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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. 2 must be submitted in *duplicate* before January 1, 1979, for vol 21, no. 3 before May 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 $\pm 1\sigma$, 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 numbers: Winter, Spring, and Summer. The deadline for v 21, no. 2 is January 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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OPTIMUM OPERATING CONDITIONS OF ^{14}C-METHANE ISOTOPE ENRICHMENT BY CONCENTRIC TYPE THERMAL DIFFUSION COLUMNS FOR USE IN RADIOCARBON DATING

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ABSTRACT. The optimum operating conditions providing minimum run-time and running costs have been studied theoretically for a thermal diffusion plant to be used for the enrichment of the radiocarbon isotope from finite sample size.

The calculations are based on a simple approximate model of the enrichment process, regarding the isotope separation column as operating under quasi-stationary state conditions. The temporal variation of the isotope accumulation is given by a single exponential term. From comparison with the numerical solution of the separation tube equation, approximate models of this simple type appear hardly sufficient for analytical work but seem well suited for optimization calculations. For column operation not too close to the equilibrium state, the approximate run-times were found accurate within 0.2 d.

The approximate model has been applied to a column of the concentric type, operated on gaseous methane. Cross-section configuration and temperatures were not varied (hot and cold wall radii: 2.0 and 2.6cm, respectively; hot and cold wall temperatures: 400°C and 14°C, respectively). The column transport coefficients used were derived from measurements. Run-time was minimized by optimizing both the operating pressure and the sample collection mode for different total sample size (range studied: 24 to 100 g), mass of enriched sample (1.8, 2.4, and 3.0 g), enrichment factor (12, 15, and 20) and column length (8 to 18 m). Optimum working pressures are between 1 and 2 atm. Usually, about 90 percent of the enriched sample mass is extracted favorably from the column itself, the length of the sampling section being about 2.5 to 5 m. Typical runtimes are between 3 days and 2 weeks, and isotope yield may reach 90 percent.

Optimum operating conditions have also been calculated for other column configurations reported in literature and are compared with the experimental results.

INTRODUCTION

The extension of the radiocarbon dating method beyond 50,000 yrs B.P. and the improvement of the statistical accuracy of the ^{14}C measurements for samples older than, say 20,000 yrs is of particular interest with regard to the history of the Earth's climate during the past 100,000 yrs. This period of time particularly, because of its proximity to the present and the availability of the ^{14}C isotope for age determination, might provide sufficient data to elucidate the interrelationship of the natural systems controlling the climate and might further allow us to elaborate a model of the climate dynamics, provided reliable and detailed time scales of the climatic variations are available.

From the present state of the measuring technique, the extension of the radiocarbon method seems best achieved by making use of both iso-

tope enrichment and high sensitive ^{14}C counting. Accordingly, several authors have been engaged in carbon-14 enrichment by thermal diffusion (deVries, Haring, and Slots, 1956; Haring, deVries, and deVries, 1958; Dickel, 1958, 1962; Pak, ms; Erlenkeuser, 1971a and ms; Felber and Pak 1973; Dickel and Kretner, 1973; Kretner, ms; Grootes and others, 1975). Successful application of this method has been reported recently by Grootes (ms) and Stuiver, Heusser, and Yang (1978).

Most of the previous attempts suffer greatly because of the large amount of radiocarbon sample required and the rather long run-times, which make isotope enrichment by thermal diffusion appear to be a method not particularly suitable for routine dating. However, as pointed out earlier (Erlenkeuser, 1971a and ms, 1976) the expenditure of sample size, run-time, and energy consumption may be reduced greatly by appropriate selection of the working conditions. We have taken up the problem of optimization anew and have studied it theoretically in greater detail than before on the basis of an approximate model of the isotope enrichment process in a thermal diffusion column.

The results show that samples up to a few g of mass may become enriched by a factor of 12 or so within a short period of time, roughly about a week, providing an isotope yield up to 90 percent. Still, it is obvious, that in spite of this high efficiency the total amount of the radiocarbon sample required appears very large and can hardly be met for many problems to be studied, such as the dating of selected foraminifera tests from deep sea cores. A solution of these problems, in a way quite different from conventional radiocarbon techniques, might be provided by the particle accelerators as used in high energy physics. This method, recently suggested by Muller (1977) and Bennett and others (1977), utilizes the large fraction of ^{14}C atoms not yet decayed and hence will require a much lower amount of sample, on the order of 1 to 100 mg.

APPROXIMATE MODEL OF THE ENRICHMENT PROCESS

The thermal diffusion plant for the enrichment of radiocarbon from samples of finite size consists of the separation column, a reservoir for storing the bulk of the sample at the negative end of the column, and, possibly, a smaller sampling volume at the opposite end, where the isotope will become concentrated (positive column end). Details have been given elsewhere (Henseler, ms, 1973; Erlenkeuser, 1976; Grootes, ms). The enrichment plant is operated on a suitable gas, such as methane or carbon monoxide prepared from the radiocarbon sample. For these gases, the heavier isotopic molecule will be transported downward and will be found enriched in the lower part of the column.

The theory of the thermal diffusion column has been worked out by Jones and Furry (1946). In a binary mixture of isotopic molecules, the transport τ of the species of interest along the column at height z is given by the transport equation

$$\tau = H\, c\, (1 - c) - K\, c_z \qquad (2.1)$$

where

c: concentration (molar fraction) of the isotope considered
c_z: partial derivative with respect to z
z: longitudinal coordinate of the column, counted in the direction of increasing concentration.

The transport coefficients H, K depend on the characteristics of the column cross section, that is the radii of the hot and cold walls, the temperatures, and the transport properties of the gas at the height z considered, and are commonly independent on z.
Introducing the equation of continuity

$$-\mu\, c_t = \tau_z \tag{2.2}$$

where

μ: mass of gas per unit length of column
c_t, τ_z: partial derivatives with respect to time t and z, respectively

we obtain the separation tube equation:

$$-\mu\, c_t = H\, c_z\, (1 - 2c) - K\, c_{zz} \tag{2.3}$$

where

c_{zz}: 2d partial derivative with respect to z

The initial concentration is

$$c\,(t = 0,\, z) = c_o \tag{2.4}$$

and the boundary conditions are

$$\begin{aligned} &\text{for } z = 0\text{: } \tau(t,\, z = 0) = -M_- \frac{dc_-}{dt} \\ &\text{for } z = L\text{: } \tau(t,\, z = L) = M_+ \frac{dc_+}{dt} \end{aligned} \tag{2.5}$$

c_-, c_+: concentrations at the negative and positive column end, respectively
M_-, M_+: mass of gas in the negative and positive reservoir, respectively
L: total active length of column

If several shorter separation units are combined and connected in series, the dead volumes and, possibly, proper exchange resistances between adjacent units have to be taken into account by means of appropriate juncture conditions (compare Erlenkeuser, 1973a). The role of dead volumes on run-time and optimum working conditions appears of secondary importance and will not be treated here in detail. As an example, these effects are briefly demonstrated in figure 4.

The quasi-linear partial differential eq (2.3) must be solved numerically by means of a finite difference scheme (Erlenkeuser, 1973a), if the calculations are to be of the same accuracy as the measurements obtained

with carefully constructed separation columns. On the other hand, several authors (Pak, ms; Felber and Pak, 1973; Kretner, ms; Kretner and Dickel, 1975; Grootes and others, 1975; Grootes, ms) report good agreement between measurements and an approximate model which describes the variation of the concentration with time by a single exponential term and one relaxation time only. A simple yet sufficiently precise model is of great interest with respect to the determination of the optimum operating conditions of the enrichment plant. It would greatly simplify the calculations and save computer time, thus allowing a more detailed investigation of the optimum working conditions with respect to run-time, total sample amount, and running costs.

Such a model has been presented by Kretner and Dickel (1975). Their model, however, neglects the isotope mass accumulated in the column itself, and this violation of the mass conservation law results in intolerably large errors under optimum working conditions at high isotope yield. Therefore, we derived another, more suitable approximative description of the enrichment process. This model was checked against the numerical solution of (2.1) and then applied to the optimization problem.

Recently, we became aware of the work of Felber and Pak (1974), who have anticipated many of the basic ideas also used in our model. However, the actual model these authors present was derived in a different way, and its accuracy suffers from an asymmetry concerning the role of the reservoirs at the column ends as compared to the amount of isotope in the column itself (compare eq 2.13).

The transport equation (2.1) is most easily solved if transport τ is assumed to be independent on the column coordinate z, that is, $\tau_z = \partial\tau/\partial z = 0$ (Fleischmann and Jensen, 1942). Strictly speaking, this assumption holds true only for the final equilibrium state and means that no isotope is being accumulated in the column itself (compare eq 2.2). Clearly, for the non-stationary state, this approximation is invalid on the long-term scale, particularly under optimum operating conditions when the positive sampling reservoir is almost negligible and a considerable amount of the isotope will be accumulated in the column. On a short-term scale, however, and under suitable boundary conditions, the enrichment process may be considered a series of consecutive stationary states, each of which accumulates a negligible amount of isotope in the column itself, while the overall accumulation is controlled by the mass conservation law. $\tau_z = 0$, then, may indeed provide a reasonably good presumption to start with.

This view appears particularly good in the case a sampling bulb is used, even a small one. The longitudinal gradient τ_z of the isotope transport and the rate of the simultaneous build-up of the concentration gradient are effectively determined by the boundary conditions. With the column end closed, the isotope carried along from the inner parts of the separation tube causes a rapid rise of concentration in an initially

infinitely small volume at the very end of the separation tube (compare boundary conditions (2.5) with $M_+ = 0$). If, on the other hand, the column feeds into a reservoir, the isotope concentration at the column end increases at a much slower rate, and the feedback on the transport τ and its variation with z is greatly reduced. With $\tau_z = 0$ and $c << 1$, eq (2.1) is solved by

$$c = \frac{\tau}{H} + \left(c_- - \frac{\tau}{H} \right) e^{2A\,z} \tag{2.6}$$

$$2A = H/K$$

Since the presumption $\tau_z = 0$ violates the equation of continuity (2.2), the mass conservation must be used explicitly in the integral form

$$M_- c_- + \mu \int_0^L c(z)\, dz + M_+ c_+ = M_0 c_0 \tag{2.7}$$

where

M_0: total working mass

Combining (2.6) and (2.7) we obtain

$$-\frac{\tau}{H} A_1 + c_- (1 + A_1) = c_0 \tag{2.8}$$

$$A_1 = \left(\frac{M_+}{M_0} + \frac{M_S}{M_0} \frac{1}{2A\,L} \right) (e^{2A\,L} - 1) - \frac{M_S}{M_0}$$

where

$M_S = \mu \cdot L$ mass of gas in the separation tube

The variation of the transport τ with time may now be derived by the aid of boundary conditions (2.5). Differentiating (2.6) with respect to time t, substituting $z = L$, and inserting (2.5) yields a simple ordinary differential equation which is solved by

$$\tau = H\, c_0\, e^{-t/\theta} \tag{2.9}$$

$$\theta = \theta_1 = \frac{1}{H} \frac{e^{2A\,L} - 1}{\frac{1}{M_+} + \frac{1}{M_-} e^{2A\,L}}$$

where

$\tau(t=0) = H \cdot c_0$ is the initial transport as given by (2.1) with $c_z(t=0) = 0$ and $c(t=0) = c_0$.

As a result of this strict mathematical treatment, the accumulation of the isotope in the column itself is reflected in the term A_1 only and does not enter the time scale parameter itself, which, for this solution, depends on the size of the reservoirs alone. From the physical point of view, however, this feature must be considered too strong a simplification, in particular for columns with small sampling bulbs as used under opti-

mum operating conditions. A better approximation may be achieved considering the isotope transport through the column cross section at the neutral point z_0, that is the point where the concentration at time t is the same as the initial one. For a concentration profile of the type as represented by eq (2.6), z_0 is found independent on time t.

$$z_0 = \frac{1}{2A} \ln (1 + A_1) \tag{2.10}$$

The isotope transport τ' at z_0 is given by the rate of the isotope depletion below or enrichment above.

$$\begin{aligned} \tau' &= -\frac{d}{dt}\left\{ M_- c_- + \mu \int_0^{z_0} c(z)\, dz \right\} \\ &= \frac{d}{dt}\left\{ M_+ c_+ + \mu \int_{z_0}^{L} c(z)\, dz \right\} \end{aligned} \tag{2.11}$$

τ' appears to represent better the average transport along the column than does the transport given by the boundary conditions (2.5). Thus, we will assume $\tau = \tau'$. Evaluating (2.11) by the aid of (2.6) and (2.10), a second relation between τ and c_- emerges in addition to eq (2.8):

$$\tau = -\left\{ M_- + \frac{M_S}{2A\,L} A_1 \right\} \frac{dc_-}{dt} + \frac{1}{H} \frac{M_S}{2A\,L} \left\{ A_1 - \ln (1 + A_1) \right\} \frac{d\tau}{dt} \tag{2.12}$$

Substituting dc_-/dt by means of (2.8) a simple differential equation is obtained providing a solution analog to (2.9) with

$$\theta = \theta_2 = \frac{1}{H} \cdot \left\{ \frac{A_1}{1+A_1} M_- + \frac{\mu}{2A} \left(\ln (1 + A_1) - \frac{A_1}{1+A_1} \right) \right\} \tag{2.13}$$

Deleting the second term in the curled brackets provides the model of Felber and Pak (1974).

Combining (2.6), (2.8), and (2.9) one obtains the concentration c as

$$\frac{c}{c_0} = e^{-t/\theta} + \frac{1 - e^{-t/\theta}}{1 + A_1} e^{2A\,z} \tag{2.14}$$

A_1 is related to the equilibrium enrichment factor m_{+eq} according to

$$m_{+eq} = \frac{c_+(t=\infty)}{c_0} = \frac{e^{2A\,L}}{1 + A_1} \tag{2.15}$$

Another quantity often used is the equilibrium separation factor q_{eq} which is given for $c << 1$ by

$$q_{eq} = \frac{c_+(t=\infty)}{c_-(t=\infty)} = e^{2A\,L} \tag{2.16}$$

Eq (2.14) fulfills the mass conservation law (2.8) regardless the functional form of θ.

Finally, the enrichment factor $\bar{m}_+$ is to be calculated of an enriched sample of mass M_{ex}, one part of which is withdrawn from the sampling section of the separation tube, while the other is collected in the positive sampling reservoir.

$$\bar{m}_+ = \frac{\mu \int_{L-\Delta}^{L} c(z)\,dz + M_+ c_+}{M_{ex} c_0} \tag{2.17}$$

$$= e^{-t/\theta} + \frac{1}{M_{ex}}\left(M_+ + M_- \frac{1 - e^{-2A\Delta}}{2A L}\right)\frac{1 - e^{-t/\theta}}{1 + A_1} e^{2A L}$$

where

Δ = length of sampling section; $0 \leqslant \Delta \leqslant L$

The run-time t_m up to a given enrichment factor $\bar{m}_+$ follows from

$$e^{-t_m/\theta} = 1 + \frac{M_{ex}(\bar{m}_+ - 1)}{M_{ex} - \frac{M_{ex} + \frac{M_S}{2A L}(1 - e^{-2A\Delta} - 2A\Delta)}{1 + A_1} e^{2A L}} \tag{2.18}$$

where $M_{ex} = M_+ + M_S \cdot \Delta/L$ and $M_+, \Delta \geqslant 0$. Note that t_m may become imaginary if the operating conditions are such that the isotope amount preassigned, $M_{ex} \cdot \bar{m}_+$, cannot be accumulated because either the column is too short and/or the total working mass of gas is too low.

COMPARISON OF THE APPROXIMATE MODEL WITH THE NUMERICAL SOLUTION

The accuracy of the approximate model derived above has been checked against the numerical solution of the separation tube eq (2.3). As shown elsewhere (Erlenkeuser, 1971a and ms, 1973a; Henseler, ms, 1977), the numerical solution provides an excellent description of the temporal behavior of the isotope enrichment at the different stages of the column, with an accuracy generally better than 1 percent of the isotope concentration, and may therefore serve as a reference for the model developed here, not only from the mathematical point of view but also with respect to the relevance of the approximate solution as to reality. The neglection of the $^{13}CH_4$ species in the following discussion is not thought to affect severely this latter point.

Both models were compared for operating conditions as of interest with respect to the radiocarbon dating method. According to the physical processes in the thermal diffusion column, the disagreement between these differently calculated enrichment factors should be greatest at the positive column end with no sampling bulb being attached. The accuracy

check has been based on this worst case in order to provide an upper limit of the error of the approximate model.

Identical boundary conditions were used, and equal numerical values were assigned to the different parameters for both computations. Since the numerical model makes no allowance for the $^{13}CH_4$ component, the numerical solution, which is valid for a ternary mixture of $^{12}CH_4$, $^{13}CH_4$, and $^{14}CH_4$, was based on a negligibly small initial concentration of the intermediate molecule of 10^{-4}, which no longer affects the ^{14}C enrichment. The calculations further assume a column without internal dead volumes.

The nature of the deviation of the approximate model from the numerical solution is illustrated by figure 1. Curves D and E (ordinate

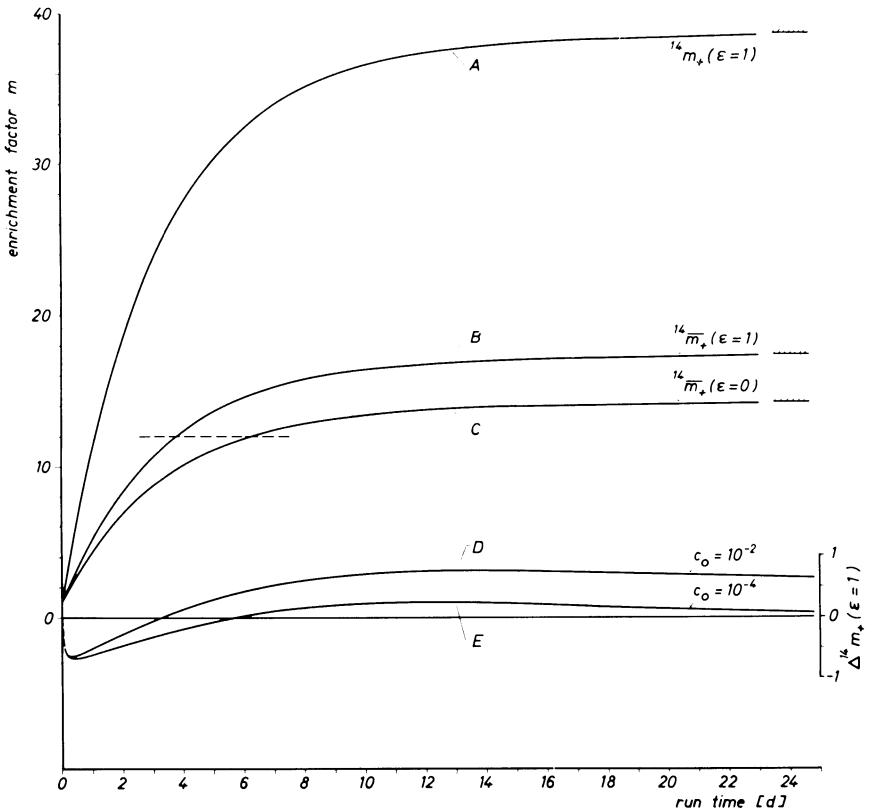

Fig. 1. Variation of different enrichment factors (curves A, B, C) and of the error of the approximate model (curves D, E) with time.

A: ^{14}C enrichment at the positive column end without sampling bulb
B: ^{14}C enrichment averaged over the sampling section of the column
C: ^{14}C enrichment in the sampling bulb
D, E: Deviation of the approximate model from the numerical solution, calculated for two concentrations of the intermediate molecule $^{13}CH_4$

(Enriched sample: 1.8g × 12, total mass of gas: 40g, column length: 10m, operating pressure: 1.4 atm).

scale at the right) show a temporal variation of the difference $\Delta^{14}m_+$ of the $^{14}CH_4$ enrichment factors at the positive column end as calculated from both methods. The enrichment factor itself is given in curve A, which represents the numerical solution. As suggested by the basic assumptions underlying the approximate model, the initial rapid rise of the isotope concentration particularly at the closed end of the column cannot be followed by the model. This is indicated by the rapidly growing deviation toward negative values (curve E). The strong isotope accumulation at the beginning, however, results in relatively steep concentration gradients, which in turn reduce the isotope transport during the later periods of time (compare eq 2.1) as compared to the approximate model which just neglects this relationship. As a consequence, the numerical solution is overtaken by the approximate model, and the deviation $\Delta^{14}m_+$ becomes progressively positive, until the mass conservation law forces both models to approach equal enrichment factors in the final equilibrium state.

The approximate model has been checked in the way just outlined for 64 working conditions that were different with respect to total working mass (grid points investigated: 24, 40, 60, 80 g), column length (6, 10, 14, 18 m), and working pressure (0.8, 1,2, 1.4, 1.8 atm), while the geometry of the column cross section and the working temperatures were not varied (table 1). Maximum isotope separation in the equilibrium state is obtained at 0.925 atm.

The greatest positive errors occur under conditions when the isotope mass in the negative reservoir will not be seriously depleted during the enrichment process, that is, for short columns, high total working mass, and intermediate pressures not too much different from the equilibrium state optimum value. The relative maximum error never exceeded +0.74 percent. It is systematically greater, however, if the proper initial concentration of the intermediate molecule, $^{13}CH_4$, is taken into account (fig. 1, curve D). This effect results from the non-linear term H c (1—c) in transport eq (2.1) indicating H (1—c) to be the effective transport coefficient rather than H itself.

TABLE 1

Fixed parameters of the thermal diffusion column

Cross-section parameters		
	Hot wall radius	: 2.0 cm
	Cold wall radius	: 2.6 cm
	Hot wall temperature	: 400°C
	Cold wall temperature:	14°C
Column transport coefficients ($^{14}CH_4$–$^{12}CH_4$)		
	H^* ($H = H^* p^2$)	: 4.4_{10-5} g/s atm^2
	K^*_c ($K_c = K^*_c p^4$):	2.6_{10-3} g cm/s atm^4
	K_d	: 1.9_{10-3} g cm/s
	$K = K_c + K_d$	

More dramatic errors occur during the initial stage. The relative maximum errors may amount to −10 percent for both $^{13}CH_4$ and $^{14}CH_4$ and are greatest when the negative reservoir is small and becomes rapidly depleted (long columns, small total working mass).

The above discussion refers to the isotope enrichment in an infinitely small mass of gas at the positive column end. Considering the integral enrichment averaged over the sampling section of the column, the relative error of the approximate model appears smaller in most cases studied but still is of the same order of magnitude. The negative error stage — the analogue to that shown in figure 1 — may extend nearly up to the equilibrium state and thus may introduce considerable error in the later period of the enrichment process. The errors observed were generally between 0 and −5 percent and never beyond −10 percent (initial $^{13}CH_4$ concentration: 10^{-4}). The positive errors in the late stages of the enrichment process were about +1 percent or less.

Similarly, the accuracy of the approximate model is not much better, if the column feeds into a sampling bulb of relatively low mass content as favored in the present context (see chap. IV). Of course, the sampling bulb greatly reduces the initial growth rate of the isotope concentration but has little effect on the transport phenomena later on, which are based on increasingly longer time scales. The latter is the result of the continuously growing fraction of the amount of gas in the separation tube becoming involved in the isotope accumulation process as it proceeds from the ends of the column toward the inner parts.

Thus, the accuracy of the approximate model under the conditions studied here appears insufficient for analytical purposes. Fortunately, however, the errors proved small enough and the rate of the isotope enrichment with time sufficiently high in most cases to provide run-time figures of reasonably good accuracy and thus make the model a useful tool for solving optimization problems. In 70 percent of the conditions studied, the run times were found to be correct within two tenths of a day, with an absolute range between 2.5 and 21 d (enriched sample: 1.8 g × 12 from column). More erroneous figures, generally too high, were found for long columns and small total working mass, when the column must be driven very close to equilibrium in order to achieve the enrichment factor wanted. Under these conditions, even small differences in the enrichment factors produce large errors in time, due to the extremely low slope of the enrichment versus time curves.

Although these results question the general value of approximate models of this simple type as studied here, they do not seriously affect their usefulness in optimization studies.

MINIMUM RUN-TIME CONDITIONS

Thermal diffusion columns for ^{14}C enrichment have been successfully operated on carbon monoxide and methane. From our view (Erlenkeuser, 1976) the latter gas appears the more convenient medium, since it is easily prepared from the radiocarbon sample, is not corrosive, can

easily be handled in the vacuum system of the enrichment plant, and can be readily analyzed for stable carbon and radiocarbon isotopes without further treatment. The following discussion is therefore confined to methane.

The run-time after which a given amount of sample gas will be found enriched by a given factor is dependent on the geometry of the separation plant, that is the width of the separation gap, the circumference of the hot tube, and the length of the separation column as well as the size and levels of the different storage, dead, and sampling volumes, and further depends on the operating conditions, that is the hot and cold wall temperatures and the working pressure. There is a complex interference of all these parameters, and the numerical evaluation of the enrichment model, even of such a simple one as derived above, can only be done by computer.

We have discussed elsewhere (Erlenkeuser, 1976) that with methane as the working gas the hot wall temperature should be as high as the thermal stability of the molecule will allow. A temperature of 400°C (673°K) appears suitable.

The width of the separation gap has a very pronounced influence on the working pressures and run-times. Although smaller gaps provide lower run-times (Erlenkeuser, 1976) problems will increase rapidly concerning the mechanical precision of the separation tube construction and, in routine work at laboratory conditions, the handling of gas pressures significantly above normal. Therefore, we have restricted the present study to a gap width of 6 mm which leads to working pressures in the range of 1 to 2 atm. The different parameters of the column cross section as used for the present calculations are compiled in table 1 and are not subjected to further discussion. The transport coefficients H and K have been derived from column experiments (Erlenkeuser, 1971a, b, 1973b).

Once the configuration of the column cross section has been selected, the working pressure affects both the distribution of the operating mass within the enrichment plant and the numerical values of the column transport coefficients H and K. As a result, the rate of the isotope enrichment is most effectively controlled by the gas pressure, and a pronounced run-time minimum can be established with respect to this parameter. This is demonstrated in figure 2 for a column 10 m long for different amounts of working gas and size of the enriched sample.

The run time is further affected by the allotment of the sample gas to be enriched to the different sampling volumes: one part, the fraction ϵ, may be withdrawn from the sampling section of the separation tube, while the other fraction, $1 - \epsilon$, will be collected in the positive reservoir. The comparatively high run-times found for small ϵ (fig 2) reflect the large amount of isotope to accumulate in the sampling bulb. As a consequence, the reservoir at the negative column end becomes far more depleted, the equilibrium enrichment factor is reduced, and the separation process must approach the equilibrium state more closely in order to achieve the enrichment factor required. This situation is illustrated

in figure 1, curves B and C. With $\epsilon = 1$, on the other hand, a higher isotope concentration must be attained at the column end in order to obtain an integral enrichment factor over the sampling section as desired. The latter mode of operation proves the more opportune (Erlenkeuser, 1976). Upon closer inspection, a compromise is found at ϵ-values about 0.7 to 0.9. In most cases, however, the minimum is flat, and run-times at optimum ϵ are hardly lower than at $\epsilon = 1$ (fig 2).

The influence of the working pressure p and the column extracted sample mass fraction ϵ on the enrichment time is illustrated in figure 2. The absolute minima as calculated from the approximate model (eq 2.18) are given by the asterisks and have been verified by the numerical solution (solid circles). Under certain conditions, such as high pressure and large sampling bulb ($\epsilon \approx 0$), the finite total amount of isotope and the limited separation power of the column do not allow the isotope to become concentrated by the preassigned factor.

In order to illustrate what run-times may be obtained at best, they have been minimized as to both working pressure and sample mass fraction ϵ and have been compiled in figure 3A in relation to the total working mass of gas for different amounts and enrichment factors of the extracted sample. All solid lines refer to a separation tube length of 10 m. Additional calculations were performed for tubes of 8, 12, 14, 16, and 18

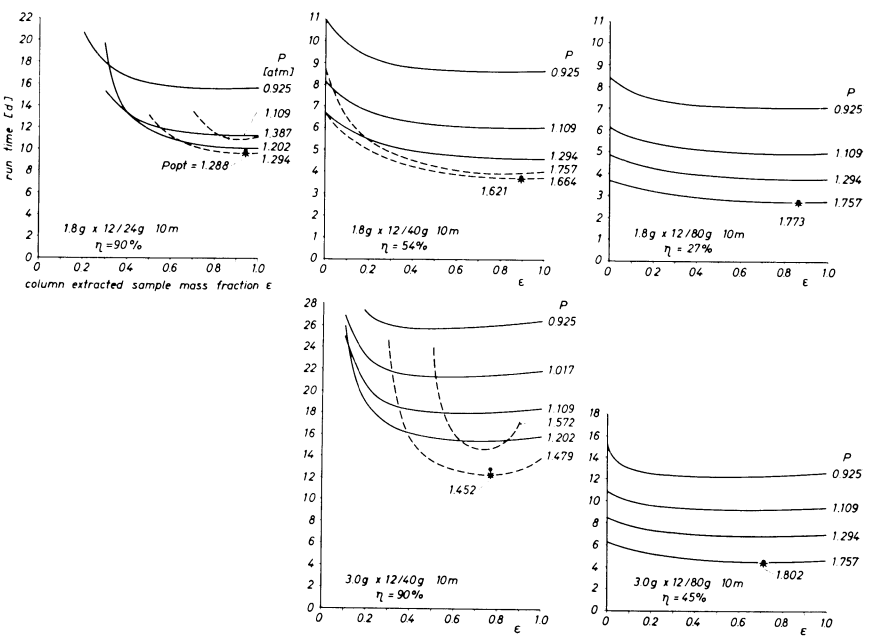

Fig. 2. The effect of working pressure and enriched sample mass fractions collected in the column itself on run-time. (Parameters given at the base of each sub-figure: mass of the enriched sample, enrichment factor, total working mass of gas, column length; η = isotope yield.)

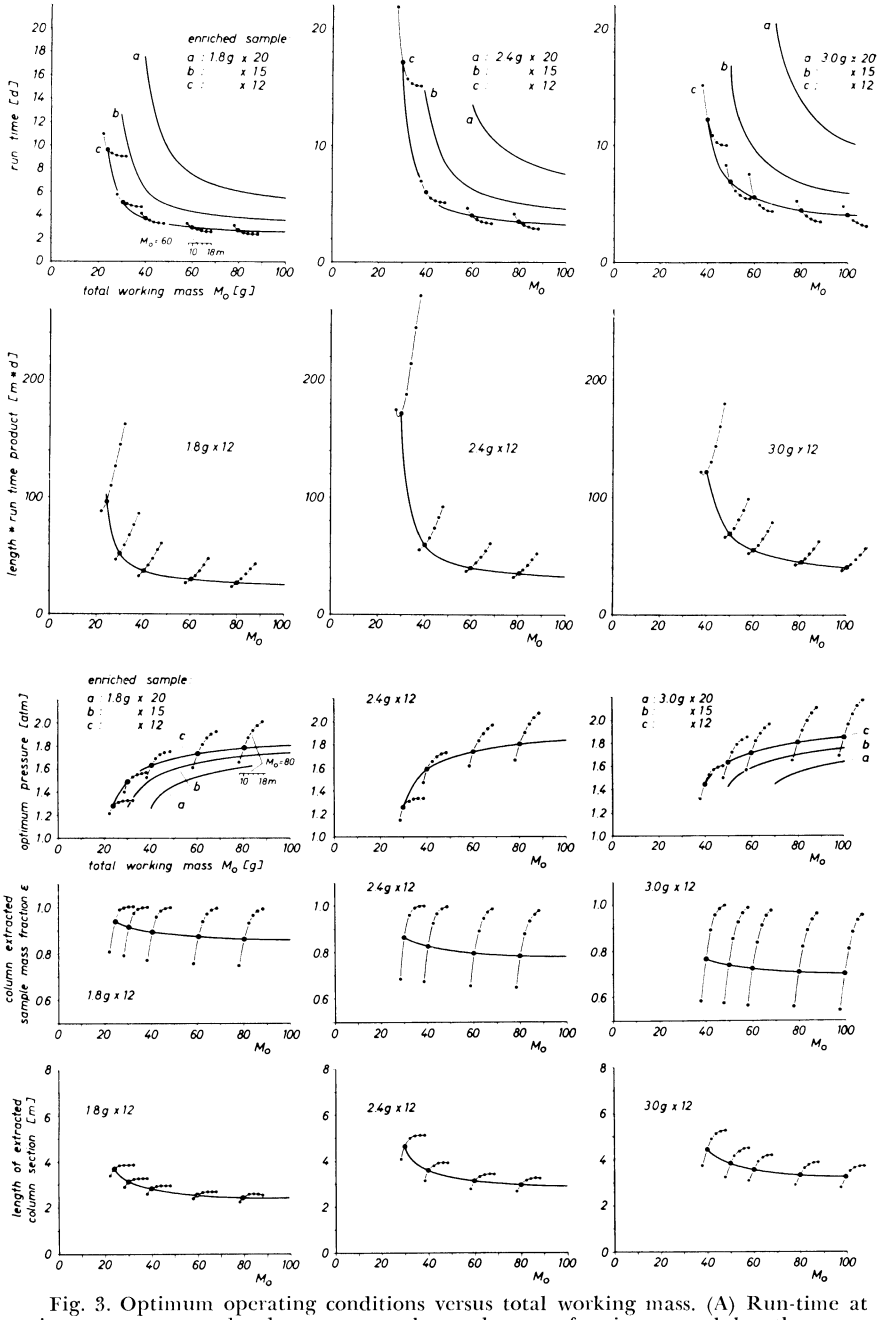

Fig. 3. Optimum operating conditions versus total working mass. (A) Run-time at optimum pressure and column extracted sample mass fraction ϵ, and length — run-time — product; (B) Optimum working pressure, optimum column extracted sample mass fraction ϵ, and optimum length of the sampling section.

m of length. These results are given by the dash-dot curves. The presentation is such that the dots proceed with column length from the left to the right, and each track relates to one single working mass m_0 which is the one indicated on the x-axis by the 10 m dot.

