatic deterioration palynologically detected.

VRI-491. Donnerau, OÖ **12,220 ± 140**

Peat from depth 6.10 to 6.20m, 10cm above base of bog, Donnerau near Neustift (48° 29′ N, 14° 52′ E), Upper Austria. Coll 1974 and subm by J Draxler, Geol BA, Vienna. No humic acids extraction. *Comment* (JD): dates beginning of peat growth.

Halldorf series, Salzburg

Wood and peat remnants in form of peat rubbles excavated from artificially opened (ballast-pit) terrace system (Slupetzky, 1975) in valley of R Salzach, Halldorf (47° 21′ N, 13° 11′ E) near St Johann im Pongau, Salzburg. Coll 1974 and subm by H Slupetzky, Geog Inst, Univ Salzburg. *General Comment* (HS): helps explain origin of finds.

VRI-444. Halldorf 1 **>36,500**

Peat rubble in sand layer (Slupetzky, 1975) ca 50cm thick, 8m below level.

VRI-449. Halldorf 2 **32,000 ± 1200**

Wood (*Juniperus* com), 2m above sand layer of Halldorf 1. No NaOH pretreatment.

VRI-489. Halldorf B9 **31,600 ± 1000**

Peat rubble in sand layer of Halldorf 1.

VRI-452. Halldorf 19D **$35{,}500^{+2600}_{-2000}$**

Wood in sand layer of Halldorf 1.

Schwarzach series, Salzburg

Wood (*Juniperus*) from basal complex of opening, ca 8m deep, in terrace of R Salzach (Slupetzky, 1975), near Schwarzach (47° 20′ N, 13° 10′ E), Pongau, Salzburg. Basal complex, differently colored sand and clay zones ca 20cm thick, lying on gravel, overlain by banded clay ca 5m thick followed by ca 3m gravel. Coll 1973 and subm by H Slupetzky.

General Comment (HS): dates basal complex.

VRI-407. Schwarzach 1/4 **12,740 ± 310**

Joined Samples 1 and 4 coll 3m apart in same horizon between underlying reddish-brown and overlying gray fine sand from lowest part of basal complex.

VRI-453. Schwarzach 3 **12,840 ± 250**

Sample 3, site similar to VRI-407 in lowest part of basal complex.

VRI-454. Schwarzach 10 **12,500 ± 170**

Sample 10 in upper part of basal complex.

VRI-483. Salzburg, Salzburg **9990 ± 150**

Wood from bog layer 50 to 70cm thick above mud sediment of dammed up lake, overlain by 2m material. Salzburg-City, Riedenburg (47° 48′ 00″ N, 13° 02′ 30″ E), Salzburg. Coll 1975 and subm by G Horninger, Geol Inst, TU Vienna. *Comment* (GH): dates bog growth, gives min age for end of mud sedimentation.

Neumarkt series, Steiermark

Peat of bog Dürnberger-Moos (47° 05′ 53″ N, 14° 21′ 29″ E), near Neumarkt, Styria. Coll 1973 and subm by E Schultze, Limnolog Inst österr Akad Wiss, Vienna.

General Comment (ES): dates events in pollen diagram. No NaOH pretreatment (HF).

VRI-415. 130-145cm **9940 ± 140**

Terrestric grass peat 130 to 145cm above base. *Comment* (ES): dates rise of spruce.

VRI-416. Base **11,840 ± 170**

Carex peat from base. *Comment* (ES): dates oscillation of *Pinus* cembra curve at beginning of reforestation.

VRI-433. Kainisch, Steiermark **12,220 ± 180**

Clay gyttja, transition from clay to peat development, from base of bog between Kame terrace and end moraine rampart NNW Lake Ödensee (47° 34′ 08″ N, 13° 49′ 36″ E), near Kainisch, Styria (van Husen, 1973). Coll 1974 and subm by D van Husen. *Comment* (DvH): dates cold phase palynologically recognized and gives min age for ice retreat in area.

Bad Mitterndorf series, Steiermark

Samples from bog near Rödschitz (47° 33′ 40″ N, 13° 54′ 50″ E) near Bad Mitterndorf, Styria. Coll 1975 and subm by D van Husen.

General Comment (DvH): dates palynologically detected climatic events.

VRI-484. Rödschitz 7.05-7.20m **15,400 ± 470**

Organic material in clay below bog, depth 7.05 to 7.20m. Pretreatment with HCl and HF for clay elimination only. *Comment* (DvH): dates climatic amelioration between 2 cold phases.

VRI-485. Rödschitz 5.39-5.40m **12,440 ± 420**

Peat from thin peat layer on clay, depth 5.39 to 5.40m. No NaOH pretreatment. *Comment* (DvH): dates beginning of strongly marked warm phase.

VRI-490. Hohentauern, Steiermark **30,700 ± 1000**

Mud in depth 105 to 106m below thick moraine at road ca 2km SW village Hohentauern, ca 100m W shelter Draxler Hütte (47° 25′ N, 14° 28′ E), Styria. Coll 1973 by E Clar from core of borehole 1/73 drilled by STEWEAG, subm by I Draxler, Geol BA, Vienna. *Comment* (ID): according to stratigraphy and pollen analysis a Würm interstadial is expected.

VRI-542. Schladming, Steiermark **30,700 ± 1200**

Peat coal between clay horizons in pre-Würm deposited Ramsauschotter. Compressed bog remnants slightly carbonized. Schladming (47° 23′ 47″ N, 13° 38′ 18″ E), Styria. Coll 1975 and subm by D van Husen. No humic acids separation. *Comment* (DvH): clue to chronology of Ramsauschotter.

Reith series, Tirol

Samples from bog Zotensenk (47° 25′ 21″ N, 11° 52′ 35″ E), 550m asl, near Reith near Brixlegg, Tyrol. Coll 1973 by G Patzelt and S Bortenschlager subm by G Patzelt, Geog Inst, Univ Innsbruck. No NaOH pretreatment.

VRI-422. Zotensenk 821-830cm **12,440 ± 160**

Organic material in clay, depth 821 to 830cm. *Comment* (GP): min age for late glacial ice retreat in area. Palynologic evidence and stratigraphic location point to older age.

VRI-423. Zotensenk 795-798cm **12,770 ± 150**

Clay gyttja in depth 795 to 798cm. Comment (GP): dates palynologically detected reforestation in area.

VRI-455. Stubaital, Tirol **7550 ± 120**

Peat from base of 139cm deep bog near shelter Dresdner Hütte (46° 56′ 48″ N, 11° 08′ 38″ E), 2300m asl, Stubai valley, Tyrol. Coll 1974 by S Bortenschlager, subm by G Patzelt. *Comment* (GP): dates beginning of organic sedimentation and gives min age for ice retreat in area.