The results show that the amount and the isotope concentration of the enriched sample as required for the purpose of radiocarbon dating may be obtained within a few days. The run-time is smaller the greater the initial amount of the isotope.

The optimum enrichment pressures (fig 3B) are between 1 and 2 atm. They are generally higher than the maximum separation pressure in the equilibrium state (0.925 atm) which they approach, however, when the negative reservoir becomes strongly depleted, and high separation factors must be attained in order to achieve the enrichment preassigned.

The column extracted sample mass fraction ϵ is found close to 1 (fig 3B), in particular for small gas samples withdrawn. On the other hand, if greater sample amounts are needed, the use of a slightly greater positive reservoir appears more opportune. The actual sampling sections are about 2.5 to 5 m long (fig 3B). Reminding the flatly shaped minimum of run-time with respect to ϵ, the length of the sampling section does not seem critical for many of the conditions of practical interest, and a section of fixed length, such as one separation unit of, say, 2.5 to 3 m, may be used throughout without appreciable loss of time.

Run-time may be further reduced by increasing the length of the separation tube (fig 3A). However, since the isotope transport along the column is determined by the cross-section data rather than by the length of the column, a noticeable gain is obtained at high isotope yield only, as due to the increased separation power (eq 2.16) which allows the enrichment process to be finished well before the equilibrium state has been approached too closely.

On the other hand, the operating costs, which may be taken proportional to the length-run-time-product, will strongly increase with column length. Henseler (1977) reports an electric power consumption of 5.6 watt per cm column length at 350°C hot wall temperature and a total cooling water flow of 650 l/h to give an average cold wall temperature of 14°C (10m column, 4 units, cooled in parallel). According to the numerical results shown in figure 3A, a column length of 10 m appears an agreeable compromise, which keeps operating costs low and simultaneously allows the desired amount of isotope to be collected within a convenient period of time. The run-times calculated above are minimum figures which do not take into account the dead volumes arising if several separation units of shorter length are arranged in series to form the actual column. Dead volumes at the ends of each unit cannot be avoided for constructional reasons and are introduced by the thermal convection loops which provide the gas exchange between consecutive units.

The approximate model has been extended to include the dead volumes at the corresponding level of the column and has been applied

to a four stage column of 10 m total length enclosing three dead volumes, 0.4 l each (for comparison: volume of one unit: 2.2 l). The column sampling length was kept constant at 2.5 m, that is the length of one unit, while the working pressure was optimized to yield minimum run-time. In general, the run-times calculated came out higher by about 0.5 d as compared to the former results shown in figure 3A. The effect of dead volumes — and of the non-optimal sampling length — becomes more pronounced at high isotopic yield and under near-equilibrium conditions. For example, run-time increased from 9.6 to 12.4 d for a sample of 1.8 g, 12-fold enriched, out of a total working mass of 24 g. With dead volumes included, the optimum working pressures are lower by a few tenth of an atm than those given in figure 3B. Another example of the effects of dead volumes is shown in figure 4C.

As a result, it appears from the calculations presented that the enrichment of ^{14}C by thermal diffusion is a sufficiently fast and low sample mass consuming method to be used in routine radiocarbon dating work.

MEASUREMENTS

The results presented above are not directly supported by measurements as one might wish in regard to the surprisingly short run-times predicted by theory. Indirect support is given by the fact, that the essential parameters not known a priori, that is the column transport coefficients, have been determined from careful column experiments. These were run at comparatively low enrichment factors, however, so that their use for predicting the behavior of the column at a higher state of enrichment might be questioned. Thus, further experimental results, even if not gained at optimum conditions, would greatly help to elucidate the relevance of the theoretical calculations.

Due to the lack of our own measurements, published data were analyzed on the basis of the model presented here. Radii and length of the separation tubes and the amount of the final gas sample and its enrichment factor were taken from the literature. The column transport coefficients, however, have been derived by a least square fit of the present approximate model to the experimental results, inserting the geometrical configuration of the column and the experimental conditions as given by the authors. The numerical values of these coefficients are closely bound to the model used in the fit and may not compare with the authors' estimates obtained on a different way. They may be affected additionally by small dead volumes not mentioned by the authors or by slightly different working conditions of the enrichment units combined in the column. Hence, the optimum conditions shown in figure 4 should be regarded as qualitative rather than quantitative results. The data used for the optimization calculations are compiled in table 2.

Felber and Pak (1973) have established a short column, 4 m long, consisting of two shorter elements; the narrow separation gap (width: 3 mm) provides a comparatively high separation power. The enriched sample is taken from a positive reservoir.

TABLE 2

Parameters of thermal diffusion ^{14}C enrichment experiments by different authors and column transport coefficients underlying figure 4

		Felber and Pak (1973)	Kretner (1973)			Henseler (1977)
Column dimensions						
Hot wall radius	R_H (cm)	1.5	2.25			2.0
Cold wall radius	R_K (cm)	1.8	2.75			2.6
Total column length	L (cm)	400**	1079***			4 × 254.5†
Neg. reservoir	V_- (l)	41 at 22°C	250 at 19°C			85 at 22°C
Pos. reservoir	V_+ (l)	0.893 at 22°C	2.0 at 19°C			0
Operating conditions*						
Hot wall temp.	T_H (°C)	480	309			334
Cold wall temp.	T_K (°C)	40	19			14
Pressure	p (atm)	4.25	0.967			1.00
Experimental results						
Enriched sample size		2.52g × 14.4	1.3g × 12			2.47g × 10.6
Collection mode		pos. bulb	pos. bulb			col. 3 + col. 4†
Run-time	(d)	15	17.2			11
Transport coefficients used for calculation			curve			
			A	B	C	
H*	($g\ s^{-1}\ atm^{-2}$)	$2.22\ 10^{-6}$	$2.32\ 10^{-5}$	$2.32\ 10^{-5}$	$2.32\ 10^{-5}$	$3.6\ 10^{-5}$
K^*_e	($g\ cm\ s^{-1}\ atm^{-4}$)	$8.31\ 10^{-6}$	$5.14\ 10^{-3}$	$5.14\ 10^{-3}$	$2.6\ 10^{-3}$	$4.2\ 10^{-3}$
K_d	($g\ cm\ s^{-1}$)	$0.7\ 10^{-3}$	$1.7\ 10^{-3}$	$1.7\ 10^{-3}$	$1.7\ 10^{-3}$	$1.9\ 10^{-3}$

* Working gas: CH_4; ** Intermediate dead volumes not known; *** No intermediate dead volumes; † Succession of separation units and dead volumes (in cm^3 at 22°C):

V_-, col. 1, 462, col. 2, 216, {246, col. 3, 216, [269, col. 4, 69,} V_+]

In curled brackets: part from which enriched gas was sampled in the experiment

In square brackets: sampling configuration for curves A A′ in figure 4C.

The column transport coefficients H, K have been determined as mentioned above. K_c was obtained from K, subtracting K_d as calculated by the authors: K_d is known to be little affected by constructional inadequacies and may be calculated from the working gas transport properties with good reliability.

The experimental result of Felber and Pak is indicated by the open circle in figure 4A. Increasing the working pressure and making use of the column itself for sample gas collection would have lowered the run-time markedly (fig 4A, curve A, at optimum pressure and collection mode conditions). Apparently, however, the column is driven rather close to the equilibrium state. An appreciable reduction of run-time will result from increasing the length of the column (curves B, C, optimum conditions). The run-times, then, are of the same magnitude as calculated earlier (fig 3A), for almost the same size of the enriched sample (2.4 g $\times$ 15).

Kretner (1973) established a one-unit-column 10 long. He presents numerous measurements of the ^{13}C enrichment at different operating pressures. However, a consistent set of the pressure reduced coefficients H^* and K^*_c ($H = H^* p^2$, $K = K^*_c p^4 + K_d$) equally valid for all pressures studied could not be derived from these results within acceptable limits of error, and no figure of K_d could be estimated from the variation of K with the operating pressure. K_d, therefore, had to be calculated theoretically from the gas transport properties. Furthermore, the rate of the ^{14}C enrichment measured by Kretner appears very much slower than expected from the ^{13}C isotope enrichment. This might be accounted for by the relatively large samples of highly enriched gas frequently withdrawn from the positive reservoir in order to measure in detail the progress of the ^{14}C enrichment with time.

In view of the low reproducibility of the column coefficients as estimated by means of our model, minimum run times have been calculated both for the most favorable set of parameters derived from Kretner's ^{13}C studies (fig 4B, curve C) and the worst case provided by the ^{14}C measurements (curve B). For comparison, curve A; like curve B, for the most unfavorable case, illustrates the run-time at optimum size of the sampling reservoir, with the pressure kept constant as used by Kretner (table 2). In this letter case, run-times are not subjected to pressure dependent errors as otherwise might arise from systematically wrong estimates of the column coefficients. According to curve A, the run-time under Kretner's conditions (open circle) would reduce at optimum collection conditions by about 3 days.

The run-times shown in figure 4B are markedly higher also in the most favorable case (curve C) than calculated earlier (fig 3A) for an enriched sample of comparable size. As compared to a theoretical estimate the figure of K_c as used in table 2 appears very high and seems to reflect a large contribution of parasitic remixing effects in the column.

Henseler (1977) operated a 10 m thermal diffusion column consisting of four enrichment units, each 2.5 m long. The units are connected by

thermoconvection loops, which did not impede the isotope exchange between adjacent units in any way. Starting with 62g of methane, Henseler obtained a sample of 2.47g, 10.6 fold enriched within 11 days (fig 4C, open circle). No positive sampling bulb was used.

The different intermediate dead volumes (table 2) between the enrichment units have been taken into account in an appropriately modified version of our model. Effective transport coefficients, the same for all elements of the column, were introduced in order to make allowance for slightly different working temperatures of the four separation units. If adjusted to the $^{13}CH_4$ enrichment, the model was found to meet the measured variation of this species with time on the different stages of the column, and the accuracy was satisfying also at the positive column end.

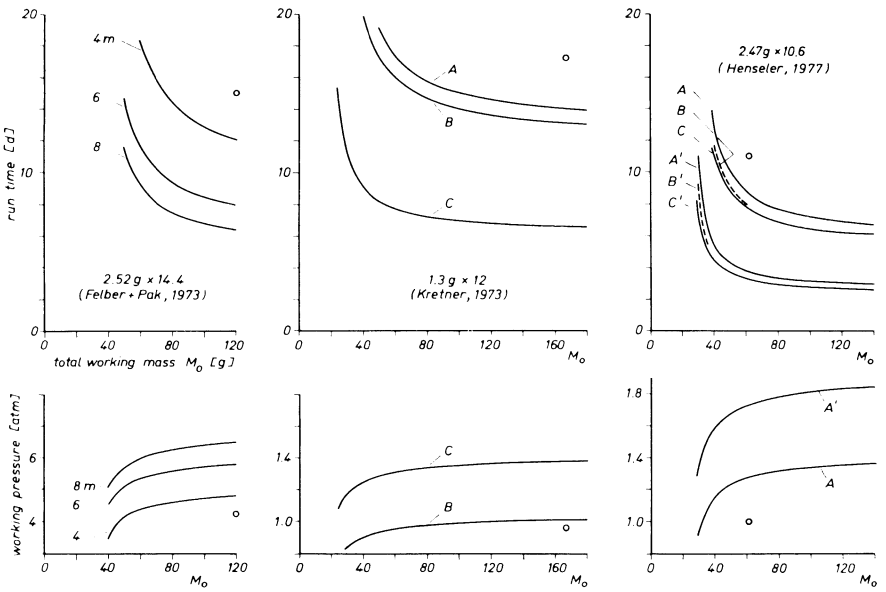

Fig. 4. Results of ^{14}C enrichment experiments (o) as compared to theoretical prediction. (Size of enriched sample as specified; for details see text and table 2.)

A. Felber and Pak (1973): 4 m column with sampling bulb; curves represent optimum working pressure and sampling mode conditions for different column lengths.

B. Kretner (1973): 10.79 m column with sampling bulb.

A: 735 Torr working pressure; optimum sampling mode conditions.

B, C: Optimum working pressure and sampling mode conditions for extrema of remixing coefficient K^*_c as obtained from re-evaluation of experiments.

C. Henseler (1977): 10.19 m 4-stage column; upper 2 columns for sample collection; no sampling bulb.

Curves: sample collected from upper column only; optimum working pressure conditions.

A, A': intermediate dead volumes included.

B, B': dead volumes set zero.

C, C': as B, B'; optimum working pressure and sample collection mode conditions.

(Parameters of A', B', C', as given in table 1.)

For collection of the enriched sample, Henseler combined the contents of the two upper separation units (table 2). This large sampling length (about 5m or half of the column length) keeps the average enrichment low and yields correspondingly long run-times. More favorable conditions are achieved if the sample collection is restricted to the upper tube, supplemented by an appropriately sized positive reservoir. Run-times obtained for these conditions at optimum working pressure are presented in curve A of figure 4C. If additionally the intermediate volumes are set to zero, run-times are lowered by another 0.5 to 1 day (curve B). No important further improvement is gained if the sampling section of the column is optimized (curve C). The optimum operating pressures for curves A, B, C are the same within a few tenths of an atm and are represented by one curve only (fig 4C, lower part).

For comparison the calculations were repeated using the column coefficients of table 1. The results are shown in figure 4C, curves A′, B′, C′, which otherwise are equivalent to curves A, B, C, respectively. The very much lower run-times are the effect of the higher hot-wall temperature assumed in table 1, which not only increases the separation coefficient H* but also yields a much lower remixing coefficient K^*_e (Erlenkeuser, 1976).

Henseler's experiments at least demonstrate that the enrichment of ^{14}C for the purpose of radiocarbon dating may be performed in a comparatively short period of time and at good isotope yield. Moreover, his results are likely to become improved further by selecting more suitable experimental conditions.

The calculations were performed on the PDP10 computer at the University of Kiel computer center.

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LA JOLLA MEASUREMENTS OF RADIOCARBON IN THE OCEANS

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INTRODUCTION

The La Jolla Radiocarbon Laboratory has measured carbon-14 concentrations in seawater samples collected from 1957 through 1972. The dissolved inorganic carbon in seawater was extracted on board research vessels and was returned to the laboratory for processing and measurement. Both surface and sub-surface samples were collected, primarily from the Pacific Ocean, but also from the Indian Ocean. The purpose of the seawater measurements was to determine the distribution of bomb-produced radiocarbon in the surface water of the Pacific and Indian Oceans, the sub-surface penetration of bomb ^{14}C, the change in $^{14}C/^{12}C$ ratios with depth, and thus the rate of uptake of bomb ^{14}C by the oceans. This project was the basis of the author's doctoral dissertation (Linick, 1975).

The carbon dioxide of the atmosphere is constantly in exchange with the dissolved inorganic carbon of the sea, the oceans containing ca 60 times the amount of carbon dioxide found in the atmosphere (Revelle and Suess, 1957; Craig, 1958). This dissolved inorganic carbon is primarily in the form of bicarbonate because of the equilibrium constants of the aqueous carbon system. Prior to this century, both the quantities of dissolved inorganic carbon and the concentrations of carbon-14 were under approximately steady state conditions, as the atmospheric CO_2 concentration and the natural production rate of ^{14}C were approximately constant. Secular variations in the ^{14}C production rate and perhaps also changing oceanographic conditions have caused variations of up to 10% in the atmospheric ^{14}C levels during the past 7000 years (Suess, 1970). Since the beginning of this century, man has added sufficient ^{14}C-free carbon dioxide from the combustion of fossil fuels to increase measurably the concentration of carbon dioxide in the atmosphere and to decrease the atmospheric $^{14}C/^{12}C$ ratio; these quantities have also changed somewhat in surface seawater. Since 1954, the detonations of nuclear weapons, particularly the tests of the USA and USSR in 1961 and 1962, have released large quantities of additional radiocarbon into the atmosphere. The measurements of seawater samples monitored the transfer of this bomb-produced radiocarbon from the atmosphere into the oceans. In addition to the La Jolla measurements, seawater ^{14}C programs have been carried out by the New Zealand laboratory of T A Rafter, which measured samples from the South Pacific (Rafter, 1968; Rafter and O'Brien, 1970; Rafter and O'Brien, 1972), the Lamont laboratory of W S Broecker, which measured samples from the Atlantic

Ocean (Broecker and Olson, 1959; Broecker *et al,* 1960), and by several laboratories in Europe.

The sampling for this laboratory was performed primarily from research vessels of the Scripps Institute of Oceanography (SIO). Generally, 200 to 225L of seawater were obtained for each sample, almost filling a polyethylene-lined steel drum. Surface water was usually collected through a non-contaminating seawater pumping system aboard the ships; in such cases the water samples came from a few meters below the sea surface at the ship's bow. Several different systems involving metal barrels with remote closing devices were used for collection of sub-surface samples. Collection of sub-surface samples (depth profiles) had to be terminated after 1965, because continuation of funding of sub-surface water collection was denied by the U S Atomic Energy Commission. The carbon dioxide was extracted aboard the ship: The seawater was acidified with sulfuric acid and heated to ca 50°C. The CO_2 was absorbed in ca 0.70L of a solution ca 15 F in NH_4OH and 1 F in $SrCl_2$. The extraction system used for the last several years of sample collection involved recirculating for at least four hours the small amount of air above the seawater through a diffuser head immersed in the sealed bottle containing the absorber solution and returning the air (with seawater carbonate removed) to the drum via a diffuser head immersed deep into the water in the drum; a Masterflex peristaltic pump was used for this gas recirculation. The inorganic carbon originally dissolved in the seawater and then in the form of CO_2 gas was swept from the drum by the air and dissolved in the absorber solution. The absorber bottle containing the $SrCO_3$ precipitate plus absorber solution was sealed and eventually returned to the laboratory for processing. In the laboratory, the solution was decanted and the precipitate dried under vacuum. The $SrCO_3$ was then reacted with 2 F HCl on the high vacuum lines; the resulting CO_2 was converted to acetylene, our counting gas, in the usual manner. The method, detectors, and electronics used are those described by Linick (1977). Counting pressures from 400 to 1000mm Hg were utilized.

The ocean-atmosphere carbon system is quite complex. The atmospheric CO_2 exchanges at the ocean surface with that dissolved in the seawater. Once in the surface water, or so-called mixed layer, of the ocean, the distribution of dissolved CO_2 is dependent on several factors: (1) the horizontal movement of water currents; (2) the vertical movement of water, *ie,* upwelling and downwelling; (3) the stratification of water masses (eg, the barrier to exchange formed by the thermocline at the bottom of the mixed layer; (4) horizontal and vertical diffusion; and (5) particulate flux, *ie,* the incorporation of "new" CO_2 by near-surface organisms, transfer via the food chain, and eventual descent (and possible dissolution en route) of dead matter to the sea floor.

The data presented here constitute all of the seawater sample measurements by this laboratory from 1957 through 1976. The radiocarbon results are given as Δ values relative to 95% of NBS oxalic acid

activity, age-corrected to 1950 and isotopically-corrected to $\delta^{13}C = -25‰$ (PDB). Some values have been published previously, in particular, those listed in Tables 1 through 14 (Bien *et al,* 1960, 1963a, 1963b, 1965; Bien and Suess, 1967). The author has re-evaluated the counting data for the years 1957 to 1969 and revised background and standard values. In a very few cases, counting data for certain samples were found to be invalid due to electronics or detector malfunctions. Such data, which had been included in previously-published tables have been omitted; in a few other cases, previously-unpublished results from 1957 to 1969 have been added here.

The measurements were carried out with an accuracy considered adequate for our purpose. A higher precision could have been achieved by using larger water samples and/or longer counting times. This, however, appeared uneconomical, time consuming, and unnecessary for the purpose of deducing basic oceanographic parameters. Likewise, measurements of the total content of inorganic carbon were considered superfluous.

As can be recognized easily, the data show an impressive minimum along the equator and in other regions of the Pacific Ocean where upwelling occurs. Consistently high Δ values are observed in the central areas of the large Pacific gyres. Evaluation of these data in terms of rates of ^{14}C-exchange, circulation, and upwelling is planned and will be published elsewhere. In this connection, continuation of these measurements for many more years appears desirable. With no further release of large ^{14}C quantities into the atmosphere the concentration differences in surface water should gradually disappear. Because of lack of funds we were not in a position to continue this program but fortunately Geosecs plans to continue these observations.

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PRESENTATION OF DATA

The measurements are given in several data tables. Each table gives results for one cruise, or sometimes for more than one cruise if only a few samples were collected on each cruise from the same approximate period of time. The tables are chronologically ordered, from earliest sampling to most recent. The tables which follow contain several columns of information that can be used in the interpretation of the radiocarbon data. An asterisk in place of a value indicates that the quantity was not measured or was otherwise unavailable. When $\delta^{13}C$ was not measured, a value of 0.0‰ was used in tables 1 through 15, a value of +1.2‰ in tables 16 through 26. Some column headings are described below:

Depth = sampling depth in meters below sea surface. Sample designated as being from Om may actually be from a few meters below the sea surface.

Salinity = as measured on a conductance bridge salinometer

σ_t = difference, ‰, between density of water of given temperature and salinity at 1 atm pressure and density of pure water at 4°C and 1 atm pressure. This is the accepted method of expressing the density of seawater. Values were calculated by the author from Knudsen (1953) and Matthews (1932) or from U S Navy Hydrographic Office (1956), which present tables of value for calculating σ_t for a given temperature and salinity.

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TABLE 1

Seawater samples collected by *Sayed el Wardanni*

LJ no.	Sample Sta No.	Collη date (1957)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-441	1	8 Aug	50 13N	177 42W	0	*	*	*	*	−72 ± 13
-442	2	8 Aug	50 13N	177 42W	6000	*	*	*	*	−170 ± 12
-443	3	13 Aug	50 42N	177 17W	0	*	*	*	*	−81 ± 13
-444	7	13 Aug	51 08N	174 41E	6200	*	*	*	*	−76 ± 13
-445	8	19 Aug	52 40N	178 05E	3500	*	*	*	*	−221 ± 12
-447	10	14 Sept	52 00N	150 46E	5200	*	*	*	*	−196 ± 12

TABLE 2

Seawater samples from *Downwind* Expedition

LJ no.	Sample Sta No.	Collη date (1957)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-58	2	26 Oct	19 35N	125 00W	0	24.4	34.69	23.33	−0.5	−26 ± 21
-59	3	28 Oct	14 58N	127 31W	2987	1.66	34.69	27.76	−1.2	−191 ± 8
-60	4	30 Oct	11 00N	128 30W	350	10.9	34.65	26.55	−1.5	−74 ± 14
-61	5	31 Oct	07 08N	129 16W	3508	1.48	34.69	27.78	−1.4	−210 ± 6
-62	6	2 Nov	05 00N	130 00W	0	28.0	34.40	21.97	−0.1	−6 ± 8
-63	7	4 Nov	02 08S	131 27W	3473	1.52	34.69	27.77	−1.3	−195 ± 8
-66	8	5 Nov	07 00S	132 00W	0	26.7	34.68	22.60	−1.0	−38 ± 19
-57	9	8 Nov	14 29S	135 30W	3450	1.58	34.69	27.78	−1.8	−190 ± 6
-67	10	23 Nov	25 00S	145 00W	3560	1.54	34.65	27.74	−2.9	−167 ± 15
-68	11	28 Nov	34 50S	135 53W	0	17.7	35.05	25.41	−0.4	+6 ± 10
-69	12	1 Dec	40 35S	132 10W	3500	1.50	34.67	27.77	−1.2	−162 ± 7
-88	13	6 Dec	46 46S	123 53W	3550	*	*	*	−2.0	−168 ± 6
-90	14	8 Dec	46 30S	116 00W	0	9.2	34.67	26.85	−0.7	−21 ± 5
-91	15	14 Dec	40 37S	103 20W	3500	1.85	34.67	27.75	−2.5	−150 ± 7
-93	16	15 Dec	42 43S	096 06W	0	14.5	34.01	25.94	−0.6	−12 ± 7
-94	17	19 Dec	39 33S	084 10W	3508	1.46	34.68	27.78	−1.9	−159 ± 6

TABLE 3

Seawater samples from *Dorado* Expedition, *Horizon* Cruise 5910H (Reid), and SIO Pier

LJ no.	Cruise	Sample/Sta No.	Collection date (1959)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-146	Dorado	1	27 July	05 32N	120 05W	10	27.5	33.50	21.38	−1.2	−75 ± 8
-140	Dorado	2	27 July	05 32N	120 05W	487	7.88	34.67	27.05	−2.5	−144 ± 6
-147	Dorado	3	28 July	05 32N	120 05W	1077	4.12	34.63	27.50	−1.8	−192 ± 11
-139	Dorado	4	30 July	08 29N	120 09W	2280	1.97	34.70	27.76	−1.7	−244 ± 5
-137	Dorado	5	30 July	08 29N	120 09W	3376	1.58	34.70	27.79	−0.7	−204 ± 6
-149	Reid	1	14 Oct	30 27N	117 48W	10	19.30	33.48	23.80	+1.9	−9 ± 5
-150	Reid	2	14 Oct	30 27N	117 48W	75	15.85	33.44	24.69	+1.0	−38 ± 6
-151	Reid	3	14 Oct	30 27N	117 48W	120	13.40	33.48	25.15	+0.2	−42 ± 8
-152	Reid	4	14 Oct	30 27N	117 48W	390	6.60	33.16	26.04	−1.9	−98 ± 11
-153	Reid	5	14 Oct	30 27N	117 48W	580	5.68	34.34	27.10	−6.0	−166 ± 8
-154	Reid	6	14 Oct	30 27N	117 48W	1970	2.04	34.66	27.73	−1.6	−215 ± 5
-155	Reid	7	14 Oct	30 27N	117 48W	2480	1.80	34.67	27.75	+0.3	−227 ± 5
-127	SIO Pier	1	6 Aug	32 52N	117 44W	0	22.6	*	*	−2.3	−90 ± 10
-534	SIO Pier	2	31 Aug	32 52N	117 44W	0	*	*	*	*	−17 ± 15

TABLE 4

Seawater samples from *Limbo* and *Tethys* Expeditions

LJ no.	Cruise	Sample/Sta No.	Collection date (1960)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-285	Limbo	1	15 June	28 12N	139 07W	518	*	34.061	*	*	−155 ± 11
-282	Limbo	2	13 June	28 12N	139 07W	1607	*	34.57	*	−1.2	−246 ± 14
-283	Limbo	3	13 June	28 12N	139 07W	2463	*	34.65	*	−1.1	−234 ± 6
-284	Limbo	4	14 June	28 12N	139 07W	3519	*	34.68	*	−1.2	−228 ± 5
-328	Tethys	1	21 July	15 42N	155 22W	0	*	*	*	+1.8	−18 ± 12
-494	Tethys	2	26 July	07 03N	158 38W	0	*	*	*	*	−45 ± 13
-495	Tethys	3	29 July	08 14N	156 38W	0	*	*	*	*	−26 ± 13

TABLE 5

Seawater samples from *Monsoon* Expedition

LJ no.	Sample/Sta No.	Colln date (1960-1961)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
		(1960)								
-484	I'-11	19 Oct	10 31S	105 34E	0	28.4	34.41	22.18	*	−38 ± 13
-396	III-4	12 Nov	10 28S	099 00E	100	*	34.336	*	*	+15 ± 10
-398	III-4	12 Nov	10 28S	099 00E	343	10.44	34.675	26.63	*	−90 ± 20
-395	III-4	12 Nov	10 28S	099 00E	960	4.94	34.624	27.40	*	−87 ± 10
-393	III-4	12 Nov	10 28S	099 00E	3000	2.68	34.672	27.67	*	−108 ± 10
-394	III-4	12 Nov	10 28S	099 00E	3424	1.33	34.695	27.79	*	−102 ± 10
-498	I'I-6	24 Nov	10 31S	094 55E	350	10.27	34.631	26.63	*	−122 ± 12
-483	III-10	27 Nov	18 49S	088 33E	0	25.53	34.571	22.89	*	−24 ± 13
-496	III-12	29 Nov	13 00S	075 00E	350	14.05	35.410	26.52	*	−46 ± 8
-499	III-16	2 Dec	14 05S	072 15E	350	10.30	34.880	26.83	*	−62 ± 8
-487	III-20	5 Dec	17 15S	063 50E	0	*	*	*	*	+48 ± 11
-497	III-20	5 Dec	17 15S	063 50E	350	*	*	*	*	−66 ± 13
-490	IV-3	13 Dec	23 00S	064 10E	0	*	*	*	*	−25 ± 13
-351	IV-5	15 Dec	23 55S	073 53E	0	23.86	35.472	24.06	*	−16 ± 8
-406	IV-5	15 Dec	23 55S	073 53E	100	*	*	*	*	−29 ± 10
-350	IV-5	15 Dec	23 55S	073 53E	1016	4.69	34.418	27.26	*	−99 ± 8
-349	IV-5	15 Dec	23 55S	073 53E	1956	2.54	34.818	27.80	*	−161 ± 8
-343	IV-5	15 Dec	23 55S	073 53E	3339	1.41	34.803	27.88	*	−184 ± 8
-342	IV-9	18 Dec	33 21S	072 42E	0	18.32	35.50	25.59	+0.6	−52 ± 14
-405	IV-9	18 Dec	33 21S	072 42E	100	*	*	*	*	−47 ± 10
-339	IV-9	18 Dec	33 21S	072 42E	1000	5.44	34.406	27.16	−0.4	−110 ± 10
-392	IV-9	18 Dec	33 21S	072 42E	3050	1.62	*	*	0.0	−193 ± 10
-340	IV-9	18 Dec	33 21S	072 42E	3987	1.15	34.703	27.82	−0.6	−204 ± 10
-404	IV-11	21 Dec	42 03S	070 45E	0	10.88	34.430	26.37	*	−52 ± 7
-403	IV-11	21 Dec	42 03S	070 45E	100	*	*	*	*	−68 ± 10
-401	IV-11	21 Dec	42 03S	070 45E	1000	3.35	34.396	27.39	*	−134 ± 10
-402	IV-11	21 Dec	42 03S	070 45E	3000	1.55	34.742	27.82	*	−171 ± 10

-374	IV-11	21 Dec	42 03S	070 45E	3400	1.25	34.689	27.79	*	−166 ± 10
-488	IV-16	25 Dec	37 51S	084 45E	0	*	*	*	*	+15 ± 10
-359	IV-19	29 Dec	36 18S	098 41E	0	15.40	35.151	26.01	*	−26 ± 14
-383	IV-19	29 Dec	36 18S	098 41E	100	*	*	*	*	−24 ± 9
-369	IV-19	29 Dec	36 18S	098 41E	1066	4.47	34.377	27.26	*	−96 ± 8
-355	IV-19	29 Dec	36 18S	098 41E	3469	1.17	34.718	27.82	*	−142 ± 8
		(1961)								
-486	IV-20	1 Jan	33 14S	108 45E	0	18.32	35.50	25.60	*	−5 ± 9
-489	V-4	12 Jan	49 29S	132 17E	0	9.3	34.339	26.58	*	−14 ± 11
-321	VI-11	7 Feb	58 20S	168 58E	0	6.32	34.038	26.77	+0.4	−57 ± 12
-320	VI-11	7 Feb	58 20S	168 58E	740	3.38	34.224	27.24	−0.5	−109 ± 7
-319	VI-11	7 Feb	58 20S	168 58E	1400	2.43	*	*	−1.3	−152 ± 7
-318	VI-11	7 Feb	58 20S	168 58E	2100	*	34.766	*	−2.0	−152 ± 17
-317	VI-11	7 Feb	58 20S	168 58E	2944	1.48	34.372	27.53	−1.1	−170 ± 9
-316	VI-11	7 Feb	58 20S	168 58E	3825	*	34.277	*	−1.4	−176 ± 6
-410	VI-17	13 Feb	64 11S	168 58W	0	1.70	34.009	27.23	*	−124 ± 6
-412	VI-20	15 Feb	60 12S	171 32W	0	5.50	34.002	26.85	*	−80 ± 7
-414	VI-23	16 Feb	57 34S	144 15W	0	*	*	*	*	−58 ± 10
-413	VI-24	17 Feb	55 39S	177 51W	0	*	*	*	*	−60 ± 7
-417	VI-26	19 Feb	52 37S	178 57W	0	*	*	*	*	−41 ± 7
-418	VI-28	20 Feb	49 42S	178 52W	0	9.3	34.34	26.58	*	−52 ± 10
-408	VII-9	3 Mar	40 22S	164 24W	0	*	*	*	*	−22 ± 6
-409	VII-14	5 Mar	36 27S	163 09W	0	*	*	*	*	−19 ± 6
-326	VII-16	7 Mar	34 04S	161 54W	0	21.4	35.103	24.50	*	−26 ± 16
-327	VII-16	7 Mar	34 04S	161 54W	3350	*	*	*	*	−218 ± 10
-415	VII-19	9 Mar	30 26S	160 32W	0	*	34.8	*	*	−3 ± 7
-325	VII-23	11 Mar	26 29S	160 33W	0	27.2	35.56	23.10	*	−37 ± 7
-324	VII-23	11 Mar	26 29S	160 33W	3500	*	*	*	*	−213 ± 10
-416	VII-25	12 Mar	24 41S	155 15W	0	*	34.88	*	*	−22 ± 6