B. Italy, Yugoslavia, Saudi Arabia

VRI-472. Fusine, Italy **8360 ± 220**

Carex peat with wood remnants in depth 115 to 123cm from bog near Fusine (46° 29′ 12″ N, 13° 40′ 30″ E), Weissenfelser saddle, Julian Alps, Italy. Coll 1975 and subm by F Kral. *Comment* (FK): dates warm period (Boreal) palynologically detected by raised values for fir, beech and woods characterized by oak.

Koprivna series, Yugoslavia

Eriophorum-carr peat from different depths of *Pinus* mugo-raised bog Zadnji travniki above Koprivna (46° 27′ 40″ N, 14° 41′ 20″ E), Eastern Karawanken, Yugoslavia. Coll 1974 by A Šercelj, subm by F Kral, Univ Bodenkultur, Vienna.

General Comment (FK): dates palynologically detected events.

VRI-469. 78-90cm **3170 ± 90**

Peat with remnants of wood from depth 78 to 90cm. *Comment* (FK): change from spruce-fir wood to spruce-fir-beech wood. Sub-Boreal, as expected.

VRI-470. 150-158cm **5960 ± 100**

Peat with clay from depth 150 to 158cm. *Comment* (FK): change from spruce wood to spruce-fir wood followed by less marked hazel max. Putting sample into older Atlanticum, because of retarded hazel max in SE Alps, date is too young for some hundred yr. Possible contamination by rootlets?

VRI-503. Wadi Birk, Saudi Arabia **2170 ± 130**

Charcoal particles in sand from several cm thick burning horizon ca 1m below surface of fluvial terrace (23° 25′ N, 46° 47′ E), Wadi Birk, Saudi Arabia. Coll 1975 by Hötzl, subm by J Zötl, Inst Hydrogeol, TU Graz. *Comment* (JZ): gives max age for overlying sediments of presumedly aeolian origin.

II. ARCHAEOLOGIC, HISTORIC SAMPLES

A. Austria

Keutschach, series, Kärnten

Wood from lake bottom. Coll 1974 by Bundesdenkmalamt, Abt f Bodendenkmalpflege, Vienna, subm by H Offenberger.

General Comment (HO): remnants of lake-dwellings.

VRI-438. Hafnersee II **4460 ± 100**

Sample (1193 % moisture) coll 30m off shore in depth ca –3m in Lake Hafnersee (46° 35′ 10″ N, 14° 08′ 00″ E), Carinthia.

VRI-439. Keutschachersee I **4900 ± 100**

Sample (847 % moisture) coll 30m off shore in depth ca –3m in Lake Keutschachersee (46° 35′ 10″ N, 14° 09′ 30″ E), Carinthia.

VRI-440. Keutschachersee II **5170 ± 150**

Sample (931 % moisture) coll 30m off shore in depth ca –3m in Lake Keutschachersee.

Böheimkirchen series, NÖ

Charcoal from excavations, Böheimkirchen (48° 12′ N, 15° 45′ E) near St Pölten, Lower Austria. Coll 1974 and subm by J W Neugebauer, Inst Ur u Frühgesch, Univ Vienna.

General Comment (JN): absolute chronology of archaeol dating. Expected ages between 3400 and 3600 BP. Discrepancies unknown.

VRI-493. Sample 1 **3060 ± 130**

Sample from layer of beams overlain by younger rampart. Settlement layer belongs to classic phase of Věteřov culture. Rampart was erected at end of this phase. Quad L1, depth 140cm. *Comment* (HF): DeVries correction (Suess, 1970) gives 1400 BC.

VRI-494. Sample 5 **2860 ± 90**

Like VRI-493.

VRI-495. Sample 6 **2640 ± 80**

Like VRI-493.

VRI-496. Sample 8 **2900 ± 90**

Sample from Pit 107, filled with waste materials (ceramics, bones, charcoal, and humus) belonging to classic or post classic phase of Věteřov culture. Quad d13, depth 150 to 170cm.

VRI-497. Sample 10 **2940 ± 90**

Like VRI-496.

VRI-498. Sample 11 **2920 ± 90**

Similar to VRI-496 except for Pit 113, Quad h13, depth 130cm.

VRI-584. Stillfried, NÖ **2700 ± 80**

Charred wood from construction of W rampart of prehistoric bulwark, Stillfried a d March (48° 25′ N, 16° 51′ E), Lower Austria. Coll 1969 and subm by F Felgenhauer, Inst Ur u Frühgeschichte, Univ Vienna. *Comment* (FF): archaeol dating is 750 BC. DeVries correction (Suess, 1970) gives 870 BC. (HF).

VRI-468. Litzelberg, OÖ **2040 ± 70**

Wooden post from bottom of L Attersee, 1.2m below level, ca 15m from shore of plot Bintner (47° 52′ N, 13° 33′ E), SW Litzelberg, Upper Austria. Coll 1972 by W Bintner, subm by H Offenberger, Bundesdenkmalamt, Vienna. *Comment* (HF): date rejects supposition that post is relic of Neolithic lake-dwelling.

VRI-445. Kramsach, Tirol **1620 ± 80**

Wood buried under boulder by landslip, N slope of mt ridge Schneidjoch (47° 29′ N, 11° 48′ E), Rofangebirge, NW Kramsach, Tyrol. Coll 1974 by F Jira, subm by R Pittioni, Inst Ur-Frühgesch, Univ Vienna. *Comment* (FJ): dates landslip.

VRI-502. Wien, Austria **510 ± 70**

Pine wood from periphery of stem of monument "Stock im Eisen" at corner Kärntnerstraße—Stock im Eisen Platz, Vienna 1. Sample taken 1975 by H Bednar, subm by O Harl, Mus d Stadt Wien. *Comment* (OH): date rejects supposition of stem renewal ca 200 yr ago.

B. Iran

Kordlar series, Iran

Charcoal excavated from 28m high settlement hill Tepe Kordlar (37° 30′ N, 45° E), near Rezaiyeh, W-Aserbeidschan, Iran. Coll 1974 and subm by A Lippert, Inst f Vor- u Frühgeschichte, Univ Innsbruck.

General Comment (AL): dates Early Iron age layers (Lippert, 1975).

VRI-446. 1301.50m **2960 ± 80**

Charcoal from Quad Hd1, depth 1301.50m, on outside E framework wall.

VRI-447. 1300.50m **2850 ± 80**

Charcoal from Quad Hd3, E side, depth 1300.50m.

VRI-448. 1300m **2880 ± 90**

Charcoal from Quad Gd4, Rm B, depth 1300m.

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Lippert, A, 1975, 3. Vorbericht zu den österr Ausgrabungen am Tepe Kordlar, West-aserbeidschan, Iran: Anthropol Gesell Wien Mitt, v 105.

Slupetzky, H, 1975, Erste Radiocarbondatierungen in Quartärablagerungen im Pongau im Bereich des inneralpinen Salzachgletschers (Vorbericht): Anz österr Akad Wiss, math-naturw Kl, Jg 1975, p 154-160.

Suess, H E, 1970, *in*: Olsson, I U, Radiocarbon variations and absolute chronology: Stockholm, Almqvist and Wiksell.

Corrections

Radiocarbon, 1976, v 18, no. 2:

VRI-346. Tennengebirge, p 241, should read: VRI-436.

VRI-421. Profile S, 35,000 BC, p 241, should read: 35,900 BC.

[RADIOCARBON, VOL. 21, No. 1, 1979, P. 120-130]

UNIVERSITY OF WISCONSIN RADIOCARBON DATES XVI

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Procedures and equipment have been described in previous date lists. Except as otherwise indicated, wood, charcoal and peat samples are pretreated with dilute NaOH and dilute H_3PO_4 before conversion to the counting gas methane; marls and lake cores are treated with acid only. Very calcareous materials are treated with HCl instead of H_3PO_4.

The dates reported have been calculated using 5568 as the half-life of ^{14}C with 1950 as the reference year. The standard deviation quoted includes only the 1σ of the counting statistics of background, sample, and standard counts. Background methane is prepared from anthracite, standard methane from NBS oxalic acid. The activities of the dated samples for which $\delta^{13}C$ values are listed have been corrected to correspond to a $\delta^{13}C$ value of $-25‰$.

Sample descriptions are based on information supplied by those who submitted samples.

ACKNOWLEDGMENTS

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I. ARCHAEOLOGIC SAMPLES

A. Illinois

WIS-918. W J Phillips site **980 ± 60**
$\delta^{13}C = -25.4‰$

Charred nut fragments (*Carya* cf *ovata*) and charred wood (*Carya, Quercus* sp, *Ulmus* sp and unidentifiable shrub) coll 1976 by William Green and L F Steinberg, Univ of Wisconsin-Madison at W J Phillips site, Schuyler Co (40° 14′ 20″ N, 90° 30′ 40″ W). Sample obtained from excavation of small oval, Late Woodland structure. In direct assoc were "Bauer Branch complex" sherds (Green, 1976) and charred remains of *Zea mays*. Sample should date structure and add to small list of (pre-Mississippian) Late-Woodland sites at which corn was present. Subm by D A Baerreis.

Peisker site

Charcoal from Peisker site, Illinois Archaeol Survey No. C-135, 5.6km S of Hardin, Calhoun Co (39° 5′ N, 90° 35′ W) coll by M L Staab, Univ Michigan. Subm by D A Baerreis. Site excavated 1962-63 by Perino

(1966a&b) and by Struever (1968). During excavations sealed Havana Hopewell component was discovered under Mound III; this small, ca 12.2m diam, isolated living area was completely excavated 1972 by M L Staab. Two earlier dates on Sub-Mound 3, M-1569 and -1570, were AD 250 and AD 70, respectively.

WIS-942. Peisker site **1955 ± 60**
$\delta^{13}C = -27.1‰$

Sample 109, wood (*Juglans, Carya*) and acorns from 27cm below surface.

WIS-947. Peisker site **1835 ± 70**
$\delta^{13}C = -26.1‰$

Sample 114, wood (*Carya, Quercus, Juglans*) and acorns from 81cm below surface.

WIS-950. Peisker site **1755 ± 60**
$\delta^{13}C = -26.3‰$

Sample 104 (*Carya*) from 74cm below surface.

Cahokia site

Excavations at Cahokia's Woodhenge structures (Wittry, 1969), Madison Co (38° 40′ N, 90° 04′ W) Aug 1977 by W L Wittry, Univ Illinois at Chicago Circle. Subm by D A Baerreis.

WIS-948. Cahokia site **1085 ± 55**
$\delta^{13}C = -27.1‰$

Small fragments of red cedar (*Juniperus*) from Feature 548, post pit of Woodhenge Circle No. 2. Sample treated with cold base and hot dilute acid.

WIS-969. Cahokia site **1060 ± 55**
$\delta^{13}C = -27.2‰$

Small fragments of red cedar from Feature 548. Acid treatment only.

WIS-976. Cahokia site **760 ± 55**
$\delta^{13}C = -25.8‰$

Charred wood from Feature 340, large pit centered at grid loc 156R70, possibly assoc with winter solstice sunrise post of Circle No. 3.

WIS-984. Cahokia site **685 ± 55**
$\delta^{13}C = -26.9‰$

Charred wood from Feature 506, post pit of Circle No. 3. Pit was superimposed by wall trench of House 302.

WIS-988. Cahokia site **1135 ± 55**
$\delta^{13}C = -25.6‰$

Charred wood from Feature 539, large pit believed to represent winter solstice sunrise post of Circle No. 4.

B. Iowa

WIS-952. Hickenbottom site (13JF52) **1320 ± 65**

$\delta^{13}C = -27.7‰$

Wood charcoal from directly above stone capped secondary burial, Feature 1. Pottery found near but not assoc with burial; suggests burial may be early Late Woodland in age. Sample coll 1977 by Joseph Tiffany, Univ Iowa, Iowa City, from mound excavation in Jefferson Co (41° 1′ N, 92° 1′ W). Subm by D A Baerreis.

WIS-926. Jones site (13CK1) **1130 ± 70**

$\delta^{13}C = -24.2‰$

Charcoal from Jones site, Cherokee Co (42° 54′ N, 95° 26′ W) coll 1974 by D C Anderson, Univ Iowa, Iowa City. Sample was recovered from charred post in Test Trench 1, Level 3. Post was oriented vertically *in situ* at base of midden deposit at depth of 61 to 90cm below present ground surface. Date should date approx beginning of occupation at site (Williams, 1975). Subm by D A Baerreis.

Helen Smith site (13LA71)

Charcoal excavated from multi-component (Woodland and Historic Anglo) Helen Smith site (Anderson, 1971; Alex, 1976) on W bank of Iowa R, Louisa Co (41° 8′ 15″ N, 91° 3′ 11″ W) in 1976 under direction of L M Alex, Spearfish, South Dakota, as part of joint salvage/amateur field school project of Iowa Archaeol Soc and Office of State Archaeologist of Iowa. Two 3m squares were excavated to sterile subsoil.

WIS-927. Helen Smith site (13LA71) **1385 ± 55**

$\delta^{13}C = -25.8‰$

Charcoal from Level 3 of Feature 3, NE corner of Sq F. Feature is steep-sided pit containing quantity of bone, charcoal, and ceramic and lithic artifacts.

WIS-931. Helen Smith site (13LA71) **1440 ± 55**

$\delta^{13}C = -25.1‰$

Charcoal from Level 6, SW quad of Sq F, near concentration of cultural debris.

WIS-966. Helen Smith site (13LA71) **1385 ± 60**

$\delta^{13}C = -25.9‰$

Charcoal from Levels 4 and 5, Sq XX, 1.5m sq opened 21.3m W of main excavation. Woodland pottery, lithic debitage, carbonized seeds, and some bone, comparable to that recovered in main excavation, encountered in this square.