TABLE 6

Seawater samples from *Swan Song* Expedition

LJ no.	Sample/Sta No.	Colln date (1961)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-420	2	20 Aug	27 27N	150 35W	10	25.04	35.283	23.56	*	−4 ± 30
-421	3	20 Aug	27 27N	150 35W	716	4.55	34.194	27.11	*	−172 ± 6
-425	5	20 Aug	27 27N	150 35W	1042	3.84	34.436	27.37	*	−206 ± 10
-426	6	20 Aug	27 27N	150 35W	2300	1.85	34.665	27.73	*	−240 ± 10
-427	7	20 Aug	27 27N	150 35W	3165	1.55	34.677	27.77	*	−231 ± 7
-428	8	20 Aug	27 27N	150 35W	3630	1.50	34.684	27.78	*	−229 ± 10

TABLE 7

Seawater samples from *Horizon* Cruise 6109G-H

LJ no.	Sample/Sta No.	Colln date (1961)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-429	1	21 Sept	44 55N	134 56W	0	16.70	32.756	23.89	*	+10 ± 6
-430	2	21 Sept	44 55N	134 56W	1200	3.00	34.306	27.36	*	−194 ± 6
-431	3	21 Sept	44 55N	134 56W	1700	2.08	34.567	27.64	*	−243 ± 10
-432	4	21 Sept	44 55N	134 56W	2188	1.80	34.615	27.70	*	−242 ± 10
-435	5	21 Sept	44 55N	134 56W	2600	1.65	34.645	27.73	*	−210 ± 6
-436	6	21 Sept	44 55N	134 56W	2996	1.58	34.625	27.73	*	−249 ± 10
-439	7	21 Sept	44 55N	134 56W	3400	1.56	34.635	27.73	*	−242 ± 10
-440	8	21 Sept	44 55N	134 56W	3630	1.55	34.679	27.76	*	−224 ± 6

TABLE 8

(A) Seawater samples from *Risepac* Expedition

LJ no.	Sample Sta No.	Collin date (1962)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-480	148	7 Jan	12 05S	142 32W	0	*	*	*	*	−15 ± 21
-478	148	7 Jan	12 05S	142 32W	800	*	34.49	*	*	−160 ± 10
-481	148	7 Jan	12 05S	142 32W	1250	3.51	34.51	27.47	*	−78 ± 13
-482	148	7 Jan	12 05S	142 32W	1724	2.50	34.56	27.60	*	−158 ± 9
-464	148	8 Jan	12 05S	142 32W	2266	1.93	34.60	27.67	*	−165 ± 10
-466	148	8 Jan	12 05S	142 32W	2763	1.76	34.61	27.71	*	−150 ± 10
-463	148	8 Jan	12 05S	142 32W	3277	1.62	34.64	27.73	*	−190 ± 10
-465	148	8 Jan	12 05S	142 32W	3772	1.42	34.65	27.75	*	−165 ± 20
-479	148	8 Jan	12 05S	142 32W	4190	1.35	34.63	27.75	*	−196 ± 11
-477	148	7 Jan	12 05S	142 32W	4600	1.36	34.63	27.75	*	−159 ± 8
-467	172	20 Jan	14 55N	133 52W	10	*	34.13	*	*	+35 ± 11
-468	172	20 Jan	14 55N	133 52W	753	6.08	34.51	27.18	*	−138 ± 21
-470	172	21 Jan	14 55N	133 52W	1039	4.38	34.56	27.41	*	−170 ± 10
-476	172	21 Jan	14 55N	133 52W	1240	3.72	34.59	27.51	*	−196 ± 10
-475	172	21 Jan	14 55N	133 52W	1711	2.68	34.61	27.63	*	−213 ± 10
-473	172	21 Jan	14 55N	133 52W	2384	1.89	34.67	27.74	*	−215 ± 10
-471	172	21 Jan	14 55N	133 52W	2757	1.73	34.70	27.78	*	−235 ± 10
-474	172	21 Jan	14 55N	133 52W	3479	1.53	34.67	27.76	*	−215 ± 10

(B) Seawater samples from *Argo* Cruise 6201A

-460	3	10 Jan	32 36N	118 11W	975	4.36	34.472	27.36	*	−195 ± 10
-461	5	12 Jan	31 52N	118 51W	969	4.18	34.499	27.39	*	−195 ± 10
-462	8	15 Jan	29 09N	117 40W	3621	1.63	34.682	27.77	*	−232 ± 10

TABLE 9

Seawater samples from *Lusiad* Expedition

LJ no.	Sample/Sta No.	Colln date (1962)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-538	0-1	20 May	35 02N	140 08W	0	16.53	34.30	25.10	*	+40 ± 8
-541	0-3	24 May	35 01N	159 58W	0	18.06	34.49	24.88	*	+52 ± 9
-542	0-3	24 May	35 01N	159 58W	50	15.27	34.51	25.55	*	+27 ± 15
-543	0-3	24 May	35 01N	159 58W	100	14.84	34.48	25.62	*	+1 ± 15
-545	0-3	24 May	35 01N	159 58W	1000	3.46	34.30	27.30	*	−151 ± 15
-547	0-3	24 May	35 01N	159 58W	3500	1.96	34.59	27.66	*	−240 ± 14
-548	0-3	24 May	35 01N	159 58W	4500	1.54	34.68	27.76	*	−200 ± 8
-549	0-4	26 May	35 46N	170 14W	0	17.50	34.69	25.17	*	+37 ± 15
-550	0-5	28 May	35 05N	180 00	0	17.79	34.80	25.19	*	+42 ± 15
-551	0-5	28 May	35 05N	180 00	50	17.40	34.76	25.25	*	+40 ± 15
-552	0-5	28 May	35 05N	180 00	100	15.48	34.68	25.63	*	−34 ± 15
-553	0-5	28 May	35 05N	180 00	500	7.99	34.06	26.56	*	−58 ± 15
-554	0-5	28 May	35 05N	180 00	1000	3.58	34.28	27.27	*	−183 ± 14
-555	0-5	28 May	35 05N	180 00	2000	1.95	34.59	27.66	*	−210 ± 14
-557	0-6	31 May	35 00N	170 02E	0	*	*	*	*	+37 ± 16
-558	0-7	2 June	34 46N	160 20E	0	20.4	34.78	24.52	*	+7 ± 15
-559	0-8	4 June	30 16N	147 49E	0	*	*	*	*	+40 ± 15
-560	0-9	6 June	27 10N	140 00E	0	25.02	35.00	23.36	*	+45 ± 15
-661	98	6 Oct	08 16N	070 37E	0	28.46	36.36	23.29	*	−9 ± 23
-662	98	6 Oct	08 16N	070 37E	100	20.45	35.51	25.04	*	−62 ± 15
-663	98	6 Oct	08 16N	070 37E	200	13.37	35.20	26.49	*	+8 ± 23
-664	98	6 Oct	08 16N	070 37E	400	10.85	35.17	26.96	*	−112 ± 15
-665	98	6 Oct	08 16N	070 37E	600	9.54	35.12	27.14	*	−116 ± 15
-666	98	6 Oct	08 16N	070 37E	800	8.38	35.08	27.30	*	−119 ± 15
-667	98	6 Oct	08 16N	070 37E	1000	7.18	35.05	27.45	*	−133 ± 15
-668	98	6 Oct	08 16N	070 37E	1995	2.73	34.80	27.78	*	−172 ± 14
-669	98	6 Oct	08 16N	070 37E	3200	1.71	34.73	27.80	*	−178 ± 15
-670	98	6 Oct	08 16N	070 37E	3800	1.66	34.73	27.80	*	−214 ± 28
-671	101	10 Oct	05 21S	075 06E	0	27.94	34.52	22.08	*	−31 ± 23

-672	101	10 Oct	05	21S	075	06E	1000	5.78	34.78	27.43	*	−144 ± 11
-673	101	10 Oct	05	21S	075	06E	2970	1.78	34.74	27.81	*	−153 ± 11
-674	101	10 Oct	05	21S	075	06E	5000	1.38	34.72	27.82	*	−130 ± 11
-675	103A	14 Oct	05	54S	063	47E	0	27.94	34.52	22.08	*	−35 ± 36
-676	103A	14 Oct	05	54S	063	47E	400	5.85	34.78	27.43	*	−172 ± 11
-677	103A	14 Oct	05	54S	063	47E	2943	1.76	34.74	27.81	*	−172 ± 11
-678	103A	14 Oct	05	54S	063	47E	3920	1.60	34.72	27.80	*	−164 ± 11
-679	106A	21 Oct	09	54S	056	20E	0	26.32	35.065	23.01	*	0 ± 16
-680	106A	21 Oct	09	54S	056	20E	3480	*	*	*	*	−164 ± 10
-681	106B	24 Oct	13	41S	059	42E	0	*	*	*	*	+14 ± 11
-682	106C	25 Oct	17	19S	057	42E	0	*	*	*	*	+18 ± 17
-683	108A	31 Oct	22	00S	057	30E	0	*	*	*	*	+19 ± 11
-684	109	2 Nov	26	54S	058	11E	0	21.84	35.56	24.72	*	+3 ± 12
-685	109	2 Nov	26	54S	058	11E	5450	0.93	34.70	27.84	*	−150 ± 11
-686	110	4 Nov	30	30S	061	53E	0	18.66	35.584	25.57	*	−5 ± 11
-687	110	4 Nov	30	30S	061	53E	3400	1.37	34.720	27.82	*	−157 ± 10
-688	110	4 Nov	30	30S	061	53E	4400	0.58	34.688	27.84	*	−162 ± 10
-689	111	7 Nov	39	45S	064	00E	0	14.57	35.372	26.38	*	−6 ± 16
-690	111	7 Nov	39	45S	064	00E	4800	0.7	34.70	27.85	*	−125 ± 15
-691	112	10 Nov	51	07S	065	51E	0	1.63	33.903	27.15	*	−51 ± 15
-692	112A	10 Nov	51	07S	065	51E	0	1.63	33.903	27.15	*	−10 ± 15
-693	112	10 Nov	51	07S	065	51E	3185	0.74	34.71	27.85	*	−137 ± 15
-695	113A	20 Nov	37	56S	087	38E	0	14.2	35.2	26.33	*	−22 ± 15
-696	114	22 Nov	33	48S	096	01E	0	14.90	35.41	26.34	*	−32 ± 15
-697	114	22 Nov	33	48S	096	01E	4300	*	*	*	*	−107 ± 15
-698	116	25 Nov	34	11S	105	49E	0	16.64	35.737	26.19	*	+5 ± 16
-699	116	25 Nov	34	11S	105	49E	3430	1.50	34.73	27.82	*	−159 ± 15
-700	117	26 Nov	32	49S	108	39E	5525	*	*	*	*	−161 ± 15

TABLE 10
Seawater samples from *Zephyrus* Expedition

LJ no.	Sample/Sta No.	Colln date (1962)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-657	32	4 Aug	40 40N	005 48E	0	*	*	*	*	+15 ± 16
-659	32	4 Aug	40 40N	005 48E	2675	*	*	*	*	−39 ± 16
-660	54	4 Oct	33 12N	028 39E	0	*	*	*	*	+17 ± 15
-653	64	14 Nov	20 40N	038 13E	0	*	*	*	*	+1 ± 15
-654	64	14 Nov	20 40N	038 13E	900	*	*	*	*	−85 ± 15
-655	64	14 Nov	20 40N	038 13E	1525	*	*	*	*	−72 ± 15
-656	66	17 Nov	16 34N	041 04E	0	*	*	*	*	+16 ± 16

TABLE 11
Seawater samples from *Amphitrite* Expedition

LJ no.	Sample/Sta No.	Colln date (1964)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-877	2-1	16 Jan	16 22S	161 49W	0	*	*	*	*	+4 ± 8
-876	3-1	1 Feb	11 25S	157 30W	0	*	*	*	*	+25 ± 8
-878	3-2	19 Feb	00 00	138 58W	0	*	*	*	*	+7 ± 8
-879	3-3	21 Feb	05 00N	134 00W	0	*	*	*	*	+17 ± 10
-880	3-4	23 Feb	10 00N	133 00W	0	*	*	*	*	+25 ± 8
-881	3-5	24 Feb	15 00N	130 00W	0	*	*	*	*	+54 ± 8
-882	3-6	26 Feb	20 00N	126 40W	0	*	*	*	*	+51 ± 8
-883	3-7	27 Feb	25 00N	123 00W	0	*	*	*	*	+87 ± 11

TABLE 12
Seawater samples from *Dodo* Expedition

LJ no.	Sample/Sta No.	Colln date (1964)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-1052	1	4 Aug	01 16S	041 30E	0	24.62	35.207	23.64	*	−7 ± 20
-1053	14	9 Aug	01 58S	049 20E	0	25.74	35.246	23.64	*	+15 ± 21
-1054	22	12 Aug	02 00N	045 38E	0	24.30	35.016	23.59	*	−27 ± 20
-1055	33	15 Aug	05 00N	050 51E	0	25.07	35.462	23.70	*	−11 ± 20
-1056	33	15 Aug	05 00N	050 51E	4700	*	*	*	*	−197 ± 17
-1057	42	18 Aug	09 18N	051 03E	0	13.32	35.113	26.44	*	−52 ± 20
-1058	47	20 Aug	08 53N	053 09E	4700	*	*	*	*	−137 ± 18
-1059	62	27 Aug	10 14N	053 01E	0	25.89	35.837	23.73	*	+22 ± 21
-1060	62	27 Aug	10 14N	053 01E	4200	*	*	*	*	−177 ± 18
-1061	70	30 Aug	02 07N	055 04E	0	27.02	35.321	22.98	*	+31 ± 10
-1062	70	30 Aug	02 07N	055 04E	4700	*	*	*	*	−179 ± 18
-1063	80	3 Sept	05 52S	055 00E	0	25.42	35.226	23.42	*	+29 ± 11
-1066	80	3 Sept	05 52S	055 00E	100	*	*	*	*	−29 ± 10
-1067	80	3 Sept	05 52S	055 00E	200	*	*	*	*	−126 ± 10
-1065	80	3 Sept	05 52S	055 00E	300	*	*	*	*	−55 ± 20
-1064	80	3 Sept	05 52S	055 00E	500	*	*	*	*	−75 ± 9

TABLE 13
Seawater samples from *Ursa Major* Expedition

LJ no.	Sample/Sta No.	Colln date (1964)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-1026	1	7 Aug	33 48N	135 01W	0	*	*	*	*	+183 ± 12
-1027	4	11 Aug	35 01N	155 00W	0	24.26	34.716	23.39	*	+148 ± 16
-1028	4	14 Aug	35 01N	155 00W	3500	1.49	34.69	27.78	*	−185 ± 10
-1033	9	15 Aug	45 00N	155 00W	0	15.85	33.031	24.29	*	+143 ± 12
-1031	9	15 Aug	45 00N	155 00W	100	7.68	33.382	26.07	*	+30 ± 25
-1032	9	15 Aug	45 00N	155 00W	200	7.22	33.905	26.54	*	−60 ± 21
-1040	9	15 Aug	45 00N	155 00W	500	3.96	34.00	27.02	*	−125 ± 20
-1039	9	15 Aug	45 00N	155 00W	998	3.10	34.354	27.39	*	−166 ± 10
-1038	9	15 Aug	45 00N	155 00W	4064	*	*	*	*	−199 ± 10
-1037	11	16 Aug	49 00N	154 58W	0	11.59	32.654	24.86	*	+115 ± 11
-1036	11	16 Aug	49 00N	154 58W	107	4.48	32.865	26.07	*	+50 ± 23
-1034	11	16 Aug	49 00N	154 58W	210	3.52	33.687	26.81	*	−68 ± 11
-1035	11	16 Aug	49 00N	154 58W	498	3.52	34.106	27.15	*	−120 ± 9
-1043	11	16 Aug	49 00N	154 58W	1021	2.81	34.393	27.44	*	−176 ± 9
-1041	11	16 Aug	49 00N	154 58W	2000	*	*	*	*	−174 ± 9
-1042	13	18 Aug	54 34N	155 00W	0	11.5	32.721	24.94	*	+114 ± 12
-1044	20	26 Aug	52 56N	155 03W	0	*	*	*	*	+44 ± 9
-1049	24	28 Aug	47 38N	155 00W	0	*	*	*	*	+75 ± 10
-1045	28	4 Sept	42 09N	155 02W	0	*	*	*	*	+40 ± 11
-1046	32	7 Sept	36 49N	155 00W	0	*	*	*	*	+123 ± 12
-1048	36	10 Sept	31 29N	155 00W	0	*	*	*	*	+123 ± 12
-1047	39	12 Sept	27 21N	155 00W	0	*	*	*	*	+137 ± 12

TABLE 14

(A) Seawater samples from *La Pared* Expedition

LJ no.	Sample/Sta No.	Colln date (1965)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-1406	0	29 Apr	27 44N	118 14W	0	*	*	*	*	+100 ± 8
-1407	5	1 May	21 00N	119 14W	0	21.9	34.02	23.53	*	+96 ± 13
-1408	5	1 May	21 00N	119 14W	100	17.0	34.05	24.81	*	+119 ± 6
-1409	5	1 May	21 00N	119 14W	200	11.0	34.23	26.20	*	−25 ± 7
-1410	5	1 May	21 00N	119 14W	300	9.3	34.47	26.69	*	−93 ± 6
-1411	5	1 May	21 00N	119 14W	400	8.1	34.47	26.87	*	−108 ± 6
-1412	5	1 May	21 00N	119 14W	500	*	*	*	*	−129 ± 7
-1417	15	4 May	15 55N	119 57W	0	*	*	*	*	+88 ± 7
-1419	15	4 May	15 55N	119 57W	200	*	*	*	*	−74 ± 7
-1420	15	4 May	15 55N	119 57W	300	*	*	*	*	−84 ± 7
-1421	15	4 May	15 55N	119 57W	400	*	*	*	*	−90 ± 7
-1423	15	4 May	15 55N	119 57W	500	*	*	*	*	−121 ± 7

(B) Seawater sample from SIO Pier

-1424	3	28 Oct	32 52N	117 44W	0	*	*	*	*	+49 ± 8

TABLE 15
Seawater samples from *Zetes* Expedition

LJ no.	Sample/Sta No.	Colln date (1966)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-1428	I-01	11 Jan	26 00N	155 00W	0	22.5	*	*	*	+136 ± 10
-1430	I-03	12 Jan	28 00N	155 00W	0	21.5	*	*	*	+134 ± 9
-1432	I-05	13 Jan	30 00N	155 00W	0	19	*	*	*	+125 ± 9
-1433	I-07	14 Jan	32 00N	155 00W	0	18	*	*	*	+127 ± 9
-1429	I-09	15 Jan	34 00N	155 00W	0	16.5	*	*	*	+142 ± 10
-1431	I-11	16 Jan	36 00N	155 00W	0	14.5	*	*	*	+73 ± 33
-1435	I-15	17 Jan	40 00N	155 00W	0	12	*	*	*	+80 ± 9
-1436	I-17	18 Jan	42 00N	155 00W	0	10.8	*	*	*	+218 ± 32
-1439	I-19	19 Jan	44 00N	155 00W	0	<9	*	*	*	+120 ± 12
-1440	I-21	19 Jan	46 00N	155 00W	0	7.3	*	*	*	+134 ± 25
-1443	I-23	20 Jan	48 00N	155 00W	0	6.5	*	*	*	+108 ± 25
-1437	I-25	21 Jan	50 00N	155 00W	0	5.2	*	*	*	+123 ± 9
-1438	I-27	22 Jan	52 00N	155 00W	0	4.0	*	*	*	+101 ± 9
-1441	I-29	22 Jan	54 00N	155 00W	0	3.5	*	*	*	+55 ± 9
-1442	I-31	23 Jan	56 00N	155 00W	0	<4	*	*	*	+60 ± 9
-1616	II-00	28 Jan	54 40N	158 40W	0	*	*	*	*	+30 ± 16
-1611	II-01	29 Jan	54 00N	165 00W	0	3.5	31.78	25.31	*	+121 ± 10
-1609	II-06	30 Jan	50 45N	165 24W	0	4.2	32.70	25.96	*	+81 ± 10
-1614	II-09	31 Jan	48 00N	165 00W	0	5.7	32.90	25.96	*	+128 ± 10
-1612	II-13	1 Feb	45 06N	165 04W	0	7.1	33.12	25.95	*	+131 ± 9
-1610	II-16	1 Feb	43 30N	165 00W	0	8.0	33.33	25.99	*	+104 ± 12
-1615	II-19	2 Feb	42 00N	165 00W	0	9.5	33.70	26.05	*	+34 ± 30
-1619	II-44	11 Feb	52 00N	168 00E	0	1.3	33.20	26.61	*	+22 ± 10
-1617	II-62	14 Feb	59 00N	167 30E	0	0.5	33.20	26.65	*	+20 ± 20
-1601	II-67	15 Feb	57 00N	172 00E	0	2.1	33.16	26.52	*	+2 ± 8
-1603	II-69	17 Feb	55 15N	175 00E	0	1.8	33.10	26.49	*	−22 ± 16
-1606	II-73	18 Feb	53 00N	176 00E	0	2.7	33.23	26.53	*	−6 ± 8
-1620	II-121	2 Mar	42 30N	175 00E	0	7.4	*	*	*	+87 ± 10
-1602	II-131	5 Mar	~43 15N	~168 00E	0	*	*	*	*	+20 ± 10
-1604	II-135	6 Mar	43 45N	164 00E	0	5.0	33.49	26.50	*	+60 ± 8
-1621	II-140	8 Mar	50 00N	162 20E	0	1.1	33.12	26.55	*	+82 ± 10
-1605	II-143	8 Mar	~51 00N	~161 45E	0	*	*	*	*	−36 ± 22
-1607	II-150	10 Mar	52 30N	160 45E	0	−1.35	*	*	*	+41 ± 8
-1622	II-160	16 Mar	47 40N	150 10E	0	−1.3	32.76	26.38	*	+43 ± 11
-1623	II-163	17 Mar	45 20N	152 50E	0	0.07	33.12	26.61	*	+20 ± 20
-1608	II-167	19 Mar	41 40N	156 40E	0	5.2	33.62	26.58	*	+23 ± 8
-1624	II-170	20 Mar	39 30N	158 30E	0	11.04	34.30	26.25	*	+32 ± 19

TABLE 16
Seawater samples from *USS Radford* Cruise 6809-R

LJ no.	Sample/Sta No.	Colln date (1968)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-1821	1	10 Sept	53 20N	157 50W	0	10.6	34.027	26.11	*	+97 ± 17
-1919	4	11 Sept	47 56N	158 09W	0	12.2	32.559	24.68	*	+136 ± 13
-1920	6	12 Sept	44 00N	158 02W	0	14.1	33.046	24.69	*	+130 ± 13
-1918	7	12 Sept	42 00N	157 50W	0	16.9	33.165	24.16	*	+121 ± 13
-1912	8	12 Sept	40 00N	157 50W	0	20.2	33.760	23.79	*	+107 ± 14
-1914	12	14 Sept	32 09N	157 47W	0	25.9	35.286	23.32	*	+120 ± 34
-1916	13	14 Sept	30 00N	157 50W	0	26.9	35.187	22.93	*	+165 ± 18
-1917	14	14 Sept	28 14N	157 45W	0	26.5	35.226	23.08	*	+152 ± 20
-1911	15	15 Sept	26 14N	157 49W	0	26.5	34.877	22.81	*	+131 ± 24
-1915	16	15 Sept	24 00N	157 50W	0	27.3	34.707	22.43	*	+137 ± 18

TABLE 17
Seawater samples from *Styx* Expedition

LJ no.	Sample/Sta No.	Colln date (1968)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-1926	0	11 Nov	13 53S	170 58W	0	27.7	35.336	22.77	*	+59 ± 17
-1929	1	8 Aug	12 00S	169 47W	0	27.2	35.679	23.19	*	+97 ± 11
-1928	2	8 Aug	10 00S	169 07W	0	27.8	35.467	22.84	*	+76 ± 13
-1927	3	9 Aug	08 05S	168 13W	0	28.3	35.597	22.77	*	+68 ± 22
-1955	4	10 Aug	05 56S	167 26W	0	27.9	35.635	22.94	*	+132 ± 17
-1951	5	10 Aug	04 00S	167 52W	0	27.3	35.419	22.97	*	+67 ± 19
-1962	6	11 Aug	02 00S	166 16W	0	27.9	35.421	22.78	*	+43 ± 15
-1924	7	11 Aug	00 00	165 42W	0	26.7	35.432	23.17	*	+54 ± 16
-1956	12	22 Nov	11 01N	155 04W	0	27.1	33.877	21.88	*	+225 ± 10
-1957	13	22 Nov	12 47N	155 38W	0	26.9	34.229	22.20	*	+119 ± 10

TABLE 18

(A) Seawater samples from *Piquero* Expedition

LJ no.	Sample/Sta No.	Colln date (1968)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-1966	1	12 Dec	20 00N	114 50W	0	*	34.409	*	*	+128 ± 7
-1967	2	12 Dec	16 00N	114 07W	0	*	33.625	*	*	+106 ± 11
-1968	3	14 Dec	12 00N	113 24W	0	*	33.503	*	*	+95 ± 7
-1969	4	14 Dec	08 00N	112 41W	0	*	33.962	*	*	+95 ± 17
-1970	5	15 Dec	04 00N	111 57W	0	*	34.524	*	*	+86 ± 8
-1971	6	16 Dec	00 00	111 15W	0	*	34.590	*	*	+43 ± 13
-1972	7	18 Dec	04 00S	109 51W	0	*	35.471	*	*	+21 ± 7
-1973	8	19 Dec	08 00S	108 30W	0	*	*	*	*	+26 ± 15
-1983	9	20 Dec	12 00S	104 30W	0	*	35.740	*	*	+55 ± 8
-1980	10	22 Dec	16 00S	100 27W	0	*	36.058	*	*	+76 ± 9
-1985	11	24 Dec	20 00S	096 26W	0	*	35.878	*	*	+93 ± 9
-1989	12	25 Dec (1969)	25 05S	091 00W	0	*	35.315	*	*	+143 ± 7
-1991	13	20 Jan	62 25S	062 00W	0	*	33.938	*	*	−38 ± 9
-1993	14	23 Jan	60 00S	064 00W	0	*	33.889	*	*	−22 ± 6
-2014	15	25 Jan	58 00S	066 20W	0	*	34.117	*	*	+11 ± 24
-2015	16	28 Jan	56 12S	071 52W	0	*	34.115	*	*	+29 ± 11
-1974	17	30 Jan	60 25S	079 30W	0	*	34.168	*	*	+22 ± 8
-1975	18	1 Feb	59 20S	082 50W	0	*	34.129	*	*	+17 ± 8
-1976	19	1 Feb	58 00S	086 45W	0	*	34.128	*	*	+23 ± 8
-1977	20	9 Feb	54 22S	090 00W	0	*	34.201	*	*	+31 ± 19
-1978	21	10 Feb	51 20S	090 40W	0	*	34.135	*	*	+41 ± 6
-1979	22	11 Feb	48 42S	091 18W	0	*	34.102	*	*	+77 ± 11
-2016	23	3 Mar	30 01S	082 00W	0	*	34.750	*	*	+158 ± 7

(B) Seawater sample from SIO Pier

-1923	4	20 Feb	32 52N	117 44W	0	*	*	*	*	+138 ± 15

TABLE 19
Seawater samples from *Scan* Expedition

LJ no.	Sample/Sta No.	Colln date (1969)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-2031	1	14 Apr	28 19N	139 54W	0	19.5	35.208	25.08	*	+169 ± 11
-2035	2	16 Apr	23 50N	139 47W	0	21.5	34.707	24.16	*	+158 ± 12
-2036	4	17 Apr	20 10N	140 23W	0	21.3	34.513	24.07	*	+158 ± 10
-2038	5	19 Apr	17 56N	139 56W	0	22.0	34.190	23.63	*	+147 ± 12
-2041	6	20 Apr	14 00N	140 31W	0	24.5	34.183	22.91	*	+140 ± 7
-2043	7	23 Apr	12 04N	140 23W	0	25.7	34.014	22.42	*	+64 ± 10
-2046	8	24 Apr	09 52N	140 22W	0	26.7	34.464	22.44	*	+83 ± 6
-2054	9	24 Apr	07 47N	140 25W	0	27.5	34.210	22.00	*	+100 ± 9
-2055	10	29 Apr	04 28N	140 17W	0	27.7	35.011	22.53	*	+62 ± 7
-2056	11	16 June	30 05N	140 03E	0	23.3	34.623	23.59	*	+140 ± 11
-2062	12	17 June	28 21N	142 19E	0	23.0	34.431	23.54	*	+204 ± 10
-2063	13	18 June	26 50N	141 28E	0	24.2	34.435	23.18	*	+196 ± 13
-2065	14	19 June	23 29N	142 59E	0	29.1	34.924	22.01	*	+170 ± 13
-2069	15	20 June	21 14N	142 47E	0	29.1	35.043	22.10	*	+181 ± 10
-2071	16	21 June	19 52N	142 22E	0	29.0	34.939	22.05	*	+184 ± 9
-2072	17	21 June	18 23N	141 42E	0	29.1	34.674	21.82	*	+160 ± 10

TABLE 20

Seawater samples from *Climax II* Expedition

LJ no.	Sample/Sta No.	Colln date (1969)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-2074	1	7 Sept	28 23N	155 20W	0	24.3	35.152	23.69	*	+169 ± 20
-2101	2	10 Sept	26 28N	155 41W	0	25.3	35.110	23.37	*	+221 ± 15
-2103	3	10 Sept	24 30N	156 25W	0	*	35.042	*	*	+141 ± 14
-2104	4	20 Sept	17 58N	155 38W	0	*	34.589	*	*	+160 ± 11
-2105	5	21 Sept	15 43N	155 00W	0	*	34.477	*	*	+167 ± 9
-2106	6	22 Sept	13 19N	154 59W	0	*	34.348	*	*	+109 ± 10
-2108	7	22 Sept	12 00N	155 02W	0	*	33.675	*	*	+136 ± 17
-2114	9	23 Sept	07 58N	154 55W	0	*	34.360	*	*	+49 ± 20
-2117	10	24 Sept	05 49N	154 57W	0	*	34.810	*	*	+54 ± 16
-2140	11	25 Sept	01 54N	155 05W	0	*	34.936	*	*	+57 ± 9
-2310	12	26 Sept	01 04S	154 58W	0	*	35.210	*	−1.1	+47 ± 8
-2139	13	27 Sept	03 02S	154 59W	0	*	35.327	*	*	+45 ± 10
-2311	14	28 Sept	05 52S	155 02W	0	*	35.398	*	+1.7	+48 ± 8
-2313	15	28 Sept	07 03S	155 03W	0	*	35.399	*	+1.1	+48 ± 8
-2369	16	29 Sept	09 14S	155 02W	0	*	35.719	*	+2.0	+54 ± 8
-2137	17	29 Sept	11 06S	155 03W	0	*	35.926	*	*	+124 ± 18
-2135	18	30 Sept	13 02S	155 00W	0	*	35.962	*	*	+92 ± 17
-2131	19	30 Sept	15 23S	155 00W	0	*	35.921	*	*	+121 ± 10
-2129	20	1 Oct	18 29S	155 01W	0	*	35.880	*	*	+127 ± 10
-2123	21	2 Oct	22 01S	155 01W	0	*	35.864	*	*	+97 ± 26
-2121	22	3 Oct	24 04S	155 00W	0	*	35.785	*	*	+133 ± 10