WIS-920. Poison Ivy site (13LA84) **255 ± 60**

$\delta^{13}C = -25.6‰$

Charcoal from Oneota site on W bank of Iowa R in Louisa Co (41° 8′ 53″ N, 91° 3′ 2″ W) (Alex, 1978). Coll June 1976 by L M Alex; subm by D A Baerreis. Samples from cultural deposit 1.2m below surface. Site is < 4.83km NE of McKinney village site (Slattery *et al*, 1975), also Oneota manifestation. Several villages of historic Indian groups are documented in journals of early European explorers in area and are believed to be present in immediate vicinity of site.

C. Missouri

Cannon Reservoir series, Victor Bridge site (23MN380)

Charcoal from Victor Bridge site, Monroe Co (39° 27′ 25″ N, 91° 49′ 02″ W) coll 1976 under direction of D R Henning, Univ Nebraska, Lincoln. Subm by D A Baerreis. Samples dated to establish position of site within seriation sequence established for Cannon Reservoir area of Salt River Valley.

WIS-912. Victor Bridge site (23MN380) **1355 ± 60**
$\delta^{13}C = -26.4‰$

Sample from 20 to 30cm below machine scraped surface in Feature 12, small vertical-sided pit with relatively flat bottom, Sq 44S-53W and 45S-54W.

WIS-921. Victor Bridge site (23MN380) **1155 ± 60**
$\delta^{13}C = -25.3‰$

Sample from charcoal concentration and dark brown pit fill of Feature 1A, vertical-sided, shallow basin-bottomed pit, 13 to 31cm below machine scraped surface, Sq 29S-43.5W. Acid treatment only.

WIS-922. Victor Bridge site (23MN380) **1220 ± 55**
$\delta^{13}C = -25.5‰$

Sample in dark brown fill of Feature 8, vertical walled, shallow basin-bottomed pit filled with quantities of burned limestone. Sample taken 9 to 19cm below scraped surface, Sq 35.5S-38.5W.

WIS-917. Victor Bridge site (23MN380) **1370 ± 65**
$\delta^{13}C = -25.4‰$

Sample from 21 to 44cm below scraped surface in dark brown pit fill of Feature 9 in Sq 33.5S-33W and 33.5S-33.5W. Acid treatment only.

WIS-911. Cannon Reservoir series,
Tom Miskell site (23MN542) **1485 ± 70**
$\delta^{13}C = -25.8‰$

Catalog nos. 165 and 134, Feature 33, 32 to 57cm below surface, and Feature 19, 30 to 51cm below surface, directly beneath plow zone. Coll 1976 under direction of D R Henning from Tom Miskell site, Monroe Co (39° 13′ N, 91° 45′ W).

Cannon Reservoir series, Muskrat Run site (23RA151)

Charcoal from Late Woodland Muskrat Run site, Rall Co (39° 32′ 35″ N, 91° 41′ 26″ W) coll 1976 under direction of D R Henning. Subm by D A Baerreis.

WIS-913. Muskrat Run site (23RA151) **1435 ± 60**
$\delta^{13}C = -27.7‰$

Sample from between and beneath limestone slabs that comprised burial structure, Feature 12.

WIS-915. Muskrat Run site (23RA151) **1290 ± 65**
$\delta^{13}C = -25.7‰$

Sample from 35 to 45cm below ground surface in large bell-shaped pit.

WIS-916. Muskrat Run site (23RA151) **1290 ± 70**
$\delta^{13}C = -25.5‰$

Charcoal from bottom portion of Feature 7B at 55 to 65cm below machine-scraped surface. This feature was superimposed by Feature 7A, basin-shaped pit. Acid treatment only.

WIS-924. Muskrat Run site (23RA151) **985 ± 65**
$\delta^{13}C = -22.5‰$

Charcoal and bone from 0 to 10cm below scraped surface in Feature 2, large shallow concentration of burned limestone.

Hatton Mound site (23MN275)

Human bone from stratified Late Archaic burial mound in Monroe Co (39° 26′ 26″ N, 91° 49′ 51″ W) coll 1961 by D R Henning; subm by D A Baerreis. Mound had 4 distinct levels of bone, each level separated from others by layer of closely spaced limestone slabs.

WIS-923. Hatton Mound site (23MN275) **4160 ± 65**
$\delta^{13}C = -21.9‰$

Unburned bone from Layer 3, which contained cremated bone in bundles, flexed and semi-flexed. Artifacts recovered included 3 chipped stone "daggers," some Late Archaic projectile points and chipped stone village refuse.

WIS-929. Hatton Mound site (23MN275) **2450 ± 55**
$\delta^{13}C = -21.1‰$

Unburned adult femora from Layer 4, which contained Late Archaic projectile points, sheet copper, antler flakers, bone awls, and bone fleshing tool.

WIS-963. Hatton Mound site (23MN275) **2600 ± 80**
($\delta^{13}C = -21.1‰$)

Unburned bone from Layer 4. Separate sample was prepared, counted only once. Carbon isotope correction was based on analysis of WIS-929.

D. Wisconsin

Preston Rockshelter (47GT157)

Charcoal from stratified rockshelter in Grant Co (42° 59′ 38″ N, 90° 32′ 58″ W). Coll in summers of 1966, 1968, 1969 by H A Palmer, Univ Wisconsin-Platteville; subm by J B Stoltman, Univ Wisconsin-Madison.

WIS-941. Preston Rockshelter (47GT157) **2780 ± 65**
$\delta^{13}C = -26.2‰$

Sample from Sq 16N36W, 2.96 to 3.02m below surface, from pre-pottery levels assoc with Preston corner-notched projectile points.

WIS-946. Preston Rockshelter (47GT157) **2710 ± 65**
$\delta^{13}C = -25.8‰$

Sample from hearth, Feature 23, Sq 20N32W, 2.6m deep. Sample from pre-ceramic levels with Durst projectile points.

WIS-943. Preston Rockshelter (47GT157) **1670 ± 65**
$\delta^{13}C = -26.8‰$

Sample from Sq 16N40W, 2.2m deep, from late Middle Woodland-early Late Woodland transition levels.

WIS-944. Preston Rockshelter (47GT157) **1220 ± 60**
$\delta^{13}C = -27.6‰$

Sample from Sq 16N32W, 1.4 to 1.5m deep, Late Woodland level assoc with Madison Ware ceramics and small triangular projectile points.

WIS-932. Preston Rockshelter (47GT157) **1150 ± 60**
$\delta^{13}C = -26.6‰$

Sample from Sq 12N36W, 1.5m deep, Late Woodland level.

II. GEOLOGIC SAMPLES

A. United States

Goshen Springs site, Alabama

Core 1976-A from center of basin in Goshen Springs, Pike Co (31° 44′ N, 86° 08′ W) coll Nov 1976 by Paul and Hazel Delcourt, Univ Minnesota; subm by Paul Delcourt. Depths are below water surface.

WIS-954. Goshen Springs site **Modern**
$\delta^{13}C = -28.3‰$

Clayey fibrous peat, segment 55 to 66cm deep.

WIS-955. Goshen Springs site **1345 ± 60**
$\delta^{13}C = -28.2‰$

Clayey fibrous peat, segment 89 to 101cm deep.

WIS-956. Goshen Springs site **5620 ± 70**
$\delta^{13}C = -27.0‰$

Black, organic, silty clay, segment 175 to 184cm deep.

WIS-957. Goshen Springs site **26,000 ± 380**
$\delta^{13}C = -31.6‰$

Dark gray-brown silty clay, 244 to 256cm deep.

WIS-958. Goshen Springs site **>33,000**
$\delta^{13}C = -30.0‰$

Silty clay, 302.5 to 309.5cm deep.

WIS-959. Goshen Springs site **>33,000**
$\delta^{13}C = -29.5‰$

Slightly clayey, sandy silt, 375 to 385cm deep.

WIS-965. Sheelar Lake site, Florida **23,880 ± 350**

Organic lake sediment, 3513 to 3525cm below surface, from Gold Head Branch State Park, Keystone Heights, Clay Co (29° 50′ N, 81° 57′ 30″ W). Coll March 1977 by H E Wright, Univ Minnesota, subm by H E Wright. Sample is base of sediment core for which pollen diagram will be prepared.

WIS-964. Taylor Lake site, Kentucky **1790 ± 60**
$\delta^{13}C = -28.3‰$

Lake sand with organic detritus from Taylor Lake near Logansport (47° 19′ N, 86° 47′ 30″ W). Sample from Core A, 915 to 930cm below water surface. Coll 1977 and subm by H E Wright.

Demont Lake, Michigan

Postglacial lake core of 9.5m length obtained from Demont Lake, Isabella Co, Michigan (43° 30′ N, 85° 3′ W) in June 1975 by R O Kapp and P J Ahearn, Alma Coll, Alma. Dates complete sequence of 5 dates on core. Pollen influx diagram which will serve as standard regional pollen record for late and postglacial record of central lower Michigan has been prepared. Subm by Thompson Webb, III, Brown Univ, Providence, Rhode Island.

WIS-930. Demont Lake **3935 ± 65**
$\delta^{13}C = -37.4‰$

Yellowish-brown peaty gyttja, Sample D-BB, from 3.45 to 3.55m level of core.

WIS-928. Demont Lake **10,770 ± 110**
$\delta^{13}C = -31.9‰$

Steel-gray sandy gyttja, quite calcareous, Sample D-RRR, from 7.35 to 7.50m level.

Wolsfeld Marsh, Minnesota

Core obtained in Wolsfeld Marsh, Hennepin Co (45° 00′ N, 93° 34′ W) in 1976 by E C Grimm, Univ Minnesota; subm by H E Wright. Core is to be used for pollen analysis.

WIS-970. Wolsfeld Marsh site **<200**
$\delta^{13}C = -29.4‰$

Sedge peat, 23.5 to 26.5cm depth.

WIS-972. Wolsfeld Marsh site **905 ± 60**
$\delta^{13}C = -28.5‰$

Sedge peat, 58.0 to 62.0cm depth.

WIS-934. Szabo Bog, New Jersey **8515 ± 85**
$\delta^{13}C = -29.8‰$

Silty organic lake sediment from Szabo Bog, Middlesex Co, New Jersey, New Brunswick quad (40° 24′ N, 74° 29′ W). Coll May 1975 by H E Wright and W A Watts, Trinity Coll, Dublin, Ireland; subm by H E Wright. Sample 60 to 65cm below mud surface, 160 to 165cm below water surface. Dates end of oak pollen increase in early Holocene.

WIS-936. Panther Run, Pennsylvania **6400 ± 75**
$\delta^{13}C = -30.4‰$

Silty organic lake sediment from Panther Run, Mifflin Co, Pennsylvania, Spring Mills quad (40° 48′ N, 77° 25′ W). Sample 70 to 80cm below mud surface, 100 to 110cm below water surface; dates pine pollen max, base of oak pollen increase. Coll May 1975 by H E Wright and W A Watts.

WIS-962. Nonconnah Creek Terrace site, Tennessee **>33,000**

Silty clay from sediment column, NC-TN-2-B, 210 to 215cm deep, coll 1976 by Paul and Hazel Delcourt from alluvial sec exposed along bank of Nonconnah Creek in Shelby Co (35° 05′ N, 89° 55′ W). Subm by H E Wright.

Lake Colebrook site, Vermont

Samples related to proglacial lake in upper Connecticut R valley, probably Lake Colebrook of Lougee (1939) in Essex Co, Vermont, along Connecticut R (44° 50′ 50″ N, 71° 38′ 30″ W). Coll Feb and Nov 1977 by N G Miller, Harvard Univ, Cambridge, Massachusetts. Subm by Thompson Webb, III.

WIS-919. Lake Colebrook site **11,390 ± 115**
$\delta^{13}C = -27.5‰$

Wood fragments and miscellaneous plant debris from sand lamina, 84cm below top of exposure of laminated clay that extends at least to depth of 3.68m.

WIS-925. Lake Colebrook site **20,500 ± 250**

Very calcareous unoxidized clay with 3 plant debris layers, 138 to 145cm below top of exposure of laminated clay. Sample contained abundant *Potamageton* leaf fragments in which "old" carbon was perhaps incorporated.

WIS-961. Lake Colebrook site **11,540 ± 110**
$\delta^{13}C = -29.0‰$

Organic detritus in sandy laminae between 152 and 158cm below top of laminated clay exposure.

WIS-935. Potts Mountain, Virginia **9140 ± 90**
$\delta^{13}C = -31.6‰$

Clayey organic lake sediments, 65 to 71cm below water and mud surface, from Potts Mountain, Alleghany Co, Potts Creek quad, on crest on Potts Mt (37° 36′ N, 80° 08′ W). Dates hemlock pollen max, base of chestnut pollen increase. Coll Aug 1971 by H E Wright and W A Watts.

WIS-933. Cranberry Glades Botanical Area, West Virginia **7325 ± 80**
$\delta^{13}C = -29.1‰$

Sec of core, 322 to 332cm, obtained 1971 from Cranberry Glades Botanical Area, Monongahela Natl Forest, Pocahontas Co, 24km E of Richwood (38° 10′ N, 80° 15′ W). Coll by W A Watts; subm by A M Swain, Univ Wisconsin-Madison. Two dates on core have been previously reported (R, 1977, v 19, p 134).

WIS-945. Oneida County site, Wisconsin **10,960 ± 105**
$\delta^{13}C = -24.6‰$

Log (*Larix laricina*) id by D J Christensen, Forest Products Lab, Madison, 14m below surface in peat at base of sphagnum bog. Coll March 1977 by D Mickelson, Univ Wisconsin-Madison from bog in Oneida Co (45° 34′ N, 89° 40′ W). This area probably part of Lake Nokomis; date should be min for deglaciation of Wisconsin Valley Lobe in this area (Mickelson *et al,* 1974). Pollen shows high spruce counts. Subm by A M Swain.