TABLE 21

Seawater samples from *Dragon* Expedition

LJ no.	Sample/Sta No.	Colln date (1969)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-2077	1	8 June	11 43N	119 17W	0	26.9	34.053	22.07	*	+104 ± 7
-2080	2	9 June	15 05N	118 55W	0	24.8	34.359	22.95	*	+109 ± 10
-2083	3	10 June	17 04N	118 39W	0	24.0	34.411	23.22	*	+124 ± 9
-2088	4	10 June	19 00N	118 25W	0	23.3	34.423	23.44	*	+132 ± 10
-2092	5	11 June	21 04N	118 16W	0	22.6	34.570	23.75	*	+151 ± 8
-2093	6	11 June	23 01N	118 02W	0	20.5	34.273	24.10	*	+188 ± 20
-2094	7	12 June	23 13N	118 16W	0	19.0	33.981	24.27	*	+193 ± 9

TABLE 22

Seawater samples from North Pacific Study Cruises of *USCGC Acushnet* and from Weather Station "P"

LJ no.	Cruise	Sample/Sta No.	Colln date (1969)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-2022	NPSC-3	1	22 May	50 00N	158 00W	0	5.4	32.845	25.95	*	+107 ± 12
-2023	NPSC-3	2	22 May	48 00N	158 00W	0	6.6	32.789	25.76	*	+54 ± 15
-2020	NPSC-3	3	23 May	46 00N	158 00W	0	7.2	33.010	25.86	*	+130 ± 16
-2024	NPSC-3	5	27 May	40 00N	158 00W	0	10.5	33.664	25.85	*	+81 ± 11
-2025	NPSC-3	6	27 May	38 00N	158 00W	0	12.5	34.147	25.80	*	+73 ± 10
-2018	NPSC-5	1	6 Dec	43 01N	157 40W	0	9.5	33.177	25.64	*	+133 ± 12
-2029	NPSC-5	2	8 Dec	41 00N	148 02W	0	12.2	*	*	*	+133 ± 16
			(1970)								
-2418	Sta P	1	14 Feb	50 00N	145 00W	0	8.1	32.648	25.45	−1.8	+146 ± 15
-2421	Sta P	3	22 Feb	50 00N	145 00W	0	8.5	32.678	25.41	−1.1	+83 ± 19
-2427	NPSC-6	1	23 Apr	44 00N	164 00W	0	7.4	33.49	26.20	−0.2	+94 ± 6
-2438	NPSC-6	2	25 Apr	41 00N	157 45W	0	10.1	33.61	25.87	0.0	+102 ± 8
-2460	NPSC-6	3	26 Apr	44 00N	157 40W	0	7.6	33.10	25.86	−0.1	+125 ± 10
-2462	NPSC-6	4	28 Apr	44 00N	148 00W	0	8.4	32.98	25.66	−0.8	+164 ± 7
-2495	NPSC-6	5	29 Apr	41 00N	148 02W	0	11.5	33.55	25.59	−2.8	+123 ± 9
-2678	NPSC-7	1	29 June	29 59N	165 01W	0	25.5	34.985	23.21	+1.4	+169 ± 8
-2498	NPSC-7	2	30 June	31 00N	164 27W	0	23.7	34.720	23.55	+1.4	+111 ± 11
-2500	NPSC-7	3	1 July	34 00N	162 48W	0	23.0	34.503	23.59	+1.1	+145 ± 29
-2504	NPSC-7	5	2 July	38 00N	160 15W	0	17.7	34.026	24.63	+2.0	+94 ± 12
-2681	NPSC-7	6	2 July	40 00N	159 14W	0	14.5	33.644	25.06	+0.6	+73 ± 9
-2691	NPSC-7	7	3 July	42 00N	158 16W	0	11.9	33.260	25.29	+2.2	+116 ± 12
-2693	NPSC-7	8	6 July	43 31N	157 45W	0	10.8	33.173	25.42	+2.2	+99 ± 7

TABLE 23

Seawater samples from *Hudson 70* Expedition†

LJ no.	Sample/Sta No.	Colln date (1970)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-2149	5	28 Apr	59 59S	149 59W	0	0.4	34.60	27.79	+0.3	+61 ± 16
-2153	6	28 Apr	58 20S	149 51W	0	1.1	34.39	27.57	+0.3	+54 ± 21
-2158	7	29 Apr	56 35S	149 58W	0	1.9	34.28	27.44	*	+68 ± 10
-2159	9	1 May	49 56S	150 00W	0	9.8	34.79	26.85	*	+77 ± 10
-2163	10	2 May	45 00S	149 59W	0	11.1	34.61	26.48	*	+77 ± 17
-2325	11	3 May	40 00S	150 01W	0	15.2	34.72	25.74	−3.9	+98 ± 12
-2384	12	5 May	35 03S	150 00W	0	18.2	35.41	25.56	+1.5	+132 ± 11
-2402	13	6 May	29 59S	149 58W	0	21.6	35.52	24.75	*	+137 ± 6
-2298	14	8 May	24 59S	150 01W	0	24.2	35.70	24.14	+0.3	+143 ± 9
-2404	15	10 May	19 58S	150 02W	0	26.8	35.80	23.42	*	+132 ± 8
-2307	16	17 May	15 03S	150 00W	0	29.0	35.74	22.65	+2.3	+124 ± 9
-2406	17	18 May	09 50S	150 02W	0	29.2	36.04	22.82	*	+90 ± 8
-2299	18	19 May	05 00S	150 04W	0	28.6	35.08	22.29	+1.7	+58 ± 6
-2429	19	20 May	02 55S	150 09W	0	28.5	35.22	22.43	+2.3	+51 ± 9
-2386	20	21 May	01 30S	150 03W	0	27.7	35.38	22.81	+2.0	+62 ± 10
-2432	21	21 May	00 03S	149 56W	0	27.1	35.38	23.01	*	+43 ± 16
-2300	22	22 May	01 40N	149 58W	0	27.6	35.12	22.65	+2.1	+64 ± 8
-2434	23	22 May	03 00N	149 59W	0	28.3	34.98	22.31	*	+71 ± 10
-2388	24	22 May	04 46N	150 00W	0	28.3	34.52	21.96	+1.3	+65 ± 6
-2408	25	24 May	10 00N	150 01W	0	26.8	34.76	22.63	*	+90 ± 6
-2302	26	26 May	16 01N	150 02W	0	25.2	34.71	23.10	+2.0	+131 ± 6
-2410	27	27 May	20 10N	150 03W	0	24.2	34.66	23.35	*	+152 ± 7
-2390	28	28 May	25 00N	150 01W	0	23.3	35.19	24.02	*	+194 ± 8
-2412	29	29 May	28 48N	149 57W	0	22.8	35.52	24.41	+1.3	+190 ± 7
-2304	30	31 May	35 54N	149 58W	0	18.2	34.22	24.65	+0.8	+144 ± 6
-2414	31	1 June	40 02N	149 58W	0	13.6	33.76	25.34	*	+171 ± 7
-2392	32	3 June	45 00N	149 59W	0	9.2	33.16	25.67	*	+169 ± 6
-2423	33	4 June	49 07N	150 00W	0	6.6	33.16	26.05	+0.6	+133 ± 14
-2305	34	5 June	54 33N	150 06W	0	6.1	33.28	26.21	+1.5	+80 ± 7

† Samples coll for C S Wong, Canadian Dept Environment; Marine Sci Dir, Pacific Region; Ocean Chemistry Div; Victoria, British Columbia, Canada, and were measured by La Jolla Lab before Canadian lab began operation.

TABLE 24

Seawater samples from *Seven-Tow* Expedition

LJ no.	Sample/Sta No.	Colln date (1970)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-2436	1	8 Apr	18 04N	161 27W	0	24.7	34.804	23.32	−0.2	+176 ± 8
-2440	2	9 Apr	15 41N	164 18W	0	26.2	34.525	22.65	+0.5	+145 ± 6
-2442	3	10 Apr	14 00N	166 21W	0	26.9	34.493	22.40	*	+133 ± 8
-2445	4	11 Apr	12 00N	168 56W	0	27.3	34.570	22.33	+1.8	+115 ± 9
-2447	5	11 Apr	09 57N	170 53W	0	27.5	34.492	22.21	*	+128 ± 8
-2449	6	12 Apr	07 59N	174 08W	0	28.8	34.802	22.02	−1.0	+113 ± 9
-2451	7	14 Apr	06 00N	176 40W	0	29.1	34.972	22.04	+1.2	+84 ± 8
-2454	9	15 Apr	01 54N	174 53W	0	27.8	35.080	22.55	+1.7	+56 ± 7
-2456	10	15 Apr	00 04S	174 00W	0	27.8	35.163	22.61	−0.5	+42 ± 11
-2458	11	19 Apr	01 59S	169 56W	0	28.5	35.333	22.52	+0.6	+57 ± 7
-2464	12	20 Apr	03 56S	170 16W	0	28.5	35.300	22.49	−1.6	+60 ± 7
-2466	13	20 Apr	06 04S	170 34W	0	29.6	35.199	22.04	−4.0	+94 ± 19
-2468	14	21 Apr	08 03S	170 44W	0	29.7	34.852	21.75	+0.1	+87 ± 10
-2475	16	6 June	07 49S	168 34W	0	30.4	35.123	21.69	+0.1	+94 ± 8
-2477	17	6 June	05 49S	168 08W	0	30.8	34.594	21.16	−2.4	+82 ± 10
-2479	18	7 June	03 52S	167 23W	0	30.2	35.250	21.86	0.0	+54 ± 9
-2481	19	7 June	01 50S	166 36W	0	29.4	35.329	22.21	+1.8	+66 ± 9
-2483	20	8 June	00 06S	165 52W	0	29.5	35.335	22.18	+0.2	+81 ± 14
-2485	21	8 June	02 08N	165 00W	0	29.0	34.867	22.00	0.0	+45 ± 16
-2486	22	10 June	04 04N	163 38W	0	29.4	34.625	21.68	+2.2	+75 ± 9
-2489	23	11 June	05 51N	160 50W	0	29.5	34.608	21.64	+0.9	+68 ± 9
-2491	24	12 June	07 57N	159 16W	0	29.4	34.551	21.63	+0.7	+24 ± 12
-2493	25	17 June	09 52N	155 22W	0	30.8	34.729	21.27	+2.4	+86 ± 7
-2507	26	4 July	23 54N	156 48W	0	25.0	34.977	23.36	+2.5	+150 ± 18
-2509	27	5 July	26 27N	155 47W	0	24.8	35.278	23.64	−0.2	+192 ± 11
-2512	28	5 July	27 58N	155 13W	0	24.6	35.295	23.72	+0.1	+188 ± 9
-2514	29	7 July	30 03N	156 11W	0	23.6	35.065	23.84	+1.9	+157 ± 9
-2518	31	12 July	33 58N	155 13W	0	23.5	35.020	23.84	+2.1	+158 ± 12
-2520	32	13 July	35 56N	161 09W	0	23.0	34.377	23.50	+1.7	+114 ± 8
-2553	33	13 July	37 52N	162 53W	0	20.7	33.973	23.82	+2.3	+76 ± 11
-2558	34	14 July	40 00N	164 47W	0	16.3	33.971	24.92	+1.7	+67 ± 9
-2560	35	15 July	42 01N	165 44W	0	14.0	33.579	25.12	+2.4	+88 ± 9
-2564	36	17 July	44 03N	166 30W	0	12.4	33.543	25.41	+2.0	+91 ± 9

TABLE 25
Seawater samples from *Aries* Expedition

LJ no.	Sample/Sta No.	Colln date (1971)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-2522	1	3 Feb	68 22S	176 02E	0	−0.5	34.086	27.42	+1.7	−69 ± 7
-2524	2	5 Feb	70 00S	168 34E	0	−1.8	34.043	27.43	+1.9	−112 ± 9
-2526	3	10 Feb	67 51S	160 24E	0	−0.3	33.437	26.88	+1.8	−86 ± 7
-2528	4	15 Feb	65 59S	160 35E	0	0.8	33.627	26.99	+1.7	−99 ± 9
-2543	5	15 Feb	63 59S	158 53E	0	0.9	33.794	27.11	+2.0	−84 ± 7
-2542	6	16 Feb	62 00S	159 01E	0	1.6	33.927	27.17	+2.0	−93 ± 7
-2545	7	16 Feb	59 10S	162 34E	0	5.5	33.825	26.71	+2.7	+17 ± 10
-2547	9	1 Mar	40 44S	177 33E	0	18.3	*	*	+3.2	+86 ± 7
-2532	10	2 Mar	38 48S	178 01E	0	19.6	*	*	+2.3	+77 ± 9
-2549	11	3 Mar	36 32S	173 05W	0	20.2	*	*	+2.4	+92 ± 7
-2534	12	4 Mar	34 49S	169 23W	0	19.6	35.278	25.10	+2.6	+131 ± 10
-2536	14	6 Mar	30 51S	160 54W	0	23.6	35.661	24.29	+1.7	+129 ± 8
-2552	15	7 Mar	28 49S	156 41W	0	25.0	35.520	23.77	+2.6	+146 ± 7
-2538	16-17	13 Mar	25 45S	154 19W	0	25.4	35.600	23.71	+2.0	+131 ± 12
-2700	18-19	2 Apr	14 13S	151 37W	0	28.3	35.946	23.04	+1.8	+93 ± 9
-2703	20	3 Apr	09 02S	154 20W	0	28.1	35.692	22.91	+3.1	+85 ± 8
-2705	21-23	4 Apr	04 41S	156 26W	0	27.3	35.451	22.99	+4.5	+50 ± 14
-2706	24-33	23 Apr	01 32N	152 14W	0	26.3	35.071	23.02	+2.6	+33 ± 11

TABLE 26

Seawater samples from *South-Tow* Expedition

LJ no.	Sample/Sta No.	Colln date (1972)	Lat	Long	Depth	Temp (°C)	Salinity (‰)	σ_t	$\delta^{13}C$ (‰)	Δ (‰)
-2729	1	8 Jan	23 48N	119 52W	0	17.0	33.65	24.51	+1.7	+202 ± 6
-2738	2	8 Jan	21 51N	120 23W	0	17.8	34.22	24.75	+1.6	+196 ± 6
-2742	3	9 Jan	19 58N	120 51W	0	19.1	34.35	24.53	+2.0	+189 ± 6
-2744	4	9 Jan	16 16N	122 00W	0	23.2	33.83	23.02	+1.0	+114 ± 6
-2731	5	10 Jan	11 38N	122 33W	0	24.2	34.33	23.10	+0.8	+39 ± 8
-2746	6	12 Jan	10 04N	123 11W	0	24.7	34.22	22.88	+0.2	+119 ± 6
-2748	7	14 Jan	07 34N	123 41W	0	25.0	33.98	22.60	+1.1	+79 ± 8
-2736	9	21 Jan	00 09S	125 32W	0	23.7	34.90	23.68	+1.7	+39 ± 6
-2752	10	22 Jan	02 02S	125 53W	0	23.8	34.83	23.60	+0.7	+28 ± 10
-2756	12	23 Jan	06 06S	126 37W	0	24.8	35.05	23.47	+1.7	+25 ± 6
-2740	13	23 Jan	08 02S	127 01W	0	25.6	35.15	23.30	+0.6	+25 ± 6
-2758	14	24 Jan	10 01S	127 22W	0	26.5	35.46	23.25	+1.7	+31 ± 8
-2760	15	25 Jan	13 57S	128 07W	0	27.8	35.86	23.14	+1.6	+57 ± 9
-2762	16	25 Jan	15 52S	128 24W	0	27.8	36.075	23.30	+1.6	+74 ± 9
-2764	17-18	26 Jan	19 57S	129 16W	0	27.5	36.600	23.79	+1.6	+157 ± 17
-2766	19	30 Jan	24 09S	129 28W	0	26.8	35.819	23.43	+1.4	+176 ± 9
-2768	20-21	16 Feb	21 22S	149 04W	0	28.0	35.931	23.13	+1.2	+161 ± 12
-2772	22-24	17 Feb	25 21S	148 25W	0	27.3	35.49	23.02	+0.9	+169 ± 10
-2775	25-26	18 Feb	30 50S	143 47W	0	24.5	35.25	23.72	+1.0	+182 ± 24
-2777	27-29	20 Feb	37 11S	139 34W	0	18.9	34.562	24.74	+2.0	+187 ± 10
-2779	30	21 Feb	40 01S	138 00W	0	15.9	34.180	25.17	+1.2	+131 ± 8
-2781	31-33	22 Feb	44 29S	134 50W	0	14.7	34.247	25.48	+1.4	+68 ± 9
-2783	34-37	1 Mar	49 31S	121 19W	0	12.0	34.317	26.09	+0.4	+69 ± 9

[RADIOCARBON, VOL. 20, No. 3, 1978, P. 360-385]

ANU RADIOCARBON DATE LIST VI

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The following list contains most of the measurements made during 1974, since our last list (R, 1973, v 15, p 241-251). All measurements were performed on a Beckman LS-200 Liquid Scintillation Spectrometer following previously published setting up (Polach, 1974), automatic cycling (Polach, 1969) and benzene synthesis (Polach and Stipp, 1966; Polach *et al*, 1972) procedures.

Ages are reported as *conventional radiocarbon ages* BP (Olsson, 1970, p 17) using, however, the *ANU Sucrose* contemporary radiocarbon dating standard (Polach, 1976, in press) as a frequent cross check of our 0.95 NBS Oxalic value. The *conventional radiocarbon ages* BP are corrected for isotopic fractionation based on either an estimated $\delta^{13}C$ value (Polach, 1976; Stuiver and Polach, 1977) with an uncertainty of estimate never smaller than $\pm 2‰$, or measured $\delta^{13}C$ value with an error of measurement never larger than $\pm 0.2‰$. The $\delta^{13}C$ values are expressed wrt to PDB; the error of estimate or measurement is incorporated in the age $\pm$ error calculation. The calculations, presentation and annotations follow the suggestions made by Stuiver and Polach (R, 1977, v 19, p 355-363). Thus $D^{14}C$ is the relative difference between the ^{13}C corrected sample activity (count rate) and the measured and ^{13}C corrected oxalic acid activity (count rate). The *conventional radiocarbon age* (t) is thus defined as

$$t = -8033 \ln \left(1 + \frac{D^{14}C}{1000} \right) .$$

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SAMPLE DESCRIPTIONS

I. GEOLOGIC SAMPLES

A. Australia

Lake George series, New South Wales

Since 1820 Lake George has been dry 6 times and has never been deeper than 7.3m, although higher lake levels occurred in colder Late

Quaternary times. Study of geomorphology, sediments and soils of surficial deposits of lake basin established a sequence of abandoned shoreline features up to 36m above lake bottom (Coventry, 1976; Coventry and Walker, 1977). Relative sequence of these deposits was determined by radiocarbon dating.

Samples, except for ANU-519, were coll by R J Coventry in 1970 within Lake George Basin (35° 25′ S, 149° 25′ E), ca 40km NE of Canberra, Australia and subm by Dept Biogeog & Geomorphol, ANU.

Detailed descriptions of sites sampled are included in Coventry (1973). Analyses, except for ANU-501 and -521/2, were made on handpicked charcoal fragments washed in hot 2N hydrochloric acid followed by washing with distilled water.

Other dates previously available within Lake George Basin are: GaK-962: 15,100 ± 300 BP; abandoned beach sediment 15m above lake base (Galloway, 1967); and GaK-2025: 3470 ± 210 BP, same beach complex as GaK-962 but different beach ridge (J N Jennings, October, 1976, oral commun).

ANU-501. **$D^{14}C = 930.9 \pm 4.7‰$** **21,470 ± 570**
Est $\delta^{13}C = -24.0‰$

Soft, finely divided, black charcoal in matrix of clay-rich angular gravel of probable fluvial origin, overlying bedrock at base of Fernhill Gully sec. Gravel overlain by rounded beach gravel related to highest level attained by Lake George during last Glacial Maximum. Gravel and large rootlets were removed by hand, sample crushed in a jaw-crusher, macerated in dilute HCl (pH=5.5), allowed to settle, supernatant water decanted; 700gm oven-dried surface crust containing charcoal-enriched fine sediment was used in 4 successive combustions and 673gm ash recovered. 1200 min count. *Comment* (RJC): pretreatment may not have removed all modern rootlet contamination and date is probably a little younger than expected. Same layer resampled and dates ANU-521/1, -521/2 obtained.

ANU-502. **$D^{14}C = -770.6 \pm 19.7‰$** **11,830 ± 720**
Est $\delta^{13}C = -24.0‰$

Hard, yellow-black, partly mineralized charcoal fragments up to 10mm long in soil matrix. From lower aeolian sand layer of Fernhill Gully, immediately overlying ANU-501, -521 and overlain by ANU-505. Dilution, 16% sample (1560 min count). *Comment* (RJC): sample is about half expected age — possibly incorporated modern, decayed, intrusive root material in field sample.

ANU-503. **$D^{14}C = -536.2 \pm 61.9‰$** **6170 ± 1150**
Est $\delta^{13}C = -24.0‰$

Small fragments of black charcoal in gravelly clay loam forming basal layer of Macgrogan Fan, directly overlying bedrock. Dilution, 4% sample (1840 min count).

ANU-504. **$D^{14}C = -964.6 \pm 10.6‰$** **$26{,}840^{+2860}_{-2100}$**

Est $\delta^{13}C = -24.0‰$

Partly mineralized, yellow-black charcoal in soil matrix. Some calcium carbonate nodules in this gravelly clay loam layer of North Barney Fan, overlying strongly weathered, basal gravel layer. Dilution, 25% sample (1820 min count).

ANU-505. **$D^{14}C = -946.3 \pm 6.8‰$** **23,490 ± 1100**

Est $\delta^{13}C = -24.0‰$

Strongly mineralized, hard, orange-black lumps of charcoal. Intermediate aeolian sand layer of Fernhill Gully overlying beach gravels deposited by Lake George during the last Glacial Maximum. From same layer as ANU-508; overlies ANU-501, -502, -521/1, -521/2 and overlain by ANU-507, -509, -510, -518. Dilution, 53% sample (1040 min counts).

ANU-506. **$D^{14}C = -509.4 \pm 19.4‰$** **5720 ± 320**

Est $\delta^{13}C = -24.0‰$

Small fragments of mineralized yellowish-black charcoal. From middle gravelly clay loam layer of Macgrogan Fan; overlies ANU-503 and overlain by ANU-520. Dilution, 20% sample (1120 min count).

ANU-507. **$D^{14}C = -96.1 \pm 17.6‰$** **810 ± 160**

Est $\delta^{13}C = -24.0‰$

Small, black charcoal fragments from lower A_2 and upper B_2 horizons of moderately differentiated yellow podzolic soil formed in aeolian clay exposed in Fernhill Gully. Dilution, 33% sample (740 min count). *Comment* (RJC): date is much younger than expected for soil of this degree of profile differentiation in clay-rich parent materials. Young age possibly due to incorporation of modern intrusive, decayed root material in field sample.

ANU-508. **$D^{14}C = -877.7 \pm 27.9‰$** **16,880 ± 2080**

Est $\delta^{13}C = -24.0‰$

Highly mineralized lumps of yellowish charcoal from C horizon of intermediate aeolian sand layer of Fernhill Gully. Layer is same as that for ANU-505. Dilution, 11% sample (1500 min count). *Comment* (HAP): pooled mean (Polach, 1969) of dates ANU-505 and ANU-508, both from same stratigraphic unit, is 21,030 ± 1270 BP.

ANU-509. **$D^{14}C = -416.1 \pm 10.3‰$** **4320 ± 145**

Est $\delta^{13}C = -24.0‰$

Highly mineralized, yellowish-black charcoal fragments up to 8mm long from base of upper aeolian sand layer of Fernhill Gully. ANU-518 from upper part, 1.5m stratigraphically higher, of same layer. Dilution, 43% sample (1140 min count).

ANU-510. **$D^{14}C = -39.6 \pm 9.0‰$** **320 ± 80**
Est $\delta^{14}C = -24.0‰$

Black, soft and friable charcoal. Fernhill Gully: from gravelly sandy clay loam sediments at base of soil stratigraphic unit that consists of fluvially reworked aeolian sands. These sands were dated by ANU-509 and -518 (1080 min count).

ANU-511. **$D^{14}C = -604.6 \pm 9.0‰$** **7450 ± 190**
Est $\delta^{14}C = -24.0‰$

Small fragments of black, slightly mineralized charcoal. From gravelly clay loam C horizon of weakly differentiated red podzolic soil of middle fan terrace of Sheridan Fan. Dilution, 27% sample (2960 min count).

ANU-512. **$D^{14}C = -183.2 \pm 11.2‰$** **1630 ± 110**
Est $\delta^{14}C = -24.0‰$

Lumps of black, brittle charcoal up to 15mm long. Basal gravelly clay loam of Hadlow Fan with gray minimal prairie soil deposited by stream after it cut through beach ridge lying 15m above lake bottom. Dilution, 45% sample (1120 min count).

ANU-513. **$D^{14}C = -253.3 \pm 6.7‰$** **2350 ± 75**
Est $\delta^{14}C = -24.0‰$

Lumps of black, brittle charcoal. Sample from base of gravelly clay loam layer with gray minimal prairie soil in One Gum Fan truncated by high stand of lake when 7m deep (1120 min count).

ANU-514. **$D^{14}C = -422.0 \pm 6.0‰$** **4400 ± 85**
Est $\delta^{14}C = -24.0‰$

Lumps of black, brittle charcoal. Gravelly sandy loam layer of middle fan terrace of South Lees Fan with reddish minimal prairie soil (1100 min count).

ANU-515. **$D^{14}C = -205.0 \pm 10.9‰$** **1840 ± 110**
Est $\delta^{14}C = -24.0‰$

Small fragments of black, brittle charcoal. From C horizon of gray minimal prairie soil formed in sediment of youngest alluvial fan terrace of North Lee Fan. Dilution, 37% sample (1560 min count).

ANU-516. **$D^{14}C = -256.7 \pm 32.2‰$** **2380 ± 360**
Est $\delta^{14}C = -24.0‰$

Small lumps of black, brittle charcoal. From C horizon of gray minimal prairie soil formed in sediment of youngest alluvial fan terrace of South Barney Fan. Dilution, 9% sample (2600 min count).

ANU-517. **$D^{14}C = -498.5 \pm 14.9‰$** **5540 ± 240**
Est $\delta^{14}C = -24.0‰$

Soft, friable, yellowish-black charcoal from medium to very coarse sand layer underlying 75cm beach gravel of Vault Embankment. Beach

gravel was deposited when Lake George stood 12m deep and is overlain by aeolian sand similar to that dated by ANU-509 and -518. Dilution, 25% sample (1100 min count).

ANU-518. **$D^{14}C = -213.2 \pm 5.4‰$** **1930 ± 60**
Est $\delta^{13}C = -24.0‰$

Lumps of partly mineralized, yellowish-black charcoal up to 15mm long. From upper aeolian sand layer of Fernhill Gully sec dated also by ANU-509 (2560 min count).

ANU-519. **$D^{14}C = -984.8 \pm 35.7‰$** **Background**
Est $\delta^{13}C = -24.0‰$

Soft, partly mineralized, yellowish-brown, decomposed twigs and charcoal fragments. Remnant of K_4 terrace within Grove Creek Etch Basin, Gearys Gap (35° 06′ S, 149° 22′ E). This basin lies immediately W of Lake George Basin. Coll July, 1968 by P H Walker & M P Green, CSIRO, Division of Soils, Canberra, Australia. Dilution, 8% sample (1680 min count). *Comment* (HAP&RJC): result was reported in press (see below) as > 15,600 using 3σ criterion. Based on recommendations by Stuiver and Polach (R, 1977, v 19, p 362) it is reported here as *Background*. Sample is stratigraphically below and is consistent with previous dates (ANU-91-95) from younger soil stratigraphic units at this locality (R, v 10, p 182-183) and is discussed by Walker & Coventry (1976) and Coventry & Walker (1977).

ANU-520. **$D^{14}C = -346.4 \pm 17.3‰$** **3420 ± 220**
Est $\delta^{13}C = -24.0‰$

Lumps of yellowish-black, brittle charcoal up to 10mm long. From upper gravelly clay loam layer at Macgrogan Fan. Overlies both ANU-503 and -506. Dilution, 24% sample (1120 min count).

ANU-521/1. **$D^{14}C = -960.0 \pm 16.0‰$** **>23,800**
Est $\delta^{13}C = -24.0‰$

Soft, black, highly mineralized charcoal. Basal layer in Fernhill Gully, 35m downstream of ANU-501, overlain by beach gravel related to highest level attained by Lake George during last Glacial Maximum. Coll by H A Polach and R J Coventry, June 1971. Dilution, 15% sample (2600 min count). *Comment* (HAP): result was reported and pub (see refs, ANU-519, above) using 3σ criterion as > 21,400 BP. Recalculated result has *apparent age*, 25,900 ± 4100 BP, consistent with 521/2 below.

ANU-521/2. **$D^{14}C = -964.7 \pm 3.7‰$** **26,870 ± 900**
Est $\delta^{13}C = -24.0‰$

Sample as for ANU-521/1. Macerated in distilled water, allowed to settle, charcoal concentrated in this manner and treated as for other samples in series (1040 min count).

General Comment (RJC&HAP): most important conclusion from this dating program is that Lake George attained a level equal to its over-

flow point, 36m above lake bottom, during last Glacial Maximum between 27,000 BP, dates ANU-501, -521/1, -521/2, and 21,000 BP, pooled mean of dates ANU-505 and -508. This high lake level was achieved under cooler and drier conditions than at present (Coventry, 1976). These dates have also fixed ages of other more recent, relatively high lake levels, and of several phases of aeolian sand deposition and alluvial fan aggradation (Coventry & Walker, 1977).

ANU-294. Borenore Arch Cave, Orange, New South Wales, Australia

$D^{14}C = -968.4 \pm 6.5‰$ **$27{,}760^{+1860}_{-1510}$**

Est $\delta^{13}C = -24.0‰$

Guano sample coll from flowstone deposit, sandwiched between alluvium, 230 to 260cm below floor of Borenore Arch Cave 20km W of Orange, New South Wales, Australia (33° 15′ S, 148° 56′ E). Deposit recorded a period of absence of streams from their previous and subsequent channels, indicating a dry climatic phase in the area. Coll Sept 1968 and subm by R M Frank, Dept Biogeog & Geomorphol, ANU. Organic matter extracted using sod pyrophosphate (2460 min count). *Comment* (RMF): result corroborated period of dry climatic phase previously dated by 2 inorganic ^{14}C dates on calcium carbonate (R2457/4, 27,300 BP, with no standard deviation given; R2457/2, 27,900 ± 1500 BP; (Frank, 1972; 1973; 1975).

ANU-749. North-west Continental Shelf, Australia

$D^{14}C = -978.5 \pm 3.0‰$ **30,850 ± 1200**

Est $\delta^{13}C = 0.0‰$

Sample resembled shallow water "calcretes" correlated with last major low sea level stand at ca 18,000 BP in NW Australia. If sample were young enough to be dated, it would imply substantial tectonic movement in area. Dredged from sea floor at 282m water depth (13° 16′ S, 123° 37′ E) in 1967. 10% of surface material removed with dilute HCl. Coll and subm by H A Jones, Bureau Mineral Resources, Canberra, Australia. Oolitic limestone. Acid hydrolysis CO_2 (1120 min count). *Comment* (HAJ): results indicate that submarine lithification has occurred during Quaternary and that no sedimentation has taken place in Holocene (Jones, 1973).

ANU-646. Mt Schank, South Australia

$D^{14}C = -894.5 \pm 4.4‰$ **18,100 ± 350**

Est $\delta^{13}C = -24.0‰$

Soft charcoal in discrete fragments coll from buried soil forming upper surface of Burleigh dune (37° 56′ S, 140° 45′ E), major ridge trending NW-SE, and according to Sprigg (1952), consisting of Pleistocene aeolianite. Mt Schank is 12.9km SSW of Mt Gambier, South Australia. Estimates of age of volcanic activity of Mt Schank vary from 150,000

to 200,000 (Sprigg, 1952, p 115) to "quite late prehistoric time" (Fenner, 1921, p 185). Coll Jan 1971 and subm by E B Joyce, School Geol, Univ Melbourne, Australia (960 min count). *Comment* (EBJ): age of activity at Mt Schank was estimated as late Pleistocene to mid-Holocene, based on preservation of volcanic features in comparison with Mt Gambier (R, 1966, v 8, p 61) and other dated volcanoes (Joyce, 1974; 1975). Date obtained by ^{14}C is within this range. It clearly indicates that activity at Mt Schank was separate from that at Mt Gambier and was also distinctly earlier than activity at several Victorian volcanoes already dated by ^{14}C as early as mid-Holocene. This is oldest volcano in SE Australia directly dated by ^{14}C, although ^{14}C dates relating to earlier activity have been obtained, as well as K–Ar dates on flows dating to late-Pliocene. In light of ^{14}C date at Mt Schank it is now necessary to re-examine suggestion of Sprigg (1952) on relationship of Mt Schank activity and higher sea levels in area.