South Waubesa Wetlands site, Wisconsin

Core samples obtained Dec, 1977 from South Waubesa marsh, Dane Co (42° 59′ N, 89° 21′ W) by T K Kratz and R M Friedman, Univ Wisconsin-Madison. Subm by C B DeWitt, Univ Wisconsin-Madison. Peat samples from selected portions of marsh dated to determine rate of lake-edge wetlands formation; results are to be used in mathematical model of wetlands formation investigating effects of spatial inter-relationships, nutrients and climate on wetlands ecosystem dynamics (Friedman & DeWitt, 1978).

WIS-953. South Waubesa Wetlands site **1915 ± 60**
$\delta^{13}C = -28.8‰$

Band of peat, 12cm, immediately above transition between fibrous and lake sedimentary peat 1.75m below surface.

WIS-951. South Waubesa Wetlands site **1995 ± 60**
$\delta^{13}C = -28.4‰$

Band of peat, 12cm, immediately above fibrous to lake sedimentary peat transition 1.36m below surface.

WIS-967. South Waubesa Wetlands site **2820 ± 65**
$\delta^{13}C = -29.3‰$

Band of peat, 12cm, overlying fibrous to lake sedimentary peat transition zone, 1.90m deep.

WIS-971. South Waubesa Wetlands site **3425 ± 65**
$\delta^{13}C = -28.8‰$

Band, 12cm, overlying fibrous to lake sedimentary peat transition zone, 1.7m below surface.

WIS-973. South Waubesa Wetlands site **5060 ± 70**
$\delta^{13}C = -28.8‰$

Band of fibrous peat, 12cm, above fibrous—lake sedimentary peat transition zone, 1.7m below surface.

WIS-974. South Waubesa Wetlands site **2015 ± 65**
$\delta^{13}C = -29.8‰$

Sample above transition zone, 1.32m below surface.

WIS-975. South Waubesa Wetlands site **1065 ± 60**
$\delta^{13}C = -29.0‰$

Band, 12cm, above transition zone, 1.25m below surface.

WIS-977. South Waubesa Wetlands site **2840 ± 65**
$\delta^{13}C = -28.8‰$

Lake sedimentary peat 2.31m below surface, 0.95m below transition zone; very calcareous sample.

WIS-978. South Waubesa Wetlands site **5850 ± 70**

Lake sedimentary peat 5.30m, 3.95m below transition between fibrous peat and lake sedimentary peat; very calcareous sample.

B. Canada

St Calixte site

Core, 630cm, from small lake near St Calixte, N of Champlain Sea, Quebec (45° 57′ 40″ N, 73° 52′ 05″ W). Coll 1977 by Pierre Richard, Univ Montreal, Canada; subm by Thompson Webb, III.

WIS-938. St Calixte site **3350 ± 60**
$\delta^{13}C = -29.6‰$

Organic lake mud, 150 to 160cm sec of core. Dates beginning of 2nd *Tsuga* max and *Fagus* max.

WIS-940. St Calixte site **6135 ± 75**
$\delta^{13}C = -31.0‰$

Gyttja, 370 to 380cm sec of core. Dates 1st *Tsuga* max and beginning of curve of *Fagus* pollen.

WIS-939. St Calixte site **8565 ± 90**
$\delta^{13}C = -28.7‰$

Gyttja, 490 to 500cm sec. Dates max of *Pinus* cf *divaricata* pollen curve for locality.

WIS-937. St Calixte site **9755 ± 100**
$\delta^{13}C = -28.9‰$

Gyttja, 570 to 580cm sec, just above silt and sand of last 50cm of core. Dates outstanding *Populus* max in afforestation phase of pollen sequence.

C. Africa

WIS-968. Lake Ikimba **1685 ± 60**
$\delta^{13}C = -17.7‰$

Black lacustrine silt, basal 4cm sec of 198cm sediment core, from Lake Ikimba, Lake Dist, United Republic of Tanzania (1° 27′ S, 31° 35′ E). Core taken under 316cm water. Coll 1977 by R A Laseski, Brown Univ, Providence, Rhode Island; subm by Thompson Webb, III.

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[RADIOCARBON, VOL. 21, No. 1, 1979, P. 131-137]

RUDJER BOŠKOVIĆ INSTITUTE RADIOCARBON MEASUREMENTS V

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The following list contains dates of samples measured since our previous list (R, 1977, v 19, p 465-475). As before, age calculations are based on the Libby half-life, 5570 ± 30 years, and reported in years before 1950. The modern standard is 0.95 of the activity of NBS oxalic acid. Solid sample pretreatment, combustion and counting technique are essentially the same as described in R, 1971, v 13, p 135-140. Groundwater samples were prepared following the procedure adopted by the IAEA (IAEA, 1977). Carbonates and hydrocarbonates from water samples were precipitated by adding saturated barium chloride solution while the alkalinity was adjusted to pH = 8 by adding carbonate-free saturated solution of sodium hydroxide. The precipitation was enhanced by adding iron salts and Praestol as coagulating medium. Carbon dioxide was evolved by acidification of the precipitate and converted to methane. Statistical processing of data has been computerized (Obelić and Planinić, 1975). Sample descriptions were prepared with collectors and submitters. The errors quoted correspond to 1σ variation of sample net counting rate and do not include the uncertainty in ^{14}C half-life.

Results were corrected for isotopic fractionation using measured $^{13}C/^{12}C$ ratios for groundwater samples and estimated values (Stuiver & Polach, 1977) for all other samples. Calculations of ages or percent of modern of speleothems and groundwaters are based on the initial activity of reservoirs equal to 65% or 85% of modern standard (i.e. 95% activity of NBS oxalic acid) depending on the geology of the catchment area (Münnich & Vogel, 1959; Geyh, 1972; Job *et al*, 1975; Sonntag *et al*, 1976).

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SAMPLE DESCRIPTIONS

I. GEOLOGIC SAMPLES

Kozlerjeva Gošča series

Peat and lake marl from bore hole at Kozlerjeva Gošča (46° 1′ 0″ N, 14° 30′ 46″ E) SE part of Ljubljansko Barje, Slovenia. Dated to deter-

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mine postglacial vegetation development and transition of lake to peat bog. Coll and subm 1976 by A Šercelj, Fac Arts Sci Ljubljana. *Comment* (AŠ): dates agree well with pollen analysis.

Z-506. Kozlerjeva Gošča **2170 ± 120**
$\delta^{13}C = -27‰$

80 to 100cm depth.

Z-507. Kozlerjeva Gošča **4240 ± 130**
$\delta^{13}C = -27‰$

220 to 235cm depth.

Z-508. Kozlerjeva Gošča **2970 ± 120**
$\delta^{13}C = -27‰$

130 to 160cm depth.

Z-509. Kozlerjeva Gošča **3310 ± 120**
$\delta^{13}C = -27‰$

190 to 210cm depth.

Z-510. Kozlerjeva Gošča **4510 ± 120**
$\delta^{13}C = -27‰$

290 to 320cm depth.

Z-526. Bezdanjača Cave **3310 ± 90**
$\delta^{13}C = -8‰$

Botryoid, clustered calcite deposit on wall of Hall of Deaf in Bezdanjača cave near Vrhovine (44° 50′ N, 15° 23′ E) Lika, Croatia. Dates variations of water level in cave. Initial content of reservoir: 85% of modern standard.

Z-543. Anhovo **18,980 ± 310**
$\delta^{13}C = -24‰$

Wooden fragments from lake marl profile at village Anhovo (46° 3′ 40″ N, 13° 39′ 0″ E) Slovenia. Dating of lake marl embedded in conglomerate terrace of older Würm was to determine age of terrace. Coll 1977 by Metka Culiberg and subm by A Šercelj, Slov Acad Arts, Ljubljana.

Z-544. Račje selo **1880 ± 120**
$\delta^{13}C = -27‰$

Peat from 245cm deep bore hole at village Račje selo (45° 55′ 40″ N, 15° 0′ 30″ E) near Trebnje, Slovenia. Dates beginning of peat-bog growth. *Comment* (AŠ): expected age: Holocene.

II. ARCHAEOLOGIC SAMPLES

Šandalja II series

Charcoal from hearth in Šandalja cave, limestone quarry (44° 52′ 57″ N, 13° 53′ 48″ E) near Pula, Istra, W Croatia. Assoc with Aurignacian artifacts of Lautsch type in Stratum F and in upper part of Stratum G

(Malez & Vogel, 1969). Coll and subm 1976 by M Malez, Yugoslav Acad Sci Arts, Zagreb.

Z-536. Šandalja **27,800 ± 800**
$\delta^{13}C = -24‰$

Charcoal from hearth, SW part of hall, Stratum G, reddish brown sandy loam with stone, 5.5 to 6m depth.

Z-537. Šandalja **22,660 ± 460**
$\delta^{13}C = -24‰$

Charcoal from hearth, S part of hall, Stratum F, yellowish red to yellowish brown sandy loam, 40 to 50cm depth.

Z-551. Vindija **27,000 ± 600**
$\delta^{13}C = -24‰$

Charcoal from Stratum 6 in Vindija Cave, Gornja Voća near Ivanec, N Croatia. Systematic investigations of Quarternary period in Vindija Cave. Dates Paleolithic culture of Aurignacian and accompanied fauna. Coll and subm 1977 by M Malez. *Comment* (MM): agrees with expected age.

Vranjičko Blato series

Fragments of wooden beam (*Pinus halepensis*) submerged in swamp Vranjičko Blato, site of Roman harbor, near Solin (Salona) (43° 13′ N, 16° 13′ E), Croatia. Coll and subm 1976 by N Cambi, Archaeol Mus, Split. *Comment* (NC): expected age: 1st century AD.

Z-519. Vranjičko Blato 1 **2060 ± 100**
$\delta^{13}C = -24‰$

Z-520. Vranjičko Blato 2 **2110 ± 100**
$\delta^{13}C = -24‰$

Z-521. Vranjičko Blato 3 **2130 ± 90**
$\delta^{13}C = -24‰$

Z-522. Gradić **1335 ± 90**
$\delta^{13}C = -24‰$

Wooden beam (*Quercus* sp) 1.2m below alluvial soil, Torčec near Koprivnica (46° 8′ N, 16° 50′ E) N Croatia. Assoc with abundant ceramic fragments, bone artifacts and burned bricks. Coll and subm 1976 by B Januška. *Comment* (BJ): expected age: Early Middle age.

Parti series

Wooden fragments of pile dwellings from Eneolithic cultural layer, 1m below surface at Parti, SE part of Ljubljansko Barje peat bog (45° 58′ 20″ N, 14° 32′ 20″ E) Slovenia. Dates pile-dwelling settlements in Lj Barje area (R, 1975, v 17, p 149; R, 1977, v 19, p 465). Coll 1976 by Tatjana Bregant, Fac Arts Sci, Ljubljana and subm by A Šercelj. *Comment* (AŠ): expected age: 4000 yr.

Z-539. Parti No. 16 **3920 ± 100**
$\delta^{13}C = -24‰$

Z-540. Parti No. 81 **4010 ± 100**
$\delta^{13}C = -24‰$

Libna series

Fragments of wooden beams from fortress wall at Libna village near Krško (45° 57′ N, 15° 32′ E) alt 359m, Slovenia. Dates construction of prehistoric settlement (Guštin, 1976). Coll and subm 1976 by M Guštin, Posavski Mus Brežice, Slovenia.

Z-541. Libna 1 **3015 ± 95**
$\delta^{13}C = -24‰$

Fragment of wooden beam 2m below surface. *Comment* (MG): date seems too old.

Z-542. Libna 2 **2565 ± 85**
$\delta^{13}C = -24‰$

Fragment of wooden beam 2.5m below surface in deepest cultural phase of settlement assoc with prehistoric ceramic. *Comment* (MG): agrees with expected age.

Z-564. Orešje **2370 ± 85**
$\delta^{13}C = -24‰$

Wooden board from cultural layer 25cm below surface, Orešje na Bizeljskom, 500m alt (46° 3′ N, 15° 43′ E) Slovenia. Dates cultural layer. Coll and subm 1977 by M Guštin, Posavski Mus, Brežice, Slovenia.

Ljuljaci series

Charcoal from cultural strata assoc with pottery at Ljuljaci village near Kragujevac (44° 1′ N, 20° 40′ E), Central Serbia. Dates development of cultural phases of Early and Middle Bronze age in Central Serbia and helps to solve some problems of Western Serbian variant of Vatin culture. Coll and subm by Zagorka Letica, Fac Arts Sci, Archaeol Dept, Belgrade. *Comment* (ZL): 1st half of 2nd millennium BC.

Z-545. Ljuljaci (No. 10) **3425 ± 95**
$\delta^{13}C = -24‰$

Sonda VIII/a, Excavation Layer V.

Z-546. Ljuljaci (No. 8) **3480 ± 100**
$\delta^{13}C = -24‰$

Sonda VIII, Zona II, Excavation Layer III.

Z-547. Ljuljaci (No. 1) **1195 ± 90**
$\delta^{13}C = -24‰$

Sonda VI/a, Excavation Layer I, 36cm below surface.

Z-548. Ljuljaci (No. 16) **3460 ± 100**
$\delta^{13}C = -24‰$

Sonda VIII, Excavation Layer VI near hearth, 82cm below surface.

Z-549. Ljuljaci (No. 12) **3370 ± 100**
$\delta^{13}C = -24‰$

Sonda VI/a, Excavation Layer IV.