Melville Island series

Pockets of monsoon forest in N Australia seem to be relics of previously wide-spread, relatively continuous flora (Specht, 1958). The discovery of abandoned mound nest of *Megapodius freycinet tumulus* Gould in eucalypt forests on Karslake Peninsula, Melville I., Australia, (11° 20′ S, 130° 39′ E), indicates recent changes in extent of monsoon forest in area. This bird constructs mound nests only in monsoon forest and related plant communities. Over a hundred abandoned mound nests were found in area of 405ha at tip of Peninsula. Coll 1967 by G C Stocker, Forest Research Inst, Dept Natl Development; subm by Geophysics, ANU.

ANU-206. $\mathbf{D^{14}C = -181.6 \pm 8.0‰}$ **1610 ± 80**
Est $\delta^{14}C = -24.0‰$

Charcoal from interval 99 to 129cm below crest of abandoned mound nest 101m from nearest monsoon forest edge (1020 min count).

ANU-207. $\mathbf{D^{14}C = -196.5 \pm 7.8‰}$ **1760 ± 80**
Est $\delta^{13}C = -2.0‰$

Marine shells (*Telescopium telescopium* Linne) from same position in mound as ANU-206. 10%, outer shell surface, by weight leached away by acid (1020 min count). *Comment* (GCS): shells probably thrown near nest by aborigines and later scratched into nest by fowls. Mound is ca 183m from, and 9m above present maximum spring tide level. No other excavated mound contained shells.

ANU-208. $\mathbf{D^{14}C = -243.3 \pm 7.2‰}$ **2240 ± 80**
Est $\delta^{13}C = -24.6‰$

Charcoal from interval 76 to 104cm below crest of abandoned mound nest 283m from nearest monsoon forest edge. A very small monsoon forest relic of a few trees is 174m from mound (1020 min count).

ANU-209. **$D^{14}C = -345.0 \pm 6.6‰$** **3400 ± 90**
Est $\delta^{13}C = -24.0‰$

Charcoal from interval 91 to 122cm below crest of abandoned mound nest 252m from nearest monsoon forest edge (1000 min count).

ANU-210. **$D^{14}C = -639.7 \pm 8.2‰$** **8200 ± 180**
Est $\delta^{13}C = -24.0‰$

Charcoal from interval 91 to 122cm below crest of abandoned mound nest 420m from nearest monsoon forest edge (1020 min count). *Comment* (GCS): mound is on S edge of area containing abandoned mound nests and may be close to old monsoon — eucalypt forest boundary.

ANU-211. **$D^{14}C = -453.8 \pm 6.0‰$** **4860 ± 90**
Est $\delta^{13}C = -24.0‰$

Charcoal from interval 61 to 91cm below crest of abandoned mound nest 402m from nearest monsoon forest edge (1060 min count).

General Comment (GCS): although abandoned mound nests are often found in monsoon forest communities throughout coastal region of Northern Territory, no other areas have as many nests in eucalypt forests as on N part of Karslake Peninsula. Considerable reduction in area occupied by monsoon forest must have occurred in this locality. Decline would have commenced after construction of mound represented by ANU-210, 8200 ± 180. Resistance of mounds to erosion and their absence from eucalypt forests in other areas suggests that monsoon forests have not all retreated and in most localities boundaries have been relatively stable during recent epoch.

Gawler River series

Samples coll from alluvium at depth 5.2m below surface of river terrace, 3.2km SW of Gawler, South Australia (34° 37′ S, 138° 43′ E). Hearths and tree trunk excavated from base of younger alluvium in valley of Gawler R. Hearths are quite numerous and are restricted to one level. Coll November 1967 by C R Twidale, Dept Geog, Univ Adelaide; subm by Australian Inst Aboriginal Studies.

ANU-204. **$D^{14}C = -29.0 \pm 8.1‰$** **235 ± 70**
Est $\delta^{13}C = -24.0‰$

Charcoal from hearth (1000 min count).

ANU-205. **$D^{14}C = -45.8 \pm 8.1‰$** **375 ± 70**
Est $\delta^{13}C = -24.0‰$

Wood, from tree trunk found *in situ* at base of younger alluvium (980 min count).

General Comment (CRT): results date period of fairly intense aboriginal occupation at site, maximum age of younger alluvium. Part of broader geomorphologic and stratigraphic study.

B. New Guinea and Pacific Islands

Huon Peninsula series

Samples are from youngest reefs of Huon coral terraces, Papua New Guinea, described by Chappell (1974) and fall into 2 groups.

The 1st contains 9 samples from emergent Holocene reef, which are combined with previous ^{14}C and ^{230}Th and ^{234}U results (R, 1969, v 11, p 254-262; Veeh & Chappell, 1970; Bloom *et al*, 1974) to provide close dating control for study of relationships between Holocene sea level change and coral reef growth (Chappell & Polach, 1976).

The 4 samples of 2nd group come from Huon Reef Complex III, well dated by $^{230}Th/^{234}U$ as 40,000 yr old, and provide additional data to complement 1st study of diagenesis and ^{14}C contamination by Chappell & Polach (1972).

Interpretation of new and previous carbon-isotope data, together with uranium-series results, appears in Chappell *et al* (1974). Coll Aug 1971 and Aug 1973; subm by John Chappell, Dept Geog, ANU.

1) Holocene reef samples

These occur in vertical sequence from crest of reef to 8m below crest. Reef grew as sea level rose, and sample ages become younger upwards. Samples are listed in terms of depth below reef crest, rather than code numbers, as this makes clear age-depth relationship.

ANU-1250. **$D^{14}C = -560.9 \pm 7.4‰$** **6610 ± 140**
Est $\delta^{13}C = 0.0‰$

Goniastrea pectinata, 0.5m below crest (6° 7′ 30″ S, 147° 38′ 22″ E). Dilution, 61% sample (900 min count).

ANU-1190. **$D^{14}C = -606.8 \pm 4.3‰$** **7500 ± 90**
Est $\delta^{13}C = 0.0‰$

Goniastrea retiformis, 4m below crest, 100% aragonite (1580 min count).

ANU-1191. **$D^{14}C = -617.7 \pm 6.8‰$** **7720 ± 140**
Est $\delta^{13}C = 0.0‰$

Leptoria phrygia, 5.5m below crest (6° 13′ 20″ S, 147° 41′ 05″ E), 99% aragonite. Dilution, 52% sample (1500 min count).

ANU-1189. **$D^{14}C = -612.1 \pm 4.3‰$** **7610 ± 90**
Est $\delta^{13}C = 0.0‰$

Favia stelligera, 6m below crest (6° 7′ 30″ S, 147° 38′ 22″ E), 100% aragonite (1500 min count).

ANU-1249. **$D^{14}C = -616.9 \pm 5.0‰$** **7710 ± 110**
Est $\delta^{13}C = 0.0‰$

Pocillopora sp, 6.3m below crest, 97% aragonite (920 min count).

ANU-1248. **$D^{14}C = -629.6 \pm 5.5‰$** **7980 ± 120**
Est $\delta^{13}C = 0.0‰$

Hydnophora mocroconus, 6.5m below crest, 100% aragonite (1020 min count).

ANU-1251. **$D^{14}C = -639.0 \pm 5.0‰$** **8180 ± 110**
Est $\delta^{13}C = 0.0‰$

Pocillopora sp, 7m below crest, 97% aragonite (920 min count).

ANU-1252. **$D^{14}C = -636.8 \pm 5.0‰$** **8140 ± 110**
Est $\delta^{13}C = 0.0‰$

Acropora humilis, 8m below crest, 100% aragonite (920 min count).

ANU-1253. **$D^{14}C = -622.6 \pm 5.2‰$** **7830 ± 110**
Est $\delta^{13}C = 0.0‰$

Goniastrea retiformis, 8.3m below crest, 100% aragonite (1000 min count).

General Comment (JC): Group 1 results are accepted as satisfactory ^{14}C age measurements. For comparison with terrestrial materials, sea water age correction, 400 ± 100 yr for Huon, must be subtracted (Chappell & Polach, 1976).

2) Late Pleistocene reef samples with diagenetic contamination

All from Huon Reef IIIb, Kanzarua area (6° 12′ 40″ S, 147° 41′ 40″ E), age 40,000 ± 2000 BP, based on $^{230}Th/^{234}U$ dates (Bloom *et al,* 1974).

ANU-1030. **$D^{14}C = -911.2 \pm 2.6‰$** **19,450 ± 240**
Est $\delta^{13}C = 0.0‰$

Coral (sp not id), 7% recrystallized to sparry low-Mg calcite (2100 min count).

ANU-1031. **$D^{14}C = -975.2 \pm 2.4‰$** **29,690 ± 830**
Est $\delta^{13}C = 0.0‰$

Coral (*Hydnophora exesa*) 3% recrystallized to sparry low-Mg calcite, $^{230}Th/^{234}U$ age 42,000 ± 3000 (Bloom *et al,* 1974, Sample L1353D) (2080 min count).

ANU-1302. **$D^{14}C = -968.2 \pm 2.5‰$** **27,710 ± 650**
Est $\delta^{13}C = 0.0‰$

Coral (sp not id), 6% recrystallized to sparry low-Mg calcite (1880 min count).

ANU-1033. **$D^{14}C = -895.8 \pm 6.3‰$** **18,170 ± 500**
Est $\delta^{13}C = 0.0‰$

Coral (*Symphyllia nobilis*) 3% recrystallized to sparry low-Mg calcite. Dilution, 44% sample (1520 min count).

General Comment (JC): ANU-1030-1033 have low percentage of recrystallization to sparry calcite, 3% to 7%, determined by x-ray diffrac-

tion by method of Chappell & Polach, 1972. Apparent ^{14}C ages are substantially lower than accepted $^{230}Th/^{234}U$ age of their parent reef, and demonstrate intrinsic unreliability of corals, bearing only slight alteration, for ^{14}C dating of Late Pleistocene reefs (Chappell *et al*, 1974).

ANU-247. Central Watom Island, New Britain

$D^{14}C = -239.6 \pm 6.9‰$ 2200 ± 80

Est $\delta^{13}C = -24.0‰$

Finely dispersed charcoal in greenish volcanic soil, from Rakival village on island's NE coast (4° 5′ S, 152° 5′ E). Coll 1967 by C A Key, Prehist, ANU, subm by Prehist (1080 min count). *Comment* (CAK): sample immediately underlies ANU-72, 720 ± 57 (R, 1968, v 10, p 194) and should establish date for last major eruption of Rabaul volcanic complex.

Ambrym Island series

Samples coll by P J Stephenson, Geol Dept, Univ Coll, Townsville, Queensland, engaged in joint project with ANU, dating caldera formations and measuring magnetization of assoc lava flows of Ambrym I., New Hebrides (Stephenson *et al*, 1968). Samples ANU-86 and -87 coll at base of nuée ardente deposit, 30.5m thick. This is youngest deposit observed on flanks of original Ambrym volcanic cone, except for mantling ash from very young (historic) and recent eruptions. Nuée overlies succession of lavas and older pyroclastic rocks, which make up upper succession of flanks of main Ambrym original cone. They were erupted in late pre-caldera times.

ANU-86. **$D^{14}C = -207.0 \pm 10.5‰$** **1865 ± 110**

Est $\delta^{13}C = -24.0‰$

ANU-87. **$D^{14}C = -218.5 \pm 10.8‰$** **1980 ± 115**

Est $\delta^{13}C = -24.0‰$

Both samples of carbonized tree trunks from basal zone of nuée deposits. Coll at foot of exposure in Spring Creek (16° 11′ S, 168° 06′ E), 1km from coast, 30cm back from face and 1.5m above bed of creek. Both 1300 min determinations.

ANU-88. **$D^{14}C = -193.2 \pm 10.9‰$** **1725 ± 110**

Est $\delta^{13}C = -24.0‰$

ANU-89. **$D^{14}C = -223.3 \pm 8.7‰$** **2030 ± 90**

Est $\delta^{13}C = -24.0‰$

Both samples of carbonized tree trunks, from outcrop in bed of NE creek inside caldera rim (16° 13′ S, 168° 11′ E), 15cm back from face. ANU-88, 2040 min count; ANU-89, 1000 min count.

General Comment (PJS): the 2 groups of ages are consistent and give a minimum age for palaeomagnetic specimens beneath. Results show extreme youth of Ambrym caldera.

C. Africa

Walvis Bay series

Shelf sediments along, biologically, very productive coastal area off SW Africa, particularly near Walvis Bay, are noted for exceptionally high concentrations of organic matter (Calvert & Price, 1971). Inasmuch as sediments of this type may represent significant sinks for uranium in the ocean (Veeh, 1967; Baturin *et al*, 1971), an attempt was made to estimate rate at which uranium is accumulating in these sediments, on basis of dated secs of sediment cores raised from sea floor in this area. Sedimentation rates in terms of cm/1000 yr can be obtained by dividing age difference between top and bottom sec of each core into depth interval separating sample mid-points (Emery & Bray, 1962). Accumulation rate of uranium, or that of any other sediment component, can then be estimated if their concentrations in sediment are known. Such accumulation rate data are indispensable for geochemical balance calculations, yet few are available from critical areas.

Samples were hydrolized, using 50% HCl. Organic residues were separated by filtration. Where sufficient material was available both organic fraction and carbonate fraction were dated; otherwise only organic fraction was used. Coll 1968 by S E Calvert, Inst Oceanog Sci, Wormley, Godalming, U K; subm by H H Veeh, School Earth Sci, Flinders Univ South Australia.

ANU-450A. **$D^{14}C = -218.7 \pm 11.3‰$** **1980 ± 120**
Est $\delta^{13}C = 0.0‰$

Outer shelf, depth 134m (22° 56′ S, 14° 00′ E). Circe 175, sample represents ½ portion of homogenized 70 to 75cm interval of 21cm diam gravity core. Carbonate fraction, dilution, 43% sample (1080 min count).

ANU-450B. **$D^{14}C = -157.8 \pm 7.8‰$** **1380 ± 80**
$\delta^{13}C = -18.9‰$

Circe 175, sample represents remaining ½ portion of 70 to 75cm interval. Organic fraction (1120 min count).

ANU-451A. **$D^{14}C = +73.9 \pm 20.4‰$** **>Modern**
$\delta^{13}C = -0.2‰$

Circe 175, sample represents ½ portion of 0 to 10cm interval of same core as ANU-450A and B. Carbonate fraction, dilution, 11% sample (2860 min count).

ANU-451B. **$D^{14}C = -87.3 \pm 6.7‰$** **730 ± 60**
Est $\delta^{13}C = -20.0‰$

Circe 175, sample represents remaining ½ portion of 0 to 10cm interval. Organic fraction (1500 min count).

ANU-452A. **$D^{14}C = -289.9 \pm 12.7‰$** **2750 ± 150**
$\delta^{13}C = -0.2‰$

Outer shelf, depth 119m (21° 52′ S, 12° 36′ E). Circe 189B, top 30cm of 4.5cm diam gravity core. Carbonate fraction, dilution, 34% sample (1120 min count).

ANU-452B. **$D^{14}C = -198.0 \pm 7.0‰$** **1770 ± 70**
Est $\delta^{13}C = -20.0‰$

Circe 189B, organic fraction (1100 min count).

ANU-453A. **$D^{14}C = -561.0 \pm 4.6‰$** **6610 ± 80**
$\delta^{13}C = 0.3‰$

Circe 189B, sample represents 60 to 84cm (bottom 24cm) of same core as ANU-452A and B. Carbonate fraction (1460 min count).

ANU-453B. **$D^{14}C = -374.9 \pm 7.7‰$** **3770 ± 100**
Est $\delta^{13}C = -20.0‰$

Circe 189B, organic fraction (740 min count).

ANU-454B. **$D^{14}C = -41.3 \pm 17.3‰$** **340 ± 150**
Est $\delta^{13}C = -20.0‰$

Outer shelf, depth 123m (22° 41′ S, 14° 08′ E). Circe 177B, top 30cm of 4.5cm diam gravity core. Organic fraction, dilution, 34% sample (720 min count).

ANU-455B. **$D^{14}C = -167.3 \pm 31.9‰$** **1470 ± 310**
Est $\delta^{13}C = -20.0‰$

Circle 177B, sample represents 110 to 130cm interval (bottom 20cm) of same core as ANU-454B. Organic fraction, dilution, 50% sample (740 min count).

ANU-456B. **$D^{14}C = -50.2 \pm 16.8‰$** **410 ± 140**
Est $\delta^{13}C = -20.0‰$

Outer shelf, depth 125m (22° 36′ S, 13° 56′ E). Circe 179B, top 30cm of 4.5cm gravity core. Organic fraction, dilution, 35% sample (740 min count).

ANU-457B. **$D^{14}C = -166.7 \pm 11.5‰$** **1470 ± 110**
Est $\delta^{13}C = -20.0‰$

Circe 179B, sample represents 80 to 110cm interval (bottom 30cm) of same core as ANU-456B. Organic fraction, dilution, 59% sample, (740 min count).

Summary and General Comment (HHV&HAP):

Core no.	Sedimentation rate (cm/1000 yr) (1)	(2)	Uranium accumulation rate* (μg/cm^2/1000 yr) (1)	(2)
Circe 175	103	34	765	267
Circe 177B	88		676	
Circe 179B	65		723	
Circe 189B	29	15	464	232

* Derived from sedimentation rates and measured uranium concentrations in same cores (Veeh *et al*, 1974)
(1) Based on ^{14}C ages of organic fraction
(2) Based on ^{14}C ages of $CaCO_3$ fraction

It appears that sedimentation rates based on the $CaCO_3$ fractions are lower than those based on the organic fraction. In view of probability of dealing with reworked, or partly wind-derived material when analyzing bulk carbonate fraction in near shore sediments (Emery & Bray, 1962; Olsson & Eriksson, 1965) sedimentation rates based on ^{14}C ages of organic fraction are believed to be more reliable.

West Sahara series

The series deals with soils of West Sahara (South Morocco and Spanish Sahara), the genesis of calcareous crusts forming a major part of thesis for which dating was required. Samples treated by HCl hydrolysis of carbonate. Coll Oct and Nov 1953; subm by K Zimmerman, Inst Soil Sci, Bonn Univ.

ANU-609. **$D^{14}C = -951.3 \pm 3.0‰$** **24,270 ± 510**
$\delta^{13}C = -3.6‰$

Fine sandy limestone of calcareous crust. From E escarpment of plateau "Hameida Tel-lia", 6km SW of Tantan, Morocco (28° 24′ N, 11° 08′ W) (1500 min count).

ANU-610. **$D^{14}C = -634.1 \pm 5.2‰$** **8075 ± 115**
Est $\delta^{13}C = -5.0‰$

Laminated hard limestone of calcareous crust. From quartzite chain 7km NE of Tilemson, Morocco (28° 19′ N, 10° 27′ W) (1500 min count).

ANU-611. **$D^{14}C = -902.4 \pm 3.8‰$** **18,690 ± 320**
Est $\delta^{13}C = -5.0‰$

Dirty gray non-laminated limestone of calcareous crust. From same site as ANU-610 (1500 min count).

ANU-612. **$D^{14}C = -801.6 \pm 3.8‰$** **13,000 ± 155**
$\delta^{13}C = -4.6‰$

Fine sandy limestone of calcareous crust. From E slope of mt chain "Kdir Lemres" 11km NNE of Tilemson (28° 22′ N, 10° 53′ W) (1500 min count).

ANU-613. **$D^{14}C = -860.3 \pm 3.6‰$** **15,810 ± 240**
$\delta^{13}C = -3.7‰$

Sandy limestone of calcareous crust with embedded fine gravelly fragments of non-carbonate rock. Crust overlays that of ANU-614. From valley of Wadi Mazcor, 1km SW of spring, 14km NNEE of Tilemson (28° 23′ N, 10° 50′ W) (1480 min count).

ANU-614. **$D^{14}C = -901.6 \pm 3.5‰$** **18,630 ± 300**
$\delta^{13}C = -5.7‰$

Fine sandy limestone of calcareous crust; gray, slightly yellowish brown, mottled. From same site as ANU-613; from naturally exposed wall of Wadi (1140 min count).

ANU-615. **$D^{14}C = -972.3 \pm 3.2‰$** **28,810 ± 980**
$\delta^{13}C = -5.7‰$

Very pure limestone cores of rounded gravel stones. From summit of N sec of Entayat Mts, 55km NNW of Tichla, Spanish Sahara (21° 58′ N, 15° 11′ W) (1120 min count).

ANU-616. **$D^{14}C = -950.9 \pm 3.3‰$** **24,210 ± 560**
$\delta^{13}C = -1.8‰$

Slightly sandy limestone of calcareous crust. From wall of small dry watercourse in narrow pass between N and S secs of Entayat Mts, Spanish Sahara (21° 57′ N, 15° 13′ W) (1100 min count).

ANU-617. **$D^{14}C = -945.0 \pm 3.9‰$** **23,300 ± 470**
$\delta^{13}C = -3.1‰$

Sandy limestone of calcareous crust with some embedded rock fragments. From low river terrace of Wadi Tueirga, Spanish Sahara (21° 54′ N, 15° 09′ W) (1120 min count).

ANU-974. **$D^{14}C = -930.9 \pm 2.9‰$** **21,470 ± 350**
$\delta^{13}C = -3.1‰$

Sandy limestone of calcareous crust. From highest terrace of Wadi Saguia el Hamra near Aaium, Spanish Sahara (27° 09′ N, 13° 12′ W) (1500 min count).

ANU-975. **$D^{14}C = -986.7 \pm 2.5‰$** **$34{,}690^{+1630}_{-1360}$**
Est $\delta^{13}C = -5.0‰$

Sandy limestone of calcareous crust. From 1st (lowest) terrace, 3km W of Tantan, Morocco (28° 26′ N, 11° 07′ W) (2000 min count).

ANU-976. **$D^{14}C = -918.0 \pm 3.7‰$** **20,090 ± 370**
$\delta^{13}C = -1.6‰$

Fine sandy limestone of calcareous crust with embedded fine gravelly fragments of non-carbonate rock (mostly quartzite). From low-lying sediment plain near Tilemson, Morocco (28° 17′ N, 10° 54′ W) (960 min count).

ANU-977. **$D^{14}C = -983.0 \pm 2.6‰$** **$32{,}740^{+1320}_{-1130}$**
$\delta^{13}C = -1.5‰$

Slightly coarse sandy limestone of calcareous crust from 1 to 1.5m below top of exposed wall of well-pit on small level plateau between 2 wadi systems within Ausert Mts, Spanish Sahara (22° 34′ N, 14° 18′ W) (1680 min count).

ANU-978. **$D^{14}C = -975.3 \pm 2.9‰$** **29,730 ± 990**
$\delta^{13}C = -2.5‰$

Coarse sandy and gravelly limestone of calcareous crust; 3 to 3.5m below top of same profile as ANU-977 (1400 min count).

ANU-980. **$D^{14}C = -937.1 \pm 3.5‰$** **22,230 ± 460**
$\delta^{13}C = -1.7‰$

Limestone with embedded sand and rock fragments. From flat level plateau of divide between 2 wadi systems in W part of Entayat Mts, 56km NNW of Tichla, Spanish Sahara (21° 58′ N, 15° 13′ W) (1020 min count).

ANU-981. **$D^{14}C = -966.2 \pm 2.8‰$** **27,210 ± 700**
$\delta^{13}C = -1.0‰$

Limestone of calcareous crust. From 40 to 50cm depth of same profile as ANU-616 (1460 min count).

ANU-982. **$D^{14}C = -965.6 \pm 2.9‰$** **27,060 ± 700**
$\delta^{13}C = -3.0‰$

Sandy limestone of calcareous crust. From 50cm depth of same profile as ANU-617 (1440 min count).

General Comment (KZ): with exception of ANU-609 and -975, samples from S of area (ANU-615-617, -977-982) are, on average, older than those from N (ANU-610-614, -974 and -976), perhaps due to better preservation or preferential accumulation of younger crust in N.

Since calcareous crusts developed as accumulation horizons within aeolian soils and sediments, crusts are, in principle, independent of geomorphologic surfaces. Therefore, relatively young crusts could appear on older surfaces, eg, ANU-609 on an old Tertiary plateau and ANU-974 on a high terrace of Pliocene age.

The aeolian soils and sediments with calcareous crusts could have been deposited on top of each other several times in the Quaternary. Therefore, in a single profile, younger crusts can appear at the top and older ones at the bottom of the profile. Examples are: ANU-613 above -614, ANU-616 above -981, ANU-617 above -982.

The lower, *ie*, older parts of such multilayered profiles can be exposed by erosion. In this way, a relatively older crust can appear on younger geomorphologic surfaces, whereas on non-eroded or only partly eroded older geomorphologic surfaces the upper parts of the profile, *ie*, a younger crust can be preserved. Examples are: ANU-975 on a

lower younger surface compared to ANU-609 on a higher older surface.

Many of the caliche crusts were younger than expected. There are indications that several times during the Quaternary phases of crust development and crust destruction cyclically alternated with each other, due to climatic oscillations. Each previously developed crust could have been influenced by the succeeding cycles of crust dissolution and renewed lime accumulation. These processes can penetrate into a considerable depth of the profiles through fissures, and can rejuvenate the older crusts. Sometimes a lower layer of a profile seems to be more affected than a layer nearer to the surface, eg, ANU-978 compared to ANU-977.

The laminar crusts were deposited subsequently on the non-laminar crust material and must therefore be relatively younger, as in the case of the laminated hard limestone, ANU-610, on the non-laminated one, ANU-611.

II. ARCHAEOLOGIC SAMPLES

Australia

Lake Victoria series

Charcoal and shells (*Velesunio ambiguus*) coll from aboriginal middens in red paleosol near top of Nulla Nulla Sand, lower of 2 formations in large dune systems on E side of Lake Victoria, New South Wales, Australia. Dating to correlate aeolian processes, river regime, changing fauna and paleo climate with activities of aborigines. 10% of shell surface was hydrolyzed using dilute HCl; charcoal was treated with hot 2N HCl, rinsed with distilled water. Coll 1969 and subm by E D Gill, then at Natl Mus Victoria (Gill, 1973a, b).

ANU-404A. $\mathbf{D^{14}C = -887.2 \pm 4.3‰}$ **17,530 ± 320**
Est $\delta^{13}C = 0.0‰$

Shells (*Velensunio ambiguus*) (34° 01′ S, 141° 20′ E) (960 min count).

ANU-404B. $\mathbf{D^{14}C = -791.7 \pm 31.1‰}$ **12,600 ± 1300**
Est $\delta^{13}C = 0.0‰$

Charcoal assoc with shell ANU-404A. Dilution, 7% sample (3040 min count). *Comment* (HAP): small sample size of 404B precluded reduction of error. Statistical agreement is ambiguous ($z = 3.7$, Polach, 1972) thus, possibility still exists that both results relate to same event. Charcoal results ANU-404B should be used to interpret site history.

ANU-405. $\mathbf{D^{14}C = -861.9 \pm 4.6‰}$ **15,900 ± 280**
Est $\delta^{13}C = 0.0‰$

Shells (*Velesunio ambiguus*) 5m below top of Nulla Nulla Sand (33° 59′ S, 141° 17′ E) (960 min count).

ANU-422. $\mathbf{D^{14}C = -875.2 \pm 4.0‰}$ **16,720 ± 260**
$\delta^{13}C = -2.4‰$

Shells (*Velesunio ambiguus*) (33° 56′ S, 141° 15′ E) (1000 min count). *Comment* (EDG): dating to cross-check shells against charcoal, and to date midden (GaK-2515, 15,300 ± 500 BP; Gill, 1973a, p 58).

ANU-423. **$D^{14}C = -4.7 \pm 9.7‰$** **Modern**
Est $\delta^{13}C = -24.0‰$

Wood charcoal from small shoots. Sample from one of series of middens in horizon of gulch on side of Lake Victoria, with no dune system. Numerous gulches represent at least 2 periods when erosion dominated over deposition, latter usually being in form of stratified piedmont fans (33° 58′ S, 141° 13′ E) (1040 min count). *Comment* (EDG): modern date shows that break-up of terrain, eg, with wide-spread gullying, occurred since European occupation. Assay also dates latest lithification by secondary carbonate, *ie*, it is contemporary process in some places at least, and provides minimal date for aboriginal bones and middens cemented by this carbonate.

ANU-421. **$D^{14}C = -89.5 \pm 19.1‰$** **750 ± 170**
Est $\delta^{13}C = -22.0‰$

Bone fragment from aboriginal burial near top of Nulla Nulla Sand (30° 59′ S, 141° 21′ E). Bones from 1 of 16 skeletons at site. Coll March, 1969 by R Blackwood and G Douglas for Natl Mus, Victoria; subm by E D Gill (Blackwood & Simpson, 1973). Human bone, collagen, obtained by acid hydrolysis (Longin, 1971). Dilution, 22% sample (1060 min count).

Lindsay River series

Fragments of aboriginal skeletons coll from burial grounds in 2 dunes, Lindsay I., Lindsay R, Victoria, Australia (35° 05′ S, 141° 02′ E). Bones from lowest 4 skeletons of 16 in tight mass grave. Many other burials in area. Coll by R Blackwood and K Simpson, Natl Mus, Victoria; subm by E D Gill.

ANU-420A. **$D^{14}C = +482.4 \pm 160.0‰$** **>Modern**
$\delta^{13}C = -26.0‰$

Water soluble bone fraction: crushed bone boiled in distilled water in pressure cooker (103kPA) for 30min (pH slightly alkaline) and water soluble fraction recovered and dated. Dilution, 2% sample (2080 min count). Result is mean of 2 dates $D^{14}C/1 = +379.2 \pm 163.9‰$. $D^{14}C/2 = +585.6 \pm 163.0‰$.

ANU-420B. **$D^{14}C = -232.6 \pm 7.9‰$** **2130 ± 85**
$\delta^{13}C = -7.6‰$

Bone carbonate: water insoluble residue of ANU-420A treated with 30% cold acetic acid to hydrolyze bone carbonate (1120 min count).

ANU-420C. **$D^{14}C = -432.1 \pm 12.9‰$** **4550 ± 185**
$\delta^{13}C = -14.0‰$

Bone apatite: acetic acid hydrolysis residue of ANU-420B treated with 50% cold HCl to recover acetic acid insoluble carbonate, *ie*, apatite (Haynes, 1968). Dilution, 32% sample (1100 min count).

ANU-420D. **$D^{14}C = -359.3 \pm 28.7‰$** **$\geqslant 3580 \pm 370$**
Est $\delta^{13}C = -24.0‰$

Acid insoluble residue; collagen (Berger *et al*, 1964): after washing and drying total acid, insoluble residue of ANU-420C was ignited. Dilution, 7% sample (7320 min count).

General Comment (HAP): validity of bone dating (Olsson *et al*, 1974; Polach, 1971; Haynes, 1968) can be established only if relating isolated fraction ages to environmental conditions or burial site. ANU-420A > Modern reflects post-depositional contamination with contemporary ^{14}C, of water soluble extract, collagen, fulvic and humic acids. Bone carbonate, ANU-420B, reflects age of pedogenic intrusive and exchangeable carbonate from environment and is not valid bone dating medium. Agreement between bone apatite and bone collagen results generally can be taken as validating bone age determination (*viz* refs quoted above). However, in presence of established humic contamination, ANU-420A, acid insoluble residue collagen, ANU-420D, can not be deemed contamination free and results must be considered as equal to or greater than ($\geqslant$) 3580 ± 370 BP. This agrees with ANU-420C apatite, which most likely represents age of burial at 4550 ± 185 BP.

III. ARCHAEOMAGNETIC SAMPLES

Australia

Murray River series

In August 1972 6 new sites, with small concentrations of charcoal and well-baked clayey silt, were found in sec of ancient point-bar deposit exposed by modern river-bank erosion on Murray R, New South Wales, Australia (35° 56′ S, 144° 28′ E). Pellets of charcoal and lumps of baked sediment, ranging in size from 1cm to ca 15cm across, and occasionally undisturbed baked sediment were found interspersed with soft unbaked sediment and are thought to result from burning of logs, tree stumps or roots. Unoriented samples of baked sediment are being used in study of ancient geomagnetic field strength, and radiocarbon dates were obtained as part of this study (Barbetti, 1973). The ^{14}C ages reported here, together with ANU-692 and -693 (R, 1973, v 15, p 250), indicate approx constant growth rate for this particular point-bar. All samples, except where noted, were dated using acid and alkali insoluble charcoal fraction. Coll 1970 by M Barbetti, subm by Research School Earth Sci, ANU.

ANU-699. **$D^{14}C = -432.3 \pm 4.4‰$** **4450 ± 60**
Est $\delta^{13}C = -24.0‰$

Charcoal and uniformly baked sediment 3m below top of bank, 75m downstream from ANU-693 (R, 1973, v 15, p 250). Result is error-weighted mean of 2 determinations on different chemical fractions of same charcoal samples: ANU-699/1, alkali soluble fraction, 4540 ± 80 BP, 1220 min count and ANU-699/2, alkali insoluble fraction, 4560 ± 90 BP, 1240 min count. *Comment* (HAP): this internal comparison

demonstrates absence of contamination by soil acids with significantly different age than original charcoal.

ANU-700. **$D^{14}C = -432.5 \pm 8.1‰$** **4550 ± 120**
Est $\delta^{13}C = -24.0‰$

Mixed charcoal and baked sediment 2.5m below top of bank, 20m downstream from ANU-699 (1200 min count).

ANU-1084. **$D^{14}C = -434.6 \pm 17.3‰$** **4580 ± 250**
Est $\delta^{13}C = -24.0‰$

Elongated vertical structure (possibly sec of collapsed root tunnel) between 3m and 4m below top of bank, 19m downstream from ANU-700 (2080 min count).

ANU-1085. **$D^{14}C = -336.0 \pm 5.8‰$** **3290 ± 70**
Est $\delta^{13}C = -24.0‰$

Mixed charcoal and baked sediment 3m below top of bank, 122m downstream from ANU-1084 (1340 min count).

ANU-1086. **$D^{14}C = -243.0 \pm 6.2‰$** **2240 ± 70**
Est $\delta^{13}C = -24.0‰$

Mixed charcoal and lumps of baked sediment 4m below top of bank, 110m downstream from ANU-1085 (1300 min count).

ANU-1087. **$D^{14}C = -121.3 \pm 6.9‰$** **1040 ± 60**
Est $\delta^{13}C = -24.0‰$

Charcoal and baked earth distributed along bedding plane 60cm to 70cm below top of bank, 107m downstream from ANU-1086 (1240 min count).

Lake Mungo

In August 1972, a newly-exposed ancient aboriginal oven was discovered in Lake Mungo lunette, New South Wales, Australia (33° 48′ S, 142° 54′ E). This oven, for which a ^{14}C age is reported here, was 350m S of a group of ancient fireplaces reported previously (ANU-667, -680-683; R, 1973, v 15, p 246-247). These ancient fireplaces have been investigated as part of detailed archaeomagnetic study of sites in SE Australia (Barbetti, 1973; 1972; Barbetti & McElhinny, 1972).

ANU-698. **$D^{14}C = -957.2 \pm 4.1‰$** **25,310 ± 810**
Est $\delta^{13}C = -24.0‰$

Aboriginal oven at base of greenish-gray sandy clay of Mungo soil-sedimentary unit (4020 min count). *Comment* (MB): age agrees well with stratigraphic evidence and previous dates (R, 1973, v 15, p 246-247).

IV. VEGETATION SAMPLES

Papua New Guinea

Kainantu series

Peat from Noreikora swamp, 12.9km SE of Kainantu, alt 1650m (6° 24′ S, 145° 53′ E) E Highlands Dist, Papua New Guinea, coll during

vegetation history project. Samples coll with peat borer 1966, Bore Hole NK14, by J M Powell; subm by Dept Biogeog & Geomorphol, ANU.

ANU-83. **$D^{14}C = -101.5 \pm 12.2‰$** **860 ± 110**
Est $\delta^{13}C = -25.0‰$

Gray-brown peat, coll by piston sampler over horizontal area of 1 to 2sqm, at depth 220 to 230cm. Dilution, 80% sample (1300 min count).

ANU-84. **$D^{14}C = -424.6 \pm 5.7‰$** **4440 ± 80**
Est $\delta^{13}C = -25.0‰$

Gray-brown compacted, fibrous peat, coll with piston sampler over horizontal area of 1 to 2sqm, at depth 345 to 355cm (1300 min count). *General Comment* (JMP): stratigraphy of swamp suggests relatively simple history. Total depth of sediments is 400cm; 2 zones of peat occur with layer of gray clay, 50 to 60cm depth, interpolated. ANU-84 dates early part of lower peat while ANU-83 dates beginning of 2nd phase of peat formation. Pollen diagrams directly correlated with these dates are not yet completed; preliminary analysis suggests that both dates will be important in interpreting human influences on vegetation surrounding swamp.

Mt Hagen Series A

Samples from Draepi swamp, 12.9km NNW of Mt Hagen township, W Highlands Dist, Papua New Guinea on Baiyer R Divide, alt 1890m (5° 42′ S, 144° 10′). Coll by J M Powell during vegetation history project. Samples coll 1966 and 1967 with a piston sampler over horizontal area of 1sqm, DR159/T83, subm by Dept Biogeog & Geomorphol, ANU.

ANU-85. **$D^{14}C = -137.7 \pm 7.5‰$** **1190 ± 70**
Est $\delta^{13}C = -25.0‰$

Very fine black detritus mud, from 5 successive bores at 250 to 260cm depth (1400 min count).

ANU-249. **$D^{14}C = -365.3 \pm 6.5‰$** **3650 ± 85**
Est $\delta^{13}C = -24.0‰$

Very fine black detritus mud, from 365 to 375cm depth (980 min count).

ANU-250. **$D^{14}C = -896.8 \pm 3.9‰$** **18,250 ± 370**
Est $\delta^{13}C = -24.0‰$

Dark red-brown wood and leaf detritus, from 440 to 450cm depth (980 min count).

ANU-192. **$D^{14}C = -943.2 \pm 3.9‰$** **23,040 ± 570**
Est $\delta^{13}C = -24.0‰$

Water-logged wood near junction of organic red-brown detritus and inorganic volcanic ash, 525 to 535cm depth. Coll from single borehole (1360 min count).

General Comment (JMP): dates are directly correlated with pollen diagram DR159. ANU-192 provides maximum age near deposit base while ANU-250 dates top of Pollen Zone H. Pollen spectra within this zone indicate that forest was present both locally and regionally. ANU-249 dates base of Pollen Zone J; by this time non-forest vegetation had increased greatly relative to forest, probably as a result of human interference. ANU-85 dates top of Pollen Zone J: pollen spectra within zone indicate that there were nearly equal areas of forest and non-forest vegetation present in the region. The overlying pollen spectra, in Pollen Zone K, indicate that areas of forest and non-forest have become more or less stabilized with the forest slightly less extensive than in Zone J.

ANU-253. **$D^{14}C = -470.5 \pm 6.1‰$** **5110 ± 100**
Est $\delta^{13}C = -24.0‰$

Coarse black detritus mud, coll from DRII/29 at 210 to 220cm depth (1060 min count).

ANU-254. **$D^{14}C = -985.5 \pm 3.0‰$** **$34{,}000^{+2000}_{-1500}$**
Est $\delta^{13}C = -24.0‰$

Dark red-brown wood and leaf detritus, from DRII/29 at 385 to 395cm depth (2020 min count).

ANU-194/1. **$D^{14}C = -975.5 \pm 3.2‰$** **29,800 ± 1250**
Est $\delta^{13}C = -24.0‰$

Dark red-brown wood and leaf detritus, from DRII/29 at 695 to 705cm depth (1380 min count).

ANU-194/2. **$D^{14}C = -982.0 \pm 2.4‰$** **32,250 ± 1100**
Est $\delta^{13}C = -24.0‰$

Portion of same sample as 194/1 (3000 min count). *Comment* (HAP): agreement between duplicates, ANU-194/1 and -194/2, involving independent sample pretreatment and benzene synthesis is excellent ($z = 1.5$, Polach, 1972). Thus, a pooled mean ANU-194, $D^{14}C = -980.1 \pm 2.2$, age = 31,470 ± 900 BP can be calculated.

General Comment (JMP): dates correlate directly with pollen diagram DR/II/29. ANU-194 and -254 date period covered by Pollen Zones F, G, and part of H. These zones are characterized by forest dominance, locally and regionally. Stratigraphically lowest date is 31,470 ± 900 yr BP, pooled mean ANU-194, while upper date is $34{,}000\ ^{+2000}_{-1500}$ yr BP, ANU-254. Ranges of the 2 dates, as defined by 2 standard deviations from each mean, overlap. Hence, sediment may have been laid down betwen 29,670 and 38,000 yr ago. But, the lowest part of Pollen Zone H in Column DR159 is dated to 23,040 ± 570 yr BP, ANU-192, so that youngest date possible for this position in DR/II/29 remains somewhat too old. ANU-253 dates base of Pollen Zone J: by this time much forest had been destroyed and woody non-forest and grassland vegetations were

widespread. During Zone J, a balance between forest and non-forest areas was achieved and maintained; more recently, Zone K, a bit more exploitation of forest took place.

ANU-255. **$D^{14}C = -250.1 \pm 7.6‰$** **2310 ± 90**
Est $\delta^{13}C = -24.0‰$

Charcoal in brown-black peat, from cooking pit, DRII/40C, at 140 to 145cm depth (1000 min count).

ANU-276. **$D^{14}C = -383.4 \pm 6.8‰$** **3880 ± 90**
Est $\delta^{13}C = -24.0‰$

Coarse brown-black peat underlying archaeol ditch. Coll from peat column, DRII/40A, at 180 to 185cm depth (1000 min count).

ANU-277. **$D^{14}C = -247.0 \pm 7.6‰$** **2280 ± 90**
Est $\delta^{13}C = -24.0‰$

Mixed peat and volcanic ash infilling ditch base. Coll from peat column, DRII/40A, at 160 to 165cm depth (1000 min count).

General Comment (JMP): dates are directly correlated with pollen diagrams DR/II/40A and DR/II/40B. ANU-276 provides a further date for area near base of Pollen Zone J, comparable to ANU-249 and -253. ANU-255 provides 1st direct evidence of human use of Draepi area. Correlated stratigraphically with column DR/II/40B, this date is near center of Pollen Zone J, when mosaic of forest and non-forest vegetations was present locally and regionally. Gardening of part of site was undertaken at about same time as evidenced by ANU-277, and was probably fairly widespread.

Mt Hagen Series B

Samples from Manton swamp archaeol site, 9.7km E of Mt Hagen township, Upper Wahgi valley (5° 50′ S, 144° 18′ E), alt 1585m. Coll 1967 by J M Powell, during vegetation history project. Subm by Dept Biogeog & Geomorphol, ANU.

ANU-251. **$D^{14}C = -109.3 \pm 17.3‰$** **930 ± 155**
Est $\delta^{13}C = -24.0‰$

Waterlogged wooden stake embedded in black mud and sand, M6/129, at 129 to 136cm depth. Taken from column cut from side of modern drain (1020 min count).

ANU-252. **$D^{14}C = -456.5 \pm 6.1‰$** **4900 ± 90**
Est $\delta^{13}C = -24.0‰$

Waterlogged wood lying at base of zone of mixed coarse brown detritus and volcanic ash, M6/195, at 195 to 200cm depth. Taken from column cut from side of modern drain (1140 min count).

General Comment (JMP): dates are directly correlated with pollen diagram M6. ANU-252 gives maximum age for base of pollen diagram since it lies below lowest sample, 161cm, of diagram and because wood,

itself, may have been old at time of incorporation. It compares well, however, with dates for other wood samples, ANU-44 (R, 1968, v 19, p 193) and ANU-288, stratigraphically near base of organic sediment. Lowest pollen spectra of diagram, Zone B, indicate woody non-forest vegetation was dominant on surrounding slopes at this time; partial clearance of forest had taken place but little grassland had developed. ANU-251 dates base of Pollen Zone D. This is a stratigraphically disturbed zone, covering period during which swamp was being gardened. Date is relatively too young compared with other date available for base of zone (ANU-43; R, 1968, v 19, p 193); it may be stratigraphically displaced or it may indicate use of this part of swamp at more recent time. Pollen spectra within zone as a whole indicate increased importance of certain trees, shrubs, and herbs compared with earlier zones; they may have been domesticated by this time.

ANU-288. $\mathbf{D^{14}C = -455.3 \pm 6.1‰}$ **4880 ± 90**
Est $\delta^{13}C = -24.0‰$

Wood lying within coarse brown wood and peat detritus, MTH34, at 195cm depth. Coll from archaeol Trench D, by R J Lampert, subm by Dept Prehistory, ANU (1320 min count).

ANU-289. $\mathbf{D^{14}C = -56.9 \pm 8.6‰}$ **470 ± 75**
Est $\delta^{13}C = -24.0‰$

Wooden stake, MTH37, lying between 35 to 65cm depth, marking junction of black mud and upper undisturbed yellow-brown fibrous peat. Coll from archaeol Trench D by R J Lampert, subm by Prehistory Dept (1100 min count).

General Comment (JMP): samples from within 1sqm horizontal area of Column M1 and may be correlated with M1 pollen diagram. ANU-288 provides maximum age near base of pollen zone A. Pollen spectra of this zone indicate that some forest was present on surrounding slopes but that woody non-forest vegetation was dominant. ANU-289 dates top of Pollen Zone D. It may be considered as maximum age for abandonment of swampland. Pollen spectra of Zone E, immediately above, indicate renewed impact on forests of surrounding slopes, followed by their partial recovery and stabilization of forest and non-forest areas.

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BERLIN RADIOCARBON DATES V

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The dates presented in this paper comprise results of determinations made on archaeologic and geologic material from Socialist Republic Vietnam since 1969. Radioactivity was measured twice for 48 hours with gas proportional counters of Houtermans-Oeschger type, using methane at 1000mm Hg pressure as filling gas. Influence of cosmic and local environmental radiation on the counters was reduced with 30 tons of shielding material as described earlier (R, 1970, v 12, p 400-420).

Chemical pretreatment was done by leaching the samples with 5% ammonium hydroxide solution in a Soxhlet-extractor. Humic acid, dissolved by the ammonium hydroxide is prepared from this solution by evaporating the solvent. If enough humic acid is available, both fractions are dated. After full or partial removal of humic acid, samples were leached with 5% hydrochloric acid. The first step in methane gas production is combustion of samples in an oxygen stream (De Vries, 1953). The carbon dioxide generated was purified by precipitating calcium carbonate. The dried calcium carbonate was placed into a bulb connected to a vacuum line and evacuated and heated to 100°C for 30 minutes. Radon was removed totally by this procedure. Purified carbon dioxide was generated by adding phosphorus acid. Methane was formed by reacting a measured amount of carbon dioxide with stoichiometric plus 10% this amount of hydrogen. Ruthenium catalyst heated to about 500°C was used for complete conversion. The purity was checked by an infrared analyzer. From shells and snails carbon dioxide was evolved with diluted hydrochloric acid.

Age calculations are based on the Libby half-life of ^{14}C, 5570 ± 30 years and the modern activity given by 95% of the activity of oxalic acid standard as well as oak-tree rings grown between 1850 and 1860 near Greifswald, GDR. Errors quoted are the standard deviation obtained from the number of counts only. For shell samples, dates are computed without any correction for environmental and isotopic fractionation. No hardwater effect has been taken in account because it depends on the type of water in which shells and snails lived. Ocean surface water has a unique average ^{14}C recent-concentration of 95 to 97%, therefore marine shells and snails may be dated about 400 years too old. The ^{14}C-content of fresh water differs between 50 and 100% of atmospheric ^{14}C-content, depending on concentration of dissolved limestone in water. An average 85% of modern atmospheric ^{14}C concentration has been measured for recent lakes, therefore freshwater snails may be dated about 1000 years too old.

Shells excavated in limestone caves were cleaned by leaching with tartaric acid. To investigate a possible exchange of inorganic carbon,

shell material was dissolved in two fractions by 10% hydrochloric acid. The two fractions, the outer part of shell denoted by No. I and the inner part denoted by II, were dated separately. If dates of fractions I and II agree well, the possibility of carbon exchange seems to be low. Large discrepancies between fractions I and II indicate possible carbon exchange.

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I. ARCHAEOLOGIC SAMPLES

The dates published are part of long standing research program, covering the chronology of prehistoric and early historic cultures. Cooperation with the Institute of Archaeology, Hanoi, made possible, for the first time, dates for Paleolithic to Medieval periods in N regions of Vietnam.

Subtropical climate is not conducive to preservation of fossil organic matter. Only shells of snails and mussels could be dated from limestone caves. Dates on freshwater shells are possibly too old, because of limestone drainage where shells were formed. For this reason we have been cautious in interpreting the chronology. Some of our results have been crosschecked at the Radiocarbon Laboratory, Chinese Academy of Sciences, Peking.

In general, most dates are correlated with stratigraphy and cultural sequence. They confirm continuity from Late Paleolithic Son Vi culture to Mesolithic or Proto-Neolithic Hoa Binh culture. Some unexpectedly old dates have been obtained from recently excavated sites with pre-Hoabinhian stone industry in NW Vietnam (Ha Van Tan, 1976b). The first evidence for "Neolithic technology" like grinding stones and axes with polished cutting edges about 10,000 BP comes from Bo Lum cave in the Bac Son massif. Little can be said about the beginning of ceramic tradition in Vietnam. Cultural layers with potsherds in mountainous areas are scarcely dated and in upper levels of coastal sites impressed or cord-marked pottery falls within the 5th millennium BC.

Similarly circumstances exist for the first use of copper or bronze. The crucial problem is the age and nature of the Phung Nguyen culture as transition from Late Neolithic to Early Bronze. A single date from Ma Dong, prov Ha Thay, and another from Hang Gon in Southern Vietnam (Saurin, 1968) point to a distribution of metal-working ca 2000 BC. The Final Bronze and Early Iron periods are dated from settlements and cemeteries of the Dong Son culture between 6th and 2nd centuries BC. The Sa Huynh culture existed at the same time in S parts of Vietnam which confirm radiocarbon dates from urnfield graves in prov Long Khanh (Delibrias *et al*, 1974) and from Hang Gon-site near Xuan Loc (Thommeret & Thommeret, 1966).

Measurements in the following list ranged in groups corresponding to chronology of sites. Dates are expressed as before AD 1950. Archaeologic data are quoted from Vietnamese publications (Le Xuan Diem; Hoang Xuan Chinh, 1977) and information was provided by the excavators and their sponsoring institutions. Owing to typographical difficulties, diacritical marks are omitted from Vietnamese words.

A. Paleolithic and Hoabinhian

Bln-1408. Tham Khuong, T K 74 **28,130 ± 2000**

Shells of land snails (*Cyclophorus siamensis* Sowerby) from rock shelter near Chieng Sinh, dist Tuan Giao, prov Lai Chau (21° 35′ N, 103° 19′ E). Site near spring of Ma R with occupation deposit 2m thick. Lithic material contained massive pebble chopping tools, pointed picks of Hoa Binh type, and other culturally indeterminate stone implements; polished tools and pottery only in uppermost horizon. Snails from 1.5m below surface coll Feb 1974 by Chu Van Tan (1976), Archaeol Inst Hanoi.

Bln-1412. **33,150 ± 2300**

Same sample as Bln-1408 in separate preparation. *Comment*: dates are inconsistent and older than expected for Hoa Binh culture. Future studies should clear up possibility of Paleolithic occupation.

Bln-1735 I. Phung Quyen, P Q 76 **18,390 ± 125**

Bln-1735 II. (2nd fraction) **18,180 ± 125**

Shells of land snails (*Cyclophorus siamensis* Sowerby) from rock shelter near Mai Hich, dist Mai Chau, prov Ha Son Binh (20° 34′ N, 105° 2′ E). Occupation deposit was 0.50m thick from end of Pleistocene to Hoa Bin culture. Sample in basal layer coll Oct 1976 by Nguyen Van Binh, Archaeol Inst Hanoi.

Bln-1855 I. **17,470 ± 125**

Bln-1855 II. (2nd fraction) **18,300 ± 125**

Shells from same sample as Bln-1735 in a separate preparation. *Comment*: relatively consistent dates point to occupation in Paleolithic time.

Bln-1844 I. Nui-I, N 76 **13,080 ± 115**

Bln-1844 II. (2nd fraction) **14,665 ± 150**

Shells of land snails (mostly *Cyclophorus siamensis* Sowerby) from cave site near Cam Giang, dist Cam Thuy, prov Thanh Hoa (20° 15′ N, 105° 30′ E). Limestone cave in mts downstream Ma R settled from end of Pleistocene to Hoa Binh period. Sample coll Oct 1976 in basal layer of Trench 4 by Hoang Xuan Chinh and Vu The Long, Archaeol Inst Hanoi.

Bln-1713 I. Con Moong, C M 76 **11,755 ± 75**

Bln-1713 II. (2nd fraction) **11,840 ± 75**

Shells of land and freshwater snails (*Cyclophorus siamensis* Sowerby, *Antimelania siamensis*, *Lanceolaria* sp) from cave site in Cu Phuong Nat Park, Thanh Yen, dist Thach Thanh, prov Thanh Hoa (20° 18′ N, 105° 54′ E). Cave Con Moong ("Beast-Cave") in limestone cliff 40m high, excavated 1975/76 by Nguyen Khac Su and Hoang Xuan Chinh (Pham Huy Thong, 1977). Occupation deposit, 3.50m thick, indicated 9 layers of cultural development from final Paleolithic (Level I) to early Hoa Binh (Level II) and late Hoa Binh, respectively, Bac Son period (Level III). Sample, from Level I, 3 to 3.20m deep, Layer 9, assoc with pre-Hoabinhian artifacts, related to Late Paleolithic Son Vi culture. Coll April 1976 by Vu The Long. *Comment*: dates agree with archaeol expectations. Cross-check of shells from same Layer 9 dated at Peking, ZK-379: 11,090 ± 185 BP. Additional soil sample mixed with ashes from Hoa Binh Level II (2 to 2.40m below surface) contained insufficient carbon for ^{14}C dating, but it was dated stratigraphically at Peking, ZK-380: 9905 ± 150 BP.

Bln-1351. Hang Pong-I, H P-I 73 **11,330 ± 180**

Shells of land and freshwater snails (mostly *Cyclophorus siamensis* Sowerby) from cave site near Muong The, dist Moc Chau, prov Son La (21° 02′ N, 104° 45′ E). Cave I in mts bounding Black R valley yielded only 0.30m thick occupation deposit dated to early pre-Hoabinhian phase. Besides characteristic Hoa Binh tools, artifacts related to Late Paleolithic Son Vi culture were also present. Sample from Trench I, 0.25m depth, coll 1973 by Nguyen Xuan Dieu and Do Dinh Truat (1974), Archaeol Inst Hanoi.

Bln-1352. **11,915 ± 120**

Same as Bln-1351 in separate preparation. *Comment*: late Pleistocene age of Hang Pong site was expected on strength of some faunal remains.

Bln-1541 I. Sung Sam, S S 75 **11,365 ± 80**

Bln-1541 II. (2nd fraction) **10,770 ± 75**

Shells of land and freshwater snails (mostly *Cyclophorus siamensis* Sowerby) from cave site near Huong Son,dist My Duc, prov Ha Tay (20° 50′ N, 105° 35′ E). Cave in mts ca 50km E of Hanoi, settled during Hoa Binh and later periods. Sample from Trench A, depth 1.20 to 1.40m below surface. Coll March 1975 by Ha Van Tan and Tran Quoc Vuong, Archaeol Dept, Univ Hanoi.

Bln-1275 I. Tham Hoi, T H 72 **10,875 ± 175**

Bln-1275 II. (2nd fraction) **10,125 ± 175**

Shells of freshwater snails (mostly *Brotia variabilis* Benson) from cave site near village Bong Khe, dist Con Cuong, prov Nghe An (19° 03′ N, 104° 50′ E). Limestone cave in mts along Ca R, excavated 1972 by Nguyen Xuan Dieu and Chu Van Tan, Archaeol Inst Hanoi. Occupation

deposit 1.6m thick, yielded numerous artifacts typologically dated to early Hoa Binh culture; trimmed axes and pottery missing. Sample coll from layer of Trench III, 0.6m deep (Hoang Xuan Chinh, Nguyen Xuan Dieu & Chu Van Tan, 1974).

Bln-1276 I. **10,255 ± 150**

Bln-1276 II. (2nd fraction) **10,815 ± 150**

Same sample as Bln-1275 in separate preparation. *Comment*: slightly older dates than Hang Chua (Bln-1274, -1304) that agree with archaeol expectations.

Bln-1273 I. Mieng Ho, M H 72 **3800 ± 70**

Bln-1273 II. (2nd fraction) **4170 ± 60**

Shells of freshwater snails (*Vivi parus* sp, *Brotia variabilis* Benson) from cave site near village Than Sa, dist Vo Nhai, prov Bac Thai (21° 48′ N, 105° 53′ E). Cave in mts from upper Cau R, excavated 1972 by Chu Van Tan and Hoang Xuan Chinh, Archaeol Inst Hanoi. Occupation deposit, 0.5m thick, yielded only massive choppers, scrapers, and many small, flaked artifacts (80%) that resembled Paleolithic types; polished tools and pottery missing. Lithic material, different from other North Vietnamese caves dated either to Mesolithic or Paleolithic period (Truong Hoang Chau, 1974). Sample coll from upper level of Trench III, 0.1m below cave surface. *Comment*: date younger than expected; perhaps cave reinhabited in late Neolithic time or shell sample was mixed with recent gastropods.

Bln-1274 I. Hang Chua, H C 72 **9075 ± 120**

Bln-1274 II. (2nd fraction) **9325 ± 120**

Shells of freshwater and land snails (*Angulyagra* sp, *Brotia variabilis* Benson, *Cyclophorus siamensis* Sowerby) from cave site near village Ky Son, dist Tan Ky, prov Nghe An (19° 06′ N, 105° 20′ E). Cave in Nui Roi Mts at left bank of Ca R yielded occupation deposit, 2m thick, with stone industry of classic Hoabinhian. In addition to sumatraliths, appear chipped, flat artifacts, resembling prototypes of Bac Son axes; but tools with polished cutting edges and pottery were not found. Sample excavated 1972 in Trench A, at 1.5m depth, by Vo Quy and Nguyen Van Hoa, Archaeol Inst Hanoi (Vo Quy, 1973).

Bln-1304. **9175 ± 120**

Same sample as Bln-1274 in separate preparation.

Bln-913 I. Hang Dang, H D 69 **7665 ± 65**

Bln-913 II. (2nd fraction) **7580 ± 80**

Shells of land snails (*Cyclophorus siamensis* Sowerby) from cave site in Nat Park Cuc Phuong, dist Nho Quan, prov Ninh Binh (20° 18′ N, 105° 55′ E). Cave with 2.05m thick occupation deposit and 3 burials

excavated 1966 by Hoang Xuan Chinh and Chu van Tan. Uppermost level of late Neolithic period (to 0.4m depth) yielded a shouldered axe and some crude potsherds. Sample coll 1969 in layer of Trench 2, 0.6m deep, assoc with tools with polished edges, grinders, and pestles of late Hoa Binh types. *Comment*: date fits well with estimated age; an older date is expected for beginning of site occupation because of distinguishing technologic traits in lower horizons.

B. Bacsonian and Coastal Neolithic

Bln-1001 I. Bo Lum, B L 70 **9990 ± 200**

Bln-1001 II. (2nd fraction) **10,295 ± 200**

Shells of land and freshwater snails (mostly *Brotia variabilis* Benson) from cave near Xuan Mai, dist Van Quan, prov Lang Son (21° 50′ N, 106° 30′ E). Site Bo Lum in limestone massif Bac Son is identical with cave Con Khe, excavated by M Colani (Mansuy, 1925). Occupation deposit dated to Bac Son culture, represented by axes with polished cutting edges and stone implements with "marques basconiennes". Sample coll 1970 from middle horizon of occupation layer, 0.6m thick, by Hoang Xuan Chinh. *Comment*: date is satisfactory although slightly early. On the other hand, chopping tools and lack of pottery indicate an older stage of Bacsonian.

Bln-915 I. Bo Nam, B N 70 **7960 ± 60**

Bln-915 II. (2nd fraction) **7875 ± 60**

Shells of land and freshwater snails (*Cyclophorus siamensis* Sowerby, *Vivi parus* sp, *Brotia variabilis* Benson) from cave near village Keo Phay, dist Bang Mac, prov Lang Son (21° 44′ N, 106° 29′ E). Cave site, better known as Keo Phay, in limestone massif Bac Son, was excavated 1922-1924 by H Mansuy (1925). Complex dated to early Bac Son culture with partial polished axes, but no pottery. Sample coll 1970 in horizon, 0.2m deep, of occupation deposit, 1m thick, by Vu The Long, Archaeol Inst Hanoi. *Comment*: date from uppermost level may be consistent with site stratigraphy, but appears late in comparison with Bacsonian stone industry of Bo Lum cave (Bln-1001).

Bln-1002 I. Tham Hai, T H 70 **9705 ± 80**

Bln-1002 II. (2nd fraction) **9645 ± 70**

Shells of land and freshwater snails (mostly *Brotia variabilis* Benson) from rockshelter near village Tan Van, dist Binh Gia, prov Lang Son (21° 54′ N, 106° 25′ E). Cave in limestone massif Bac Son with faunal remains from Pleistocene and Holocene was partly excavated 1964 by joint expedition of Vietnamese and German Democratic Republic Paleontologists; basal layers were not investigated. Snails from upper level, 0.2m depth, were assoc with artifacts of early Bac Son types. Coll 1970 by Vu The Long.

Bln-1407. Da But, D B 71 **6095 ± 60**

Marine shells (*Corbicula* sp, *Placuna planceta* L) from open site at left bank of Ma R, dist Vinh Loc, prov Than Hoa (20° 01′ N, 105° 43′ E). The kitchen midden, 50 × 32m wide, 5m high, is now some 40km from coast, first excavated by E Patte (1932). Cultural assemblage dates to final or post-Bacsonian Neolithic period. Polished axes, grinders, pestles, and cord-marked pottery similar to finds from Quynh Van shell midden in same prov. Sample from Trench A 0.7m below surface. Coll April 1971 by Luu Tran Tieu, Mus Hist Vietnam, Hanoi. *Comment*: date for upper layer of Da But settlement agrees with archaeol expectations and probably indicates ^{14}C age that is too late for Quynh Van (Bln-914). At time of occupation, sea level was 2 to 3m higher.

Bln-914 I. Quynh Van, Q V 69 **4785 ± 75**

Bln-914 II. (2nd fraction) **4730 ± 75**

Marine shells (*Placuna planceta* L, *Arca granosa* L, *Turritella balillum* Kiener) from open air dwelling and burial, in dist Quynh-Luu, prov Nge An (19° 11′ N, 105° 40′ E). Type site of Neolithic Quyn Van culture is shell midden, ca 7000m² wide and 5 to 6m high in plain 5km from coast, excavated 1963-64 (Hoang Xuan Chinh, 1966; Boriskovsky, 1968-70). Cultural assemblage of Quynh Van complex characterized by tools and axes of chipped basalt flakes, heavy grinders and pestles and also by potsherds already found in bottom layer. Sample coll 1969 at 0.50m depth by Hoang Xuan Chinh, Archaeol Inst, Hanoi. In same upper level were 31 graves with skeletons in sitting position. *Comment*: date, compared to Da But (Bln-1407: 6095 ± 60 BP) is younger than expected, perhaps due to dating problems peculiar to marine shells. But small difference between both determinations indicates no isotopic fractionation.

Bln-1350. Cai Beo, C B 73 **≥40,000**

Charcoal from open settlement Cai Beo on coast of Cat Ba I, prov Hai Phong (20° 40′ N, 107° 03′ E). The 800m² coastal site dating like shell midden Quynh Van and Da But in post-Bacsonian Neolithic period; excavated 1973 by Hoang Xuan Chinh and Nguyen Khac Su, Archaeol Inst, Hanoi. Occupation deposit, 3.2m thick, shows 3 levels in stratigraphic sequence: uppermost (III) with shouldered and stepped adzes belongs to late Neolithic Ha Long culture: intermediate (II) yielded shouldered axes and cord-marked pottery; lower (I) bifacial chipped stone tools and crude sherds from basket-impressed pottery. Sample coll from Trench 1, 2.2m below surface at top of Level I (Hoang Xuan Chinh *et al*, 1974). *Comment*: this anomalously old date remains unexplained; perhaps indicates use of fossil wood washed ashore in prehistoric times. Control date for portion of same sample at Peking (ZK-306: ≥ 40,000) confirmed our supposition.

Bln-1437. C B 73—Trench 3 **3425 ± 60**

Animal bones from Cai Beo site (see above) from Level I, Trench 3, 3 to 3.2m below surface.

Bln-1486. **3850 ± 60**

Same as sample Bln-1437 in separate preparation. *Comment*: bone dates are inconsistent with each other and with expected age. Because no collagen was isolated, only inorganic fraction of bone was measured. Probably truer age of site occupation indicated by another Peking date (ZK-328.0: 5645 ± 60 BP) for sample from base of Level II.

Bln-1439 I. Ha Lung, H L 75 **6310 ± 60**

Bln-1439 II. (2nd fraction) **6485 ± 60**

Shells of freshwater snails (*Brotia variabilis* Benson, *Vivi parus* sp) from cave site near San Duong, dist Hoanh Bo, prov Qang Ninh (21° 04′ N, 107° 02′ E). Cultural layer assoc with polished stone tools, grinders, and pottery assigned to post-Bacsonian Neolithic period. Sample coll March 1975 in layer, 0.4m deep, by Nguyen Van Hao, Archaeol Inst, Hanoi.