Z-563. Trg **Modern ($\Delta^{14}C = -14‰$)**
$\delta^{13}C = -25‰$

Fragment of axe-hewn log boat (*Quercus robur*) buried in muddy bed of Kupa R near Ozalj (45° 37′ N, 15° 30′ E). Coll and subm by H Malinar. *Comment* (NM): expected age: 100 to 300 yr.

Z-553. Slavonski Brod **240 ± 80**
$\delta^{13}C = -25‰$

Fragment of axe-hewn log boat (*Quercus robur*) buried in muddy bed of Sava R near Slavonski Brod (45° 10′ N, 18° 2′ E). Coll and subm 1977 by H Malinar and B Vrbek, Croatian Inst Restoration, Zagreb.

Zlarin series

Fragments of wooden ship under 15cm thick sandy layer, 32m below sea surface, off Zlarin I. (43° 40′ 30″ N, 15° 52′ 20″ E) near Šibenik, S Croatia. Dates antique ship. Coll and subm 1977 by Z Brusić, Šibenik Mus. *Comment* (ZB): expected age: ca 2000 yr.

Z-567. Zlarin **2235 ± 85**
$\delta^{13}C = -24‰$

Fragment of rib (*Castanea sativa* or *Quercus* sp).

Z-568. Zlarin **2245 ± 90**
$\delta^{13}C = -24‰$

Fragment of hull (*Picea* sp).

Z-571. Gradina **2010 ± 95**
$\delta^{13}C = -24‰$

Fragment of wooden beam, 80cm below sandy and muddy layer, 200cm below sea surface, Zaton near Nin (44° 14′ N, 15° 20′ E). Dates antique harbor Aenone (Z Brusić, 1969). Coll and subm 1977 by Z Brusić, Archaeol Mus, Zadar. *Comment* (ZB): expected age: ca 2000 yr.

III. HYDROGEOLOGIC SAMPLES

Libyan water series

Isotopic analyses of water samples from Libya have been made as part of complex hydrogeol study performed by Energoprojekt, Belgrade, in Tripolitania, Libya, between 28° 45′ and 32° 20′ N, and 12° 00′ and 16° 20′ E, including confluences of temporary surface flows (wadis) Sawfajjin, Zamzam, Bay al Kabir and Jufrah region. Radiocarbon measurements and other isotopic analyses (tritium, deuterium and ^{18}O) resulted in valuable information for planning and development of exploitation of groundwaters in arid and desert regions of Tripolitania (Zogović & Filipovski, 1978; Obelić *et al*, 1978). Samples were coll from March 1975 to February 1976 by Energoprojekt experts and chemically

TABLE 1

Sample No.	Well Name	Water Depth (m)	Location N Lat	Location E Long	$\delta^{13}C$ (± 0.05)	^{14}C Percent Modern	^{14}C Apparent Age (yr)	Aquifer
Z-443	WS-10	172	31° 10′	15° 06′	−3.77	3.8 ± 0.5	26,300 ± 900	Eocene
Z-446	WS-21	75	31° 17′	15° 11′	−3.77	4.8 ± 0.5	24,300 ± 800	Eocene
Z-442	WS-1	130	30° 52′	15° 19′	−2.17	2.3 ± 0.5	$30,200 {}^{+1600}_{-1500}$	Eocene
Z-465	Hun Old Well	445	29° 05′	15° 55′	−6.17	1.8 ± 0.5	$32,400 {}^{+1900}_{-1800}$	Eocene
Z-474	Abu Nujaym 1	450	30° 35′	15° 27′	−3.88	<0.6	>40,000	Eocene (Paleocene)
Z-473	Abu Nujaym 2	450	30° 35′	15° 27′	−2.39	<0.6	>40,000	Eocene
Z-466	Socna 4	180	29° 04′	15° 50′	−4.77	1.4 ± 0.5	$34,100 {}^{+2300}_{-2200}$	Socna
Z-467	Socna 2	202	29° 04′	15° 50′	−4.29	2.0 ± 0.5	$31,300 {}^{+1700}_{-1700}$	Socna
Z-468	Socna 11	150	29° 04′	15° 50′	−4.18	<0.6	>40,000	Socna
Z-472	Ferjan J − 3T	332	28° 55′	15° 38′	−4.77	2.3 ± 0.5	$30,200 {}^{+1500}_{-1500}$	Socna
Z-463	Nesma 2	70	31° 02′	13° 25′	−5.47	24.7 ± 0.6	11,200 ± 190	Tigrinna
Z-464	No. 22	80	31° 02′	13° 25′	−1.49	6.5 ± 0.5	21,900 ± 600	Tigrinna
Z-470	WS-9	500	31° 34′	14° 23′	−6.86	23.0 ± 0.6	11,730 ± 200	Mizdah
Z-460	Bani Walid (271)	300	31° 45′	14° 04′	−3.78	12.8 ± 0.5	16,500 ± 300	Gharyan
Z-462	Bir Sanam	450	31° 21′	13° 41′	−1.19	2.9 ± 0.5	28,300 ± 1200	Gharyan
Z-448	GW-7 Garabulli	—	32° 44′	13° 45′	−2.67	<0.6	>40,000	Gharyan
Z-441	ZZ-1	1000	31° 09′	15° 03′	−5.47	1.7 ± 0.5	$32,600 {}^{+2000}_{-1900}$	Chiclah
Z-459	ZZ-2	1000	31° 10′	15° 05′	−5.42	2.2 ± 0.3	$30,700 {}^{+1200}_{-1100}$	Chiclah
Z-469	Well Nura	975	31° 47′	13° 53′	−6.86	<0.6	>40,000	Chiclah
Z-511	WS-2	1010	30° 58′	14° 35′	−4.65	1.2 ± 0.3	$35,300 {}^{+1600}_{-1500}$	Chiclah
Z-513	WS-4	801	30° 24′	13° 36′	−5.54	<0.6	>40,000	Chiclah
Z-471	WS-14 M	772	31° 27′	13° 00′	−7.46	11.6 ± 0.4	17,300 ± 270	Kabaw
Z-515	WS-8	460	29° 02′	14° 18′	−3.40	5.8 ± 0.3	22,800 ± 400	Paleozoic
Z-518	No. 1	519	29° 20′	15° 22′	−3.35	4.5 ± 0.3	24,900 ± 600	Paleozoic
Z-476	G-XII Garabulli	—	32° 44′	13° 45′	−5.47	14.8 ± 0.5	15,300 ± 270	Azzizia
Z-477	E-IV Garabulli	—	32° 44′	13° 45′	−4.77	2.9 ± 0.4	28,500 ± 900	Azzizia

processed in Tripoli by our staff. $^{13}C/^{12}C$ ratio was measured by D Stefanović, IRB, and simultaneously at GSF, Munnich by W Stichler. Results of measurements are presented in Table 1. Apparent age of water samples is calculated on the basis of initial activity of reservoir equal to 85% of modern standard (95% NBS oxalic acid) and under the assumption that no recharge, mixing or depletion of activity due to isotopic fractionation has taken place.

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