C. Early and Middle Bronze Age

Bln-1277. Ma Dong, M D 72 **4145 ± 60**

Charcoal mixed with soil from prehistoric settlement Ma Dong, near Duong Lam, prov Ha Tay (21° 05′ N, 105° 30′ E). Excavations reveal occupation in late Neolithic and Bronze age periods. Sample from layer of Trench III, 0.6m deep, dated from transition phase to Early Bronze age. Coll Jan 1972 by Pham Ly Huong, Archaeol Inst Hanoi.

Bln-891. Trang Kenh, T K 69 **3405 ± 100**

Charred wood mixed with loam from prehistoric settlement and burial place near Minh Duc, prov Hai Phong (20° 57′ N, 106° 45′ E). Large dwelling site, at foot of rocky hills, ca 20km NE of Hai Phong, archaeol dated to transitional period from late Neolithic to early Bronze age. Ceramics with geometric decorations and different types of stone tools indicate assoc with Halong and Phung Nguyen cultures. Excavations since 1968 yielded vegetal remains of beans, pumpkins, gourds, and first firm evidence for rice cultivation (*Oryza sativa*). Sample in Trench I, 1.9 to 2.1m below surface, coll Nov 1969 by Nguyen Thanh Thrai and Trinh Minh Hien, Archaeol Inst Hanoi. *Comment*: charcoal from higher level, 1.4m below surface, of same site was dated in Peking: ZK-307: 3005 ± 90 BP.

Bln-830. Dong Dau, D D 69 **3330 ± 100**

Charred wood from prehistoric settlement Dong Dau, dist Yen Lac, prov Vinh Phu (21° 30′ N, 105° 10′ E). Excavations since 1965 yields 4 levels of occupation from late Neolithic to Bronze age periods. Stratigraphy indicates Phung Nguyen, Dong Dau, and Go Mun cultures. Sample in basal layer, Trench I, depth 4m below surface, dates to late Phung Nguyen culture. Coll 1969 by Hoang Xuan Chinh, Archaeol Inst Hanoi.

Bln-1409. Doi Giam, D G 74 **2900 ± 60**

Charred wood and organic matter from Bronze age settlement near Quat Thuong, dist Viet Tri, prov Vinh Phu (21° 10′ N, 105° 43′ E). Occupation layer of partially excavated site, ca 60m², contained decorated pottery and bronze objects dating to Phung Nguyen culture. Sample coll April 1974 in Trench I, 1m below surface, by Ha Van Tan, Archaeol Dept, Univ Hanoi (Ha Van Tan, 1976a). *Comment*: compared to ^{14}C date of late Phung Nguyen culture from Dong Dau (Bln-830: 3330 ± 100) date is younger than expected.

Bln-894. Go Vuon Chuoi, G V C 69 **3070 ± 100**

Charred wood from prehistoric settlement, Go Vuon Chuoi, near Kim Chung, dist Hoai Duc, prov Ha Tay (21° 3′ N, 105° 42′ E). Sample from Trench I, 0.8m below surface to Dong Dau culture of Middle Bronze age with archaeol date from 2nd half of 2nd millennium BC. Coll 1969 by Nguyen Duy Ty, Archaeol Inst Hanoi.

Bln-829. Vinh Quang, V Q 69 **3045 ± 120**

Charred wood from Bronze age dwelling and burial site, Vinh Quang, village SW of Hanoi in prov Ha Tay (20° 45′ N, 105° 50′ E). Assemblage assoc with some wheel-made pottery and bronze tools belonging to late Go Mun culture, commonly dated to end of 2nd and beginning of 1st millennium BC. Sample from Trench I, depth 1.8m below surface, Coll 1969 by Nguyen Duy Ty.

D. Dong Son culture and Early Iron Age

Bln-1438. Chau Can, C C 74 **2325 ± 60**

Wood of dug out canoe-like coffin in Iron age cemetery Chau Can, dist Phu Xuyen, prov Ha Tay (21° 05′ N, 105° 30′ E). Sample from Burial M 4 with ceramic and other grave goods dated to late phase of Dong Son culture. Coll Sept 1974 by Luu Tran Tieu, Mus Hist Vietnam, Hanoi. *Comment*: date possibly result of greater tree age of coffin is somewhat older than expected.

Bln-1718. T N 75 **995 ± 55**

Wood of agricultural implement (?) found near Chau Can necropolis (see above). Coll 1975 at 1.6m depth by Luu Tran Tieu. *Comment*: wooden object, 1st estimated at Iron age, is from Medieval period.

Bln-893. Go Chien Vay, G C V 69 **2350 ± 100**

Powdered charcoal mixed with loamy soil from settlement near village Kim Hoang, dist Hoai Duc, prov Ha Thay (21° 03′ N, 105° 42′ E). Occupation layer with decorated potsherds and only a few metal objects of Dong Son culture dated to transition from late Bronze to early Iron age. Sample in Trench I, 0.65m below surface, coll Feb 1969 by Nguyen Duy Ty.

Bln-1278. Go Mun, G M 72 **2385 ± 60**

Charcoal mixed with loamy soil from Bronze age settlement near Thach Vi village, dist Lam Thao, prov Vinh Phu (21° 17′ N, 105° 18′ E). Excavations since 1963 at type site of Go Mun culture demonstrated occupation from early to late Bronze age. Sample in Trench III, depth 1m below surface, 1st dated to Go Mun culture. Coll Jan 1972 by Nguyen Duy Ty. *Comment*: Bln-1278 is 6 centuries younger than date of Go Mun culture from Vinh Quang (Bln-829: 3045 ± 120 BP). This sample probably assoc with Dong Son culture, which was also present at site (Nguyen Linh and Tran Huong Van, 1969).

Bln-1733. Lang Ca, L G 76 **2235 ± 40**

Charred wood from grave pit in prehistoric cemetery Lang Ca, dist Viet Tri, prov Vinh Phu (21° 18′ N, 105° 24′ E). Burial with ceramic and bronze objects dated to Dong Son culture. Sample coll Oct 1976 by Nguyen Duy Chiem, Archaeol Inst Hanoi. *Comment*: date agrees with archaeol expectations for age of Dong Son culture.

Bln-1324. Lang Vac, L V 63 **1140 ± 80**

Soil mixed with charcoal detritus from stone-bordered grave pit in cemetery of Dong Son culture in Lang Vac, village Nghia Hoa, dist Nghia Dan, prov Nghe An (19° 20′ N, 105° 24′ E). Wealthy burials contained, besides pottery, decorated bronze drums, weapons, and tools of late Van Lang epoch; imported from China were some Warring States bronzes dated to 415 to 220 BC (Trinh Minh Hien, 1974). Sample coll April 1973 from Grave 5, 1m deep, by Nguyen Duy Ty. *Comment*: archaeol unacceptable date may be explained by poor quality of sample. Intrusion of organic matter probably caused rejuvenation. A 2nd sample from same cemetery dated by Peking (ZK-310: 1990 ± 85 BP) agrees better with true age (Diep Dinh Hoa, 1976).

Bln-950. Viet Khe, V K 61 **2480 ± 100**

Wood of canoe-like coffin, 4m long, from Viet Khe cemetery, dist Thuy Nguyen, prov Hai Phong (21° 3′ N, 106° 42′ E). Very rich burials contained > 100 grave goods, including decorated vessels, tools and bronze weapons, wooden oars, spear handles, painted boxes, and also a hide shield with silver application. Cemetery belongs to Dong Son culture of final Bronze or early Iron age. Sample from coffin in alluvial soil, 1.5 to 2m deep. Coll May 1961 by Le Van Lan, Mus Hist Vietnam, Hanoi (Viet Khe, 1965).

Bln-1227. V K 61-A **2415 ± 100**

Wood from coffin burial in Viet Khe, excavated 1961.

Bln-1249. **2320 ± 100**

Same sample as Bln-1227.

General Comment: primary sample, is somewhat older, perhaps due to greater tree age of big coffin, but all dates agree with archaeol expected age of Dong Son culture.

E. Medieval Period

Bln-1542. An Khe **715 ± 45**

Wood from coffin, found near An Khe, dist Quynh Phu, prov Thai Binh (20° 30′ N, 106° 15′ E). Grave dated to initial period of dependence of Chinese feudal state; excavated Feb 1975 by Bui Duy Lan, Office Cultural Monuments, Thai Binh.

Bln-892. Bach Dang, D B 69 **1335 ± 100**

Wood of pile from river bank Bach Dang, near Yen Giang, prov Quang Ninh (20° 57′ N, 106° 45′ E). Pile belongs to palisade several hundred m long, supposedly part of extensive fortification system during battle of Bach Dang, AD 1288. Coll May 1969 in brackish water by Phan Dai Doan and Diep Dinh Hoa (1970), Mus Hist Vietnam, Hanoi.

Bln-952. B D 69-A **1100 ± 100**

Sample from another pile at same location as Bln-892. *Comment*: though still possible that samples come from inner core of rotted wood, both dates are considerably older than expected. An earlier historic date of battle of Bach Dang, AD 938, was also discussed.

Bln-949. Hoa Lu, H L 70 **1295 ± 100**

Peat with fern (*Acrostichum aureum* L) from Medieval citadel Hoa Lu, dist Gia Khanh, prov Ninh Binh (20° 15′ N, 105° 55′ E). Sample from ditch of large earthwork, 2.5m deep, probably dated to 10th century AD to Vietnamese Dinh and Le dynasties. Coll 1970 by Nguyen Manh Loi, Mus Hist Vietnam, Hanoi. *Comment*: sample derives from layer that was periodically flooded. Date inconsistent with archaeol expectations and further studies may demonstrate still older fortification (Pham Van Kinh and Nguyen Minh Chuong, 1970).

II. GEOLOGIC SAMPLES

Bln-1572. Noi Linh, N L 75 **30,160 ± 300**

Wood embedded in lacustrine sediments from Noi Linh, dist Tien Lu, prov Hai Hung. Sample coll 1m below surface by Geol Service, Hanoi.

Bln-1715. L K-9/5m **7190 ± 80**

Organic matter embedded in alluvial clay from drill-hole L K-9, dist Gia Loc, prov Hai Hung. Sample from 5m below surface and dated ca 6000 BP; coll 1975 by Hoang Ngoc Ky, Geol Service, Hanoi.

Bln-1716. L K-9/23m **≥40,000**

Sample containing organic matter from same location as Bln-1715, 23m below surface.

Bln-1717. H P 3336/3 **4145 ± 50**

Sediments with organic matter from drill-hole H P 3336, dist Gia Loc, prov Hai Hung. Sample from sands 2m deep dated to Holocene; coll 1976 by Hoang Ngoc Ky.

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BIRBAL SAHNI INSTITUTE RADIOCARBON MEASUREMENTS I

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The Radiocarbon Dating Laboratory of the Institute was established in 1974 primarily to assist in the program of research undertaken by the Institute's Department of Quaternary Palynology (Rajagopalan and Vishnu-Mittre, 1977). The measurements carried out by the Laboratory up to December 1977 are presented in this date list.

The specific activity of ^{14}C in samples is measured by counting methane synthesized from sample carbon (Agrawal *et al*, 1971) in an Oeschger-Houtermans gas proportional counter (Houtermans and Oeschger, 1958). The counter is filled to a pressure of 900mm mercury. The background and net NBS oxalic acid counting rates were close to 2.45cpm and 10.25cpm, respectively, throughout the measurement of the samples presented here. The experimental methods of methane synthesis are very similar to the ones described by Agrawal *et al* (1971). Samples are counted for 2500 minutes, initially, and a repeat counting for 1000 minutes is made after 30 days.

Dates are based on the value of 5570 years for the half-life of ^{14}C and 95% of the activity of NBS oxalic acid. The error on the date refers to 1σ value which is calculated taking into account the counting statistics, uncertainty in the half-life and instability in the counting system (Kusumgar *et al*, 1963; Kusumgar, 1973). $\delta^{13}C$ measurements have not been made on these samples.

We have carried out measurements of the specific activity of ^{14}C on a number of samples kindly supplied by D P Agrawal for cross-checking purposes. These samples are portions of well-dated charcoal samples from archaeologic sites in India. Table 1 presents the comparison on measurements made at the Birbal Sahni Institute and at the Tata Institute Lab, Bombay.

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Technical help from V S Panwar and P S Saluja are thankfully acknowledged.

The electronics units were constructed in the Electronics shop of the Physical Research Laboratory. One of us (G R) had the privilege of

learning design details of the glass system at the Radiocarbon Lab in the Physical Research Laboratory. We are indebted to D P Agrawal, the staff of Radiocarbon Lab and the staff of the Electronics shop for help and facilities extended.

We are thankful to the Director of the Central Drug Research Institute, Lucknow for the supply of liquid air.

SAMPLE DESCRIPTIONS

QUATERNARY SAMPLES

BS-2. Mandhata, Uttar Pradesh **4380 ± 130**

Carbonaceous sediments, depth 2 to 2.1m, from Horse Shore Lake, Mandhata (25° 40′ N, 82° E), Dist Pratapgarh. Sample subm by H P Gupta, Birbal Sahni Inst Palaeobot (BSIP), Lucknow.

Kashmir series

Haigam Lake (34° 3′ N, 74° 29′ E), Kashmir Valley. Clayey organic sediment samples coll 1963 by Vishnu-Mittre & B D Sharma and subm by Vishnu-Mittre. Pollen diagram was previously pub (Vishnu-Mittre & Sharma, 1966).

BS-36. Carbonaceous clay **1640 ± 115**

Depth 4 to 5m.

BS-37. Carbonaceous clay **2120 ± 110**

Depth 5 to 6m.

Comment: pollen sequence was interpreted to date from Neolithic, *ie*, ca 5000 BP. ^{14}C dates are younger.

TABLE 1
Cross check samples

Sample/site	Birbal Sahni Inst age (yr)	Tata Inst TF no.	age (yr)	Ref
Charcoal Kalibangan	3925 ± 125	163	3910 ± 100	R, 1965, v 7, p 293
Charcoal Kalibangan	3570 ± 125	152	3615 ± 85	R, 1966, v 8, p 447
Charcoal Kalibangan	3585 ± 120	149	3675 ± 140	R, 1966, v 8, p 448
Charcoal Kalibangan	4010 ± 165	156	3740 ± 105	R, 1966, v 8, p 448
Charcoal Kayatha	3490 ± 125	777	3625 ± 95	R, 1969, v 11, p 503
Charcoal Taklaghat	2370 ± 120	784	2435 ± 95	R, 1969, v 11, p 504
Charcoal Inamgaon	2855 ± 150	923	2890 ± 170	R, 1971, v 13, p 85
Charcoal Nindwari	3840 ± 235	862	3900 ± 105	R, 1971, v 13, p 86
Charcoal Paiyampalli	1125 ± 100	829	985 ± 105	R, 1971, v 13, p 87
Carbonized kernals Lena Athula	7190 ± 155	1094	7640 ± 110	R, 1975, v 17, p 220

Tsokar Lake (33° 20′ N, 78° E), alt 4600m, Dist Ladakh. Samples coll by Geol Survey India, subm by Vishnu-Mittre dated for origin, history, vegetation, and climate of Tsokar Lake and region.

Samples from bore hole Core TP-6

BS-5. Carbonaceous clay **11,830 ± 500**
Depth 3m.

BS-9. Carbonaceous clay **15,800 ± 1110**
Depth 5.15m.

BS-11. Carbonaceous clay **20,500 ± 2000**
Depth 12m.

BS-17. Biogenic deposit **30,600 ± 1400**
Depth 21.85m.

Samples from bore hole Core TSD-1

BS-28. Biogenic deposit **34,170 ± 3370**
Depth 7.7 to 8.2m.

BS-29. Carbonaceous clay **>40,000**
Depth 13.5 to 13.7m.

BS-30. Carbonaceous clay **>41,000**
Depth 18.5m.

BS-31. Carbonaceous clay **>15,000**
Depth 23.2 to 23.85m.

Comment: biogenic deposits from bore hole Cores TP-6 and TSD-1 (BS-17 & 28) indicate warm fluctuation within Weichselian glaciation. Pollen sequence is under preparation.

Lahul series

Batal (32° 14′ 30″ N, 77° 33′ 40″ E), Lahul Valley, Dist Lahul & Spiti. Samples coll from trial trench along river bed and subm by A Bhattacharya, BSIP. Samples date pollen sequence.

BS-54. Varved silty clay **495 ± 90**
Depth 7 to 17cm.

BS-60. Varved silty clay **1370 ± 135**
Depth 60 to 97cm.

Rajasthan series

Samples from trial trenches from lakes in Rajasthan desert coll and subm by A K Saxena, BSIP to date origin and history of these lakes and of vegetation and climate of Rajasthan desert.

Didwana Salt Lake (27° 30′ N, 74° 30′ E), Dist Nagaur.

BS-24. Laminated dark clay **1960 ± 160**
Depth 40 to 75cm.

BS-26. Laminated dark clay **3725 ± 125**
Depth 130 to 135cm.

BS-34. Laminated dark clay **6110 ± 125**
Depth 230 to 235cm.

BS-35. Laminated dark clay **7835 ± 165**
Depth 290 to 295cm.

Comment: pollen sequence from this lake pub earlier (Singh *et al*, 1974) had a single date (WIS-415 — 2970 ± 65 BP) at depth 125cm. Present profile has consistent dates; bottom date agrees with estimates made by Singh *et al* (1974). Immigration of *Calligonum polygonoides*, a psammophytic sp, from extreme W of desert into vicinity of Didwana as observed in pollen diagram (Singh *et al*, 1974) is dated by BS-34 to ca 6000 BP. Pollen analysis of present profile is in progress.

Kanod (29° N, 71° E), Dist Jaisalmer.

BS-50. Sandy clay **8700 ± 200**
Depth 50cm.

BS-51. Sandy clay **9570 ± 160**
Depth 120cm.

Comment: deposits of Kanod playa are dated to 10,000 BP, same as some of salt lakes in N of Rajasthan desert. Sedges dominated grasses in vicinity of this playa until 8700 BP. Thereafter, grasses dominated. Pollen grains of thorn forest elements are scarce.

Pushkar lake (26° 29′ N, 74° 33′ 50″ E), Dist Ajmer.

BS-12. Sandy clay **Modern**
Depth 110 to 115cm.

BS-13. Sandy clay **1035 ± 110**
Depth 130 to 135cm.

Comment: beginning of *Anogeissus* forest with low frequencies of *Calligonum* and abundance of sedges is dated by BS-13. This is in contrast to changes observed at nearly same depth in Pushkar lake diagram pub by Singh *et al* (1974).

Budh Pushkar Lake (26° 29′ N, 74° 33′ 50″ E), Dist Ajmer.

BS-4. Sandy clay **Modern**
Depth 20 to 25cm.

BS-6. Sandy clay **425 ± 80**
Depth 105 to 110cm.

Comment: BS-6 dates occurrence of grassland-chenopod savannah in vicinity of lake.

Nilgiri series

Colgrain (11° 35′ N, 76° 52′ E), Dist Nilgiris. Samples from bore holes in peat deposits, subm by K Prasad, BSIP to date pollen diagram.

BS-19. Peaty clay **7840 ± 125**
Depth 20 to 50cm.

BS-20. Clay **27,450 ± 1000**
Depth 70 to 100cm.

BS-21. Peaty clay **21,350 ± 450**
Depth 120 to 150cm.

BS-23. Peaty clay **14,500 ± 930**
Depth 220 to 250cm.

Comment: middle 2 dates are highly inconsistent. BS-23 dates profile from late Weichselian. Pollen diagram reveals that ca 15,000 yr ago a grassland with *Impatiens* occurred around Colgrain and Shola forest was established here ca 8000 yr ago (Vishnu-Mittre & Gupta, 1971).

Upper Bhawani (11° 21′ N, 76° 45′ E), Dist Nilgiris. Samples from bore hole in peat deposits coll and subm by H P Gupta. Samples date pollen diagram.

BS-52. Peaty clay **5690 ± 110**
Depth 1.4m.

BS-53. Peaty clay **18,540 ± 290**
Depth 2.15m.

Comment: hiatus in stratigraphy seems involved. Pollen analysis of profile is in progress.

GEOLOGIC SAMPLES

BS-7. Nainital flats, Uttar Pradesh **1470 ± 100**

Wood assoc with landslide debris recovered by drilling at depth 61m from Nainital Flats (29° 23′ 30″ N, 79° 27′ 30″ E), Dist Nainital. Samples subm by Geol Survey of India.

BS-8. Mothranwala Swamp, Uttar Pradesh **585 ± 140**

Clay from Mothranwala swamp (30° 15′ N, 78° 2′ E) alt 680m Dist Dehra Dun. Sample, depth 70 to 90cm, subm by B S Venkatachala, Indian Inst Petroleum.

BS-18. Corubathan, Bengal **250 ± 115**

Charcoal fragments from excavation at Corubathan (27° 6′ 6″ N, 88° 48′ 53″ E), Dist Darjeeling. Excavated across exposed terrace. Subm by S Ghosh, Geol Survey India.

BS-33. Vettikod, Kerala **>40,000**

Wood fragment removed from stump in natural exposure, pit depth 1.5m at Vettikod (9° 10′ 30″ N, 76° 35′ 15″ E), Dist Allepey.

BS-32. Vettikod, Kerala **>40,000**

Lignite from natural, exposure, pit depth 1.5m at Vettikod (9° 10′ 30″ N, 76° 35′ 15″ E), Dist Allepey.

BS-27. Kutheravattam, Kerala **23,300 ± 600**

Lignite from well dug in Kutheravattam (9° 11′ N, 76° 36′ 40″ E), Dist Allepey. Sample from depth 8m. Samples BS-33, 32 and 27 subm by Dir Geochronol Div, Geol Survey India to date occurrence of lignite in Kerala. *Comment*: lignite deposits in Kerala are believed by geologists to be of Late Tertiary age (Wadia, 1961). It is interesting to find that BS-27 is dated to late Quaternary.

BS-47. Rajdanda, Bihar **36,560 ± 2535**

Carbonized wood from natural exposures, 1.5m below surface, along river at Rajdanda (23° 45′ 37″ N, 84° 07′ 28″ E), Dist Palamau. Sample dates rich fossiliferous shell horizon. Subm by V P Misra, Geol Survey India.

BS-48. Khetri, Rajasthan **140 ± 90**

Gray-colored fire wood stacked at head of Madan (Khetri) copper mine (28° N, 75° 47′ E), Dist Jhunjhunu. Date of copper mining in area is too recent; it was known to be much earlier from other evidence.

ARCHAEOLOGIC SAMPLES

BS-15. Tilapat, Haryana **290 ± 150**

Decaying timber (*Adansonia digitata*) from exposed stump at Tilapat (28° 30′ N, 77° 20′ E), Dist Gurgaon. Felling date of tree is unknown but is believed to have been planted during Mahabaratha period. Subm by K M Vaid, Forest Research Inst, India. *Comment*: younger than expected.

BS-38. Appukullu, Madras **2235 ± 140**

Charcoal from APKL-1. Systematic excavation at Appukullu (12° 52′ N, 78° 59′ 2″ E), Dist N Arcot. Subm by K V Raman, Univ Madras. Dated for sequence and chronology of Neolithic and Megalithic cultures of Tamil Nadu.

BS-39. Lumbini, Nepal **2105 ± 100**

Charcoal, Sample 3, depth 2m, from Lumbini (27° 20′ N, 83° 30′ E), Dist Taulihawa, believed to be birth place of Lord Buddha, Nepal. Systematic excavation by Dir Archaeol, HMG, Nepal, and Archaeol Adviser, Indian Cooperation Mission, Nepal. Subm by Vishnu-Mittre. Date is close to archaeol estimate.

BS-42. Marakadola, Assam **660 ± 95**

Charcoal from Trench 3, systematic excavation, Marakadola (26° N, 91° 48′ E), Dist Kamrup. Subm by S N Rao, North Eastern Hill Univ, Shillong.

BS-44 Dazelling, Arunachal Pradesh **410 ± 125**

Carbonized rice coll from a pit, depth 40cm, at Dazelling (27° 30′ N, 92° 20′ E), Dist Kameng. Subm by S K Dutta, Dibrugarh Univ, Assam.

OCEANOGRAPHIC SAMPLES

BS-40. Off-Bombay Coast **9830 ± 180**

Sediment core coll by R V Oceanographer, Off-Bombay Coast (20° 10′ N, 70° 26′ 59″ E). Top sample of Core 4. Subm by M G A P Shetty, Natl Inst Oceanog (NIO), Goa.

BS-45. Off-Bombay Coast **20,940 ± 450**

Sediment core coll by RV Oceanographer, Off-Bombay Coast (18° 35′ 12″ N, 69° 17′ 12″ E). Bottom sample, No. 7, of Core 2. Subm by M G A P Shetty, NIO, Goa.

GEOPHYSICAL SAMPLES

Minicoy series

Dead corals from natural exposure near Light House, Minicoy (8° 0′ 8″ N, 73° E). Sample to date storm beaches and formation of islands. Subm by H N Siddiquie, NIO, Goa.

BS-56. **Modern**

BS-57. **205 ± 105**

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[RADIOCARBON, VOL. 20, No. 3, 1978, P. 405-415]

GLIWICE RADIOCARBON DATES IV

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All samples described in this date list have been measured since July 1973 to Oct 1975 using carbon dioxide filled proportional counters. Most of samples have been dated with Counter No. 1 (L1) as in our previous list (Mościcki and Zastawny, 1976). Some samples were measured with Counter No. 3 (L3), with a total volume of 1.5l and background and NBS oxalic acid standard counting rate of respectively, 3.50 or 4.00 cpm and 10.05 or 20.40 cpm when filled to 1 or 2 atm pressure (Mościcki and Zastawny, 1977).

All dates reported here are conventional radiocarbon dates calculated using the Libby value for the half life of radiocarbon. For water samples the results of measurements are given as per cent of modern. Measurement errors are calculated from statistics of counts including one-sigma standard deviations of sample, modern and background counting rates and the uncertainty of gas pressure in the counter. No corrections for isotopic fractionation were made. Background carbon dioxide is prepared from anthracite coal, modern tree activity standard is prepared from NBS oxalic acid by wet oxidation. The $\delta^{13}C$ value for carbon dioxide obtained from NBS oxalic acid standard is $-19.41 \pm 0.08‰$ with respect to the PDB standard. Sample descriptions, comments and references to publications are based on information supplied by the persons who submitted the samples.

During 1975 and 1976 an improvement in measurement techniques was achieved through the application of a new method for counting gas purity control and continuous monitoring of counting efficiency. The method is based on calculating the ratio of the number of muon coincidence counts between proportional counter and guard counters to the number of muon coincidence counts between two independent sections of the guard counter. This ratio was proven to be a very sensitive tool for monitoring counting efficiency and allows for correction of counting efficiency when the filling gas has impurities (Pazdur *et al*, 1978).

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SAMPLE DESCRIPTIONS

I. ARCHAEOLOGIC SAMPLES

Gd-259. Grzegorzewice No. 40 **1960 ± 140**

Incompletely burned charcoal from Site 1, Furnace 40, Grzegorzewice, Opatów dist (50° 09′ N, 21° 02′ E). Furnace hole of bloomery type

filled with iron slags was excavated in undisturbed loess. Base of furnace hole, 45cm diam, was submerged into loess 35cm. Also found were remains of 104 furnaces of bloomery type. Coll and subm 1973 by K Bielemin, Archaeol Mus, Cracow. *Comment*: charcoal from Furnace 16, this site was dated in Berlin, Bln-1349, 1810 ± 60 (K Bielenin, written commun, 1973). *Cf* other dates of similar objects from Poland: Gd-229, 1920 ± 150 (R, 1976, v 18, p 56), Gd-263, 1770 ± 140; Gd-298, 1660 ± 120, this list, see also Mościcki *et al* (1967) and Bielenin (1977).

Swiecica series

Charcoal from Mound II in Swięcica, Sandomierz dist (50° 48′ N, 21° 40′ E). Coll 1973 and 1974 and subm 1974 by A Kempisty, Dept Prehist & Early Medieval Archaeol, Warsaw Univ.

Gd-320. Swiecica 62/73 **1210 ± 70**

Sample from one of accumulations of charcoal in central part of mound at depth 1.33 to 1.55m below surface. *Comment* (AK): agrees fairly well with archaeol estimate.

Gd-323. Swiecica 823/74 **3695 ± 90**

Sample representing colln of small lumps of charcoal spreaded in entire fill of Pit III, at depth 1.7 to 3.1m below surface, N part of mound. *Comment* (AK): Pit III is dated as belonging to Mierzanowice culture from Period I of Bronze age, ca 1700BC.

Nieborowa II series

Charcoal from campfire stands in Nieborowa, Chełm Lubelski dist (51° 19′ 43″ N, 23° 29′ 11″ E). Cultural sites excavated in alluvial layer of sandy soil in denudational valley on slope of fluvioglacial hill Pagór Uhruski. The valley is covered with eolically transformed alluvial sands. Coll and subm 1973 by H Mackiewicz, Inst Hist Material Culture, Polish Acad Sci, Warsaw.

General Comment (HM): archaeol dating indicates latest period of Mesolithic age contemporary with fully developed Neolithic culture. Stands belong probably to decline of Atlantic and beginning of Sub-Boreal period.

Gd-325. Nieborowa II/1/A **2200 ± 80**

From campfire at depth 30 to 40cm.

Gd-322. Nieborowa II/1/B **2550 ± 120**

From campfire at depth 40 to 50cm.

Gd-321. Nieborowa II/1/C **980 ± 100**

From campfire at depth 60 to 80cm.

General Comment: *cf* other dates from Nieborowa I: Gd-140, 2400 ± 100; Gd-144, 5730 ± 130 (R, 1976, v 18, p 55).

Gd-301. Pieczyska I **1210 ± 110**

Carbonized wood from elements of earth-wooden wall construction of early medieval settlement covered with layer of humus at margin of loess highland, Pieczyska I, Zawichost-Podgórze, Sandomierz dist (50° 48′ 00″ N, 21° 51′ 30″ E). Sample from 2nd horizon of wall remains at depth 50 to 55cm. Coll and subm 1974 by S Tabaczyński, Inst Hist Material Culture, Polish Acad Sci, Warsaw.

Gd-300. Otalazka I **1790 ± 110**

Charcoal and pieces of partly burned wood from Hearth Area 4, Otalązka I, Mogielnica village, Grójec dist (51° 41′ N, 20° 45′ E). Cultural layer found between 2 peat layers at depth 180 to 190cm (Bender & Stupnicka, 1974; Oświt & Żurek, 1974; Dzięczkowski, 1974). Coll and subm 1973 by W Bender, Inst Hist Material Culture, Polish Acad Sci, Warsaw. *Comment* (WB): site is dated between 4th and 6th centuries AD.

Dobrzen Maly series

Charcoal from iron-foundry settlement dating from period of Roman provincial cultural influences, ca 1.2km E of Dobrzeń Mały, Opole dist (50° 45′ 00″ N, 17° 52′ 45″ E), NE of prevalley of Odra R. Coll 1974 by K Bielenin and E Tomczak; subm 1974 by J Rozpędowski, Inst Hist Architecture Arts & Technology, Wrocław Tech Univ, Wrocław.

Gd-263. Dobrzen Maly ob 19 **1770 ± 140**

From Stand B, ar 89, Structure 19. Sample from lower part of primitive smelting cupola furnace with loamy base covered with fine iron slags and remains of charcoal.

Gd-298. Dobrzen Maly ob 25 **1660 ± 120**

From Stand B, ar 331, Structure 25. Sample taken from lower part of heating furnace ca 15m below its remaining roof part.

Debczyno series

Carbonized wood (*Quercus* sp) id by M Klichowska, from Site 3 in Dębczyno, Koszalin dist (53° 58′ 15″ N, 16° 00′ 32″ E). Subm 1974 by J Zak, Dept Archaeol, A Mickiewicz Univ, Poznań. Samples taken from fill of pit dwelling composed mainly of clay mixed with fossil humus. Pieces of charcoal from fireplace scattered over large area in lower part of habitation.

Gd-318. Debczyno 32 **1670 ± 140**

From pit dwelling 4. Coll 1971 by C Strzyzewski. *Comment* (JZ): cultural dating, 3rd to 4th centuries AD.

Gd-319. Debczyno 300 **2050 ± 130**

From pit dwelling No. 22. Coll 1974 by E Slaska. *Comment* (JZ:) cultural dating, 4th to 5th centuries AD.

Krusza Zamkowa series

Charcoal from Krusza Zamkowa, Inowrocław dist (52° 45′ N, 18° 12′ E). Subm by A Cofta Broniewska, Dept Archaeol, A Mickiewicz Univ, Poznań.

Gd-309. Krusza Zamkowa, Site 13 **5140 ± 140**

From Grave III in passage graves cemetery belonging to Globular Amphora culture. Coll 1974 by U Narozna.

Gd-317. Krusza Zamkowa, Site 3 **1990 ± 100**

From Pit 5 in big settlement of Przeworska Culture. Coll 1973 by A Szułdzyński.

Gd-324. Koscielec Kujawski KK448 **5240 ± 160**

Charcoal from Site 16 at Kościelec Kujawski, Inowrocław dist (52° 46′ N, 18° 04′ E). Coll 1974 by L Czerniak and subm by A Cofta Broniewska. *Comment* (ACB): date consistent with archaeol estimate.

Gd-336. Lacko L1 **2580 ± 130**

Charcoal from Site 6 at Lącko, Inowrocław (52° 49′ N, 18° 06′ E). Fragments of sherd (TRB culture). Coll 1973 by L Domańska, subm 1974 by A Cofta Broniewska.

Gd-345. Krepnica K-1-I/74 **5180 ± 160**

Charcoal from dune on terrace of Bóbr R, ca 1/2km NW of Krępnica village, Bolesławiec dist (51° 20′ N, 15° 34′ E). Site consists of 3 contemporaneous hearths surrounded with stones, found at depth .45m inside pit dwelling belonging to fishing and hunting population, assoc with carbonized bird bones, broken stone and flint tools. Coll and subm 1974 by Z Bagniewski, Dept Archaeol, Wrocław Univ. *Comment* (ZB): typology of assoc material indicates end of Atlantic period.

Gd-337. Pobiel P-10-I/71 **7550 ± 190**

Charcoal from cultural layer on terrace of Orla R, at depth .84m under organic layer of primary oak ca 1km S of Pobiel village (51° 33′ N, 16° 45′ E). Pollen analysis by P Szczypek, Inst Geog, Wrocław Univ, indicates Atlantic period. *Comment* (ZB): based on assoc material this site probably belongs to Komornicka culture from beginning of Atlantic period.

II. GEOLOGIC SAMPLES

A. Poland

1. Mazury Lakeland

Gd-225. Nowe Miasto Lubawskie **470 ± 150**

Charcoal from sandy soil layer at depth 1 to 1.3m on left side of Drwęca R at Nowe Miasto Lubawskie, voi Olsztyn (53° 24′ N, 19° 35′ E). Coll 1972 by A. Olszewski and subm 1973 by Z Churska, Inst Geog, M Kopernik Univ, Toruń (Churska, 1969)

Gd-224. Fletnowo II **10,200 ± 270**

Peat from base of post-lacustrine depression at Fletnowo, Swiecie dist, voi Bydgoszcz (53° 32′ N, 18° 39′ E). Sample from depth 8.57 to 8.63m, basal layer of peat covered with upper peat layer and gyttja. Coll 1973 by K Więckowski and subm by L Roszko, Inst Geog, M Kopernik Univ, Toruń. *Comment* (LR): pollen analysis of bottom layer by B Noryśkiewicz indicates end of younger Dryas (Roszko, 1968).

2. Great Poland Lowland

Mirkow 1 series

Holocene deposits in floodplain of Prosna R consisting of muds, 0 to 1.5m, sandy-organic muds, 1.5 to 2.1m, with trunks and wood fragments, and various-grained sands, below 2.1m, at Mirków, Wieruszów dist (51° 18′ N, 18° 09′ E). Coll 1973 by K Rotnicki and subm by S Kozarski, A Mickiewicz Univ, Inst Geog, Poznań. Samples dated for Holocene conf in 1974. Pollen analysis of organic layer dates Atlantic period (Kozarski & Rotnicki, 1977).

Gd-241. Mirkow 1/155 **7730 ± 190**

Fossil plant fragments from top layer of sandy mud at depth 1.55m.

Gd-234. Mirkow 1/185 **7760 ± 220**

Wood, individual trunk from depth 1.85m.

Gd-233. Mirkow 1/205 **9380 ± 210**

Wood, individual trunk from depth 2.05m.

Gd-232. Mirkow 1/290 **9770 ± 250**

Wood, individual trunks found under organic layer at depth 2.9m.

Mirkow 2 series

Wood from two organic layers separated with stratified silty sands with rich admixture of wood fragments in fossil river channel at Mirków, Wieruszów dist (51° 18′ N, 18° 09′ E). Coll 1973 by K Tobolski and subm by S Kozarski (Kozarski & Rotnicki, 1977).

Gd-235. Mirkow 2/280 **4920 ± 170**

Wood from depth 2.8m.

Gd-236. Mirkow 2/210 **3120 ± 160**

Wood from depth 2.1m.

Gd-293. Jaszkowo **9650 ± 240**

Coarse-detrital gyttja from continuous layer of deposits in filling fossil meander channel on Warta R floodplain; depth 2.74 to 2.80m, at

Jaszkowo, Srem dist (52° 10′ N, 16° 57′ E). Coll 1974 by B Nowaczyk and subm by S Kozarski.

Kraski series

Charcoal in single pieces from organic layer separating 2 series of dune sands in parabolic dune on terrace of Warsaw-Berlin ice-marginal valley at Kraski village, Łęczyca dist (52° 02′ N, 18° 54′ E). Coll 1974 by K Krajewski and subm 1974 by A Dylikowa, Inst Geog, Lódź Univ (Dylikowa, 1967; 1969; Wasylikowa, 1964).

Gd-294. Kraski 1 **10,530 ± 585**

From N part of dune bank, depth 4m. *Comment*: sample diluted with inactive CO_2 for counting.

Gd-295. Kraski 2 **3050 ± 130**

From S part of dune bank, depth 1.6m.

Gd-304. Borki Lipkowskie 1 **10,500 ± 250**

Charcoal from dune at Borki Lipkowskie, dist Poddębice (51° 51′ N, 18° 54′ E). Single pieces of charcoal found at depth 5m in organic layer separating 2 series of dune sands. Coll 1973 by K Krajewski and subm 1974 by A Dylikowa.

3. Mazowiecka Plain

Wolumen series

Peat, coll and subm 1974 by W Morawski, Inst Geol, Warsaw (Morawski, 1975; 1976).

Gd-308. Wolumen T-I **>30,000**

Peat from bed in post-lacustrine depression at Wawrzyszew, Warsaw (52° 17′ 00″ N, 20° 56′ 15″ E). Depth 2.4 to 2.6m. *Comment*: date based on 3σ criterion.

Gd-343. Wolumen T-II **720 ± 120**

Peat from highest layer of organic deposits in lake bowl at Warsaw (52° 17′ 20″ N, 20° 56′ 00″ E). Depth 1.90 to 2m.

Gd-246. Czarnow **9860 ± 440**

Charcoal from fossil soil layer at depth ca 3.5m in dune at Czarnów village, Piaseczno dist, ca 20km SSE of Warsaw (52° 04′ N, 21° 06′ E). Coll 1973 by K Urbaniak Biernacka, subm by J Rózycki, Fac Geod Cart, Warsaw Tech Univ. *Comment*: sample diluted with inactive CO_2 for counting.

Gd-245. Ciesle Stare **3410 ± 150**

Carbonized wood from depth 2.8m in flood terrace of Mołtawa R valley at Cieśle Stare village, Płock dist (52° 27′ 54″ N, 20° 59′ 30″ E). Coll 1973 by J Kotarbiński, subm by J Rózycki.

4. Kraków-Częstochowa Highland

Siewierz series

Charcoal from fossil soil levels in dune near Siewierz, Czarna Przemsza R valley (50° 29′ N, 19° 13′ E). Coll and subm 1974 by P Szczypek, Inst Geog, Silesian Univ, Sosnowiec.

Gd-339. Siewierz 2 **4100 ± 150**

From younger level, depth .5 to 2.5m.

Gd-341. Siewierz 1 **9420 ± 500**

From older level, depth 3m. *Comment*: sample diluted with inactive CO_2 for counting.

B. Spitsbergen

Spitsbergen 1973 series

Moss and peat samples coll 1973 by Polish Spitsbergen Expedition for study of intensity of slope processes and sequences of glacial extension and retreat during Holocene. Sample Gd-264 coll and subm 1973 by S Baranowski, Geog Inst, Wrocław Univ. Other samples coll and subm 1973 by K Pękala, Inst Earth Sci, M Skłodowska Univ, Lublin.

Gd-264. Spitsbergen 51/1973 **760 ± 145**

Moss from Spitsbergen, Norway (77° 04′ 40″ N, 15° 13′ 00″ E). Fossil vegetation in clusters lying on older ground moraine of Werenskiold Glacier Forefield under thin, 5 to 10cm, cover of younger ground moraine.

Gd-278. Spitsbergen 104/1973 **930 ± 135**

Peat, fossil vegetation in form of compact cover on nunatak (weathered rock shelf) from Spitsbergen, Norway (77° 02′ 45″ N, 15° 25′ 30″ E). Peat layer on weathered sandy-loam soil covered with .5m rubble. *Comment* (KP): not long before terrain was covered with glacial ice.

Gd-279. Spitsbergen 79/1973 **920 ± 140**

Fossil vegetation, compact cover on flat surface and slope of nunatak, partly covered with rubble, from Spitsbergen, Norway (77° 01′ 45″ N, 15° 26′ 16″ E).

Gd-280. Spitsbergen 126/1973 **<425**

Peat, fossil vegetation, compact cover on N slope of nunatak, covered with 1.2m layer rubble, from Spitsbergen, Norway (77° 01′ 45″ N, 15° 26′ 16″ E). *Comment*: date based on 3σ criterion.

III. GEOCHEMICAL SAMPLES

The purpose of this study was to trace origins of water from inrushes in deep coal mines of Rybnik coal region. First series of measurements was reported in our previous list (Mościcki & Zastawny, 1976; Mościcki,

1977). Present list summarizes results obtained since 1973 to 1975. All samples were coll by lab staff. The results of measurements are presented as per cent of modern $0.95A_{ox}$ activity. No corrections for $^{13}C/^{12}C$ were made. Samples denoted with asterisk (*) were counted after dilution of sample CO_2 with inactive gas. Unless stated explicitly sampling localities are essentially the same as in previous list.

A. Deep water samples

Shaft RJ-1 series (cont'd)

Zone of great tectonic disturbances, depth 400m. Three separate water outflows were distinguished: Outflow A—large dispersed water outflow from ceiling ca 10m from end of gallery, fresh water. Outflow B—mineralized water, moderate outflow from side wall of gallery, ca 10m from sampling point A. Outflow C—fresh water, greatly dispersed outflow from ceiling, ca 80m from sampling point B. Results pub in previous list were obtained for sampling point A, but some water samples were probably coll as mixtures of water from sampling points A and B.

Lab no.	Location	Colln date day/mo/yr	% of $0.95A_{ox}$ NBS
Gd-251	A	14/03/74	1.3 ± 0.8
Gd-261	A	24/05/74	1.3 ± 0.8
Gd-305	A	23/11/74	2.0 ± 0.8
Gd-270	B	24/05/74	1.0 ± 0.8
Gd-306	B	23/11/74	0.0 ± 0.6
Gd-269	C	24/05/74	0.5 ± 0.8
Gd-307	C	23/11/74	2.0 ± 0.8

Shaft RVI-1 series (cont'd)

Water leakage from ceiling of cutting leading to coal bed. Depth 400m, ca 2km from sampling point RJ-1.

Lab no.	Colln date day/mo/yr	% of $0.95A_{ox}$ NBS
Gd-252	14/03/74	21.0 ± 0.9
Gd-260	24/05/74	24.0 ± 0.9
Gd-356	12/06/75	18.0 ± 1.4

Shaft RR-1 series (cont'd)

Two newly formed water outflows of ca 100m in testing gallery leading to fault region, depth 430m. Coll 16/11/74. *Comment*: results based on 3σ criterion.

Gd-302. RR-1A **<1.8% of 0.95A_{ox} NBS**

Gd-303. RR-1B **<2.2% of 0.95A_{ox} NBS**

Shaft CC-1 series (cont'd)

Water outflow from wall of the gallery traversing sandy crevice near fault region, depth 390m. Coll 4/04/74.

Gd-255. **0.7 ± 0.8% of 0.95A_{ox} NBS**

Shaft AJ-1 series (cont'd)

Water leakage from wall of shaft, depth ca 160m, sample coll 4/04/74.

Gd-254. **30.4 ± 1.0% of 0.95A_{ox} NBS**

Shaft AZ-1 series (cont'd)

Series of water outflows from wall of shaft crossing water-bearing gypsum bed. Samples taken from 3 levels: Outflow C—at depth ca 20m, fresh water. Outflow B—at depth ca 43m, water containing sulphuric compounds. Outflow A—at depth ca 57m, fresh water with admixture (ca 30%) of sulphuric water from leakage at depth ca 50m.

Lab no.	Location	Colln date day/mo/yr	% of 0.95A_{ox} NBS
Gd-331	A	29/01/75	13.6 ± 0.8
Gd-256	B	4/04/74	32.3 ± 1.0
Gd-274	B	31/05/74	33.7 ± 1.3
Gd-332	B	29/01/75	30.9 ± 1.0
Gd-353	B	14/05/75	31.5 ± 6.1*)
Gd-271	C	31/05/74	59.2 ± 1.3
Gd-333	C	29/01/75	48.2 ± 1.7
Gd-354	C	14/05/75	42.1 ± 0.8

B. Ground water samples

Niedobczyce Niewiadom draw well series

Draw well in Niedobczyce Niewiadom village, ca 3km SW of Rybnik, depth ca 30m.

Lab no.	Colln date day/mo/yr	% of 0.95A_{ox} NBS
Gd-262	25/04/74	60.6 ± 1.3
Gd-297	15/10/74	56.0 ± 1.2
Gd-334	7/03/75	61.0 ± 1.4
Gd-351	23/04/75	56.2 ± 2.3*)
Gd-352	11/06/75	53.4 ± 2.5*)

Zawada draw well series

Draw wells in Zawada village, ca 2.5km SSW of Pszów.

Lab no.	Location	Colln date day/mo/yr	% of $0.95A_{ox}$ NBS
Gd-272	Draw well 1643	31/05/74	75.6 ± 1.5
Gd-346	Draw well NN	29/01/75	90.1 ± 6.3*)

Zawada spring series

Meadows springs, water containing sulphuric compounds, at Zawada village, ca 2.5km SSW of Pszów.

Lab no.	Colln date day/mo/yr	% of $0.95A_{ox}$ NBS
Gd-329	29/01/75	31.3 ± 1.0
Gd-349	14/05/75	40.9 ± 0.9

Gd-350. Jejkowice draw well **100.7 ± 1.1% of $0.95A_{ox}$ NBS**

Draw well, at Jejkowice village, ca 2.5km NWW of Rybnik, depth ca 15m. Coll 7/03/75.

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[RADIOCARBON, VOL. 20, No. 3, 1978, P. 416-435]

UNIVERSITY OF LUND RADIOCARBON DATES XI

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INTRODUCTION

Most of the ^{14}C measurements reported here were made between October 1976 and October 1977. Equipment, measurement, and treatment of samples are as reported previously (R, 1968, v 10, p 36-37; 1976, v 18, p 290).

Age calculations are based on a contemporary value equal to 0.950 of the activity of NBS oxalic acid standard and on the conventional half-life for ^{14}C of 5568 yr. Results are reported in years before 1950 (years BP). Errors quoted ($\pm 1\sigma$) include standard deviations of count rates for the unknown sample, contemporary standard, and background. When measured activity is less than 2σ above background, minimum age is given. Basis for calculation of age limit is measured net activity plus 3σ. If net activity is negative, only $+3\sigma$ is used for age limit.

Corrections for deviations from $\delta^{13}C = -25.0‰$ in the PDB scale are applied for all samples; also for marine shells. The apparent age for marine material must be subtracted from our dates on such samples.

The remark, "undersized; diluted", in *Comments* means the sample did not produce enough CO_2 to fill the counter to normal pressure and "dead" CO_2 from anthracite was introduced to make up the pressure. "% sample" indicates amount of CO_2 derived from the sample present in the diluted counting gas; the rest is "dead" CO_2. Organic carbon content reported for bone samples is calculated from yield of CO_2 by combustion of gelatine remaining after treatment. Organic carbon lost during treatment is not included in calculated percentage.

The description of each sample is based on information provided by the submitter.

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SAMPLE DESCRIPTIONS

I. GEOLOGIC SAMPLES

A. Sweden

Håkulls mosse series

Sediment from bog Håkulls mosse on hill ridge Kullaberg, NW Scania (56° 17′ N, 12° 31′ E). Alt ca 125m. Coll 1975 and subm by B E Berglund, Dept Quaternary Geol, Univ Lund. Samples are from core taken with Livingstone sampler, 100mm diam. Depths refer to bog sur-

face. Site and older pollen diagram described earlier (Berglund, 1971). No carbonate content. All samples pretreated with HCl; Nos. 5, 6, and 8 also with NaOH.

Lu-1262. Håkulls mosse 1, 866 to 868cm **13,020 ± 135**
$\delta^{13}C = -23.7‰$

Clay gyttja. Beginning of Bölling zone.

Lu-1263. Håkulls mosse 2, 859 to 861cm **12,660 ± 125**
$\delta^{13}C = -24.9‰$

Clay gyttja. Middle of Bölling zone.

Lu-1264. Håkulls mosse 3, 854 to 856cm **12,440 ± 120**
$\delta^{13}C = -22.9‰$

Clay gyttja. Later part of Bölling zone.

Lu-1265. Håkulls mosse 4, 847 to 849cm **12,150 ± 120**
$\delta^{13}C = -22.4‰$

Clay gyttja. Older Dryas zone.

Lu-1331. Håkulls mosse 5, 806 to 808cm **11,240 ± 110**
$\delta^{13}C = -24.4‰$

Gyttja. Transition Alleröd/Younger Dryas.

Lu-1332. Håkulls mosse 6, 804 to 806cm **11,050 ± 110**
$\delta^{13}C = -24.6‰$

Clay gyttja. Transition Alleröd/Younger Dryas.

Lu-1333. Håkulls mosse 7, 753 to 755cm **10,430 ± 105**
$\delta^{13}C = -24.3‰$

Clay gyttja. Later part of Younger Dryas zone.

Lu-1334. Håkulls mosse 8, 730 to 732cm **10,240 ± 100**
$\delta^{13}C = -26.0‰$

Clay gyttja. Transition Younger Dryas/Pre-Boreal.

Lu-1335. Håkulls mosse 9, 724 to 726cm **10,110 ± 100**
$\delta^{13}C = -26.9‰$

Clay gyttja. Transition Younger Dryas/Pre-Boreal.

Lu-1336. Håkulls mosse 10, 653 to 655cm **9310 ± 95**
$\delta^{13}C = -29.6‰$

Gyttja. Later part of Pre-Boreal zone.

Jämjö series

Wood samples from silty and sandy deposits in valley of rivulet Åbyån, N of Jämjö, E Blekinge. Coll 1976 and subm by S Björck, Dept Quaternary Geol, Univ Lund. Dating is part of study of influence of sea-level changes on erosion and accumulation in valley and of relation between solifluction material and climatic and vegetational changes and/or human influence in area. Samples pretreated with HCl and NaOH.

Lu-1261. Jämjö church **1570 ± 50**
$\delta^{13}C = -26.8‰$

Wood fragments (*Alnus* sp) id by T Bartholin from humic sand and silt 1.7m below surface at Jämjö church (56° 11′ 30″ N, 15° 50′ 5″ E). Stratified sand and silt from 2.5m below surface and further down.

Lu-1296. Hagalund 6 **4890 ± 70**
$\delta^{13}C = -26.5‰$

Unid wood fragments from sand 2.25m below surface at Hagalund 6, ca 1km N of Jämjö church (56° 12′ N, 15° 50′ 15″ E). Silt with clay layers from 3.5m below surface and further down. *Comment*: sample undersized; diluted; 91% sample.

Sämbosjön series

Sediment from Lake Sämbosjön, Halland, SW Sweden (57° 10′ N, 12° 25′ E). Alt 38m; area 0.2sq km; max depth 6m. Coll 1976 and subm by G Digerfeldt, Dept Quaternary Geol, Univ Lund. Dating is part of study of Flandrian development of lake and vegetational history of surrounding region. Samples come from profile in central part of lake (Livingstone sampler, diam 100mm). Water depth 6m at sampling point. Depths given are below sediment surface. Lu-1267 through Lu-1271 pretreated with HCl only. All other samples pretreated with HCl and NaOH.

Lu-1270. Sämbosjön, 610 to 615cm **9860 ± 95**
$\delta^{13}C = -22.9‰$

Clay gyttja.

Lu-1267. Sämbosjön, 595 to 600cm **9390 ± 95**
$\delta^{13}C = -27.2‰$

Slightly clayey detritus gyttja.

Lu-1268. Sämbosjön, 555 to 560cm **9170 ± 90**
$\delta^{13}C = -27.2‰$

Slightly clayey detritus gyttja.

Lu-1269. Sämbosjön, 515 to 520cm **9190 ± 90**
$\delta^{13}C = -26.4‰$

Slightly clayey detritus gyttja.

Lu-1271. Sämbosjön, 460 to 465cm **8280 ± 85**
$\delta^{13}C = -25.6‰$

Detritus gyttja.

Lu-1272. Sämbosjön, 420 to 425cm **7820 ± 85**
$\delta^{13}C = -28.3‰$

Detritus gyttja. *Comment*: part of this sample was dated without NaOH treatment at 7710 ± 80.

Lu-1273. Sämbosjön, 380 to 385cm **6740 ± 75**
$\delta^{13}C = -28.5‰$

Detritus gyttja.

Lu-1274. Sämbosjön, 340 to 345cm **6220 ± 70**
$\delta^{13}C = -28.3‰$

Detritus gyttja.

Lu-1275. Sämbosjön, 300 to 305cm **5200 ± 65**
$\delta^{13}C = -27.6‰$

Detritus gyttja.

Lu-1276. Sämbosjön, 260 to 265cm **4270 ± 60**
$\delta^{13}C = -28.4‰$

Detritus gyttja.

Lu-1277. Sämbosjön, 220 to 225cm **3130 ± 55**
$\delta^{13}C = -28.5‰$

Detritus gyttja.

Lu-1278. Sämbosjön, 180 to 185cm **2440 ± 55**
$\delta^{13}C = -28.3‰$

Detritus gyttja.

Lu-1279. Sämbosjön, 140 to 145cm **2030 ± 50**
$\delta^{13}C = -28.4‰$

Detritus gyttja.

Hullsjön series

Sediment from Lake Hullsjön, Västergötland, central Sweden (58° 17′ N, 12° 23′ E). Alt 38m; area 1.8sq km; max depth 1.5m. Coll 1976 and subm by G Digerfeldt. Dating is part of study of Late Flandrian development of lake and vegetational history of surrounding region. Samples come from profile in central part of lake (Livingstone sampler, diam 60mm). Water depth 1.5m at sampling point. Depths given are below sediment surface. All samples pretreated with HCl.

Lu-1305. Hullsjön, 380 to 385cm **5440 ± 70**
$\delta^{13}C = -27.8‰$

Clay gyttja.

Lu-1306. Hullsjön, 355 to 360cm **4950 ± 65**
$\delta^{13}C = -28.0‰$

Clayey detritus gyttja.

Lu-1307. Hullsjön, 295 to 300cm **3490 ± 60**
$\delta^{13}C = -27.5‰$

Clayey detritus gyttja.

Lu-1308. Hullsjön, 255 to 260cm **2670 ± 55**
$\delta^{13}C = -27.4‰$

Clay gyttja.

Lu-1309. Hullsjön, 195 to 200cm **1410 ± 50**
$\delta^{13}C = -28.1‰$

Clayey detritus gyttja.

Lu-1310. Hullsjön, 160 to 165cm **760 ± 50**
$\delta^{13}C = -28.1‰$

Clay gyttja.

Långsjön series

Sediment from Lake Långsjön, Stockholm (59° 16′ N, 17° 58′ E). Alt 31m; area 0.3sq km; max depth 3.1m. Coll 1976 and subm by G Digerfeldt. Dating is part of study of Late Flandrian development of lake and vegetational history of surrounding region. Samples come from profile in deepest part of lake (Livingstone sampler, diam 60mm). Water depth 3.1m at sampling point. Depths given are below sediment surface. All samples pretreated with HCl.

Lu-1368. Långsjön, 481 to 486cm **4880 ± 65**
$\delta^{13}C = -25.4‰$

Slightly clayey algae gyttja. Just above isolation level.

Lu-1338. Långsjön, 471 to 476cm **4940 ± 65**
$\delta^{13}C = -24.8‰$

Slightly clayey algae gyttja.

Lu-1339. Långsjön, 421 to 426cm **4450 ± 65**
$\delta^{13}C = -27.2‰$

Slightly clayey detritus gyttja.

Lu-1340. Långsjön, 371 to 376cm **4180 ± 60**
$\delta^{13}C = -27.7‰$

Detritus gyttja.

Lu-1341. Långsjön, 321 to 326cm **4070 ± 60**
$\delta^{13}C = -28.1‰$

Detritus gyttja.

Lu-1342. Långsjön, 271 to 276cm **3780 ± 60**
$\delta^{13}C = -28.9‰$

Detritus gyttja.

Lu-1343. Långsjön, 221 to 226cm **3370 ± 60**
$\delta^{13}C = -29.5‰$

Detritus gyttja.

Lu-1344. Långsjön, 171 to 176cm **2440 ± 50**
$\delta^{13}C = -29.6‰$

Detritus gyttja.

Lu-1345. Långsjön, 121 to 126cm **2040 ± 50**
$\delta^{13}C = -29.9‰$

Detritus gyttja.

Lu-1366. Långsjön, 95 to 97cm **1720 ± 50**
$\delta^{13}C = -29.9‰$

Detritus gyttja.

Lu-1367. Långsjön, 70 to 72cm **990 ± 50**
$\delta^{13}C = -29.7‰$

Detritus gyttja.

Lu-1297. Innaren **>40,600**
$\delta^{13}C = -26.9‰$

Peat from ca 5m below surface found by well-digging near S end of Lake Innaren, South Swedish Upland (56° 58′ 10″ N, 14° 58′ 55″ E). Alt ca 180m. Coll Oct 1976 by U Lettevall; subm by G Digerfeldt.

Fjällsjön Series II

Sediment from Lake Fjällsjön, 3km SE of Sandhult church, central Västergötland (57° 45′ 6″ N, 12° 51′ 40″ E). Coll 1975 and subm by A Hilldén, Dept Quaternary Geol, Univ Lund. Dated as complement to Fjällsjön series (R, 1977, v 19, p 427-428). Depths refer to water surface. Water depth at sampling point ca 4m. Pretreated with HCl.

Lu-1363. Fjällsjön 1, 839 to 842cm **11,700 ± 125**
$\delta^{13}C = -21.9‰$

Clay gyttja. *Comment*: undersized; diluted; 90% sample.

Lu-1364. Fjällsjön 1, 831 to 833cm **11,250 ± 120**
$\delta^{13}C = -22.4‰$

Clay gyttja. *Comment*: undersized; diluted; 91% sample.

Lu-1392. Ljungsjön, 833 to 837cm **11,160 ± 125**
$\delta^{13}C = -25.8‰$

Clay gyttja from Lake Ljungsjön, 8km SW of Ulricehamn, central Västergötland (57° 44′ 3″ N, 13° 18′ 38″ E). Coll 1975 and subm by A Hilldén. Dated as complement to Ljungsjön series (R, 1977, v 19, p 427). Depth refers to water surface. Pretreated with HCl. *Comment*: undersized; diluted; 66% sample. (3 1-day counts.)

Björksjödamm series

Sediment from mire pool Björksjödamm, 1km N of Rya, 30km E of Göteborg (57° 42′ 20″ N, 12° 22′ 35″ E). Alt ca 87m. Coll 1977 and subm by A Hilldén. Samples are from core taken with Livingstone sampler, 100mm diam. Depths refer to water surface. Water depth ca 2m at sampling point. No carbonate content. Pretreated with HCl. All samples slightly undersized; diluted. Amount of CO_2 from sample is given in *Comment* below as "% sample".

Lu-1394. Björksjödamm 1 + 2, 842 to 848cm **12,550 ± 145**
$\delta^{13}C = -25.1‰$

Muddy clay and silt. Bölling zone. *Comment*: 82% sample.

Lu-1395. Björksjödamm 3, 836 to 840cm **12,290 ± 140**
$\delta^{13}C = -23.2‰$

Muddy clay. Older Dryas zone. *Comment*: 88% sample.

Lu-1396. Björksjödamm 4, 830 to 834cm **12,030 ± 125**
$\delta^{13}C = -23.8‰$

Muddy clay. Beginning of Alleröd zone. *Comment*: 97% sample.

Lu-1393. Björksjödamm 6, 818 to 822cm **11,170 ± 90**
$\delta^{13}C = -24.1‰$

Muddy clay. Transition Alleröd/Younger Dryas zone. *Comment*: 88% sample. (3 1-day counts.)

Lu-1397. Björksjödamm 5, 808 to 812cm **10,830 ± 120**
$\delta^{13}C = -24.9‰$

Muddy clay. Beginning of Younger Dryas zone. *Comment*: 85% sample.

Lu-1362. Ven **>41,600**
$\delta^{13}C = +0.8‰$

Redeposited marine shell fragments (*Mya truncata, Macoma calcarea,* and *Hiatella arctica*) id by K Strand Petersen, Geol Survey Denmark, Copenhagen, from gravelly sand at +2.5m near S end of Ven I. in Öresund, S Sweden (55° 53′ 28″ N, 12° 49′ 53″ E). Sand is part of glacial sequence. Dated to obtain maximum age of overlying tills. Coll 1976 and subm by L Adrielsson, Dept Quaternary Geol, Univ Lund. *Comment*: outer 23% of shells removed by acid leaching. (3 1-day counts.)

B. Norway

Varanger Peninsula Series II

Sediment from lakes on Varanger Peninsula, N Norway. Dated as complement to Varanger Peninsula series (R, 1974, v 16, p 317-318). For other dates from area, see also Angsnes series (R, 1977, v 19, p 431-432). Coll 1976 and subm by B Malmström and O Palmér, Dept Phys Geog, Univ Lund. Samples represent transition from minerogenic to organogenic deposits. Depths are below sediment-water interface. Pretreated with HCl. All samples undersized; diluted. Amount of CO_2 from sample is given in *Comments* below as "% sample".

Lu-1254. Bergebyvand 1, 272 to 280cm **10,420 ± 160**
$\delta^{13}C = -19.2‰$

Light greygreen muddy clay. *Comment*: 55% sample.

Lu-1258. Bergebyvand 5, 275 to 280cm **10,590 ± 145**
$\delta^{13}C = -19.6‰$

Light greengray muddy clay. *Comment*: 51% sample. (3 1-day counts.)

Lu-1255. Holmfjeldvand, 265 to 270 cm **9200 ± 100**
$\delta^{13}C = -20.8‰$

Graygreen clay gyttja. *Comment*: 86% sample.

Lu-1256. Østrevand 3, 200 to 205cm **11,640 ± 130**
$\delta^{13}C = -24.1‰$

Light graygreen muddy clay. *Comment*: 69% sample. (3 1-day counts.)

Lu-1257. Østrevand 4-lb, 149 to 157cm **11,550 ± 140**
$\delta^{13}C = -25.2‰$

Light graygreen muddy clay. *Comment*: 62% sample. (3 1-day counts.)

Lu-1259. Stjernevand, 197 to 209cm **9370 ± 150**
$\delta^{13}C = -22.6‰$

Clayey gyttja. *Comment*: 54% sample.

Sotra series (I)

Sediment from small lakes on Sotra I., Hordaland, W Norway. Coll 1976 and subm by K Krzywinski, Hist Mus, Univ Bergen. Dated as part of study of sea-level changes in area. All samples pretreated with HCl and then separated in acid-precipitated part of NaOH-soluble fraction and insoluble residue (called soluble and residue, respectively, below).

Lu-1353A. Sotra no. 5815, soluble **9290 ± 95**
$\delta^{13}C = -26.7‰$

Lacustrine dy from Lommatjønn (60° 15′ N, 5° 02′ E) from isolation contact formed during Pre-Boreal regression. Threshold alt +11.4m.

Lu-1353. Sotra no 5815, residue **9340 ± 95**
$\delta^{13}C = -27.9‰$

Lu-1354A. Sotra no. 5830, soluble **7400 ± 100**
$\delta^{13}C = -28.3‰$

Lacustrine dy from Lommatjønn from transition to brackish gyttja deposited during Tapes-transgression. *Comment*: sample undersized; diluted; 68% sample.

Lu-1354. Sotra no. 5830, residue **7380 ± 80**
$\delta^{13}C = -29.6‰$

Lu-1355A. Sotra no. 5884-5, soluble **5490 ± 65**
$\delta^{13}C = -30.0‰$

Lacustrine gyttja from Lommatjønn from isolation contact formed during regression following Tapes-transgression.

Lu-1355. Sotra no. 5884-5, residue **5400 ± 65**
$\delta^{13}C = -31.0‰$

Comment: sample undersized; diluted; 75% sample. (3 1-day counts.)

Lu-1358A. Sotra no. 5940-1, soluble **4260 ± 60**

$\delta^{13}C = -26.6‰$

Lacustrine dy from Midtjønn (60° 14′ N, 5° 02′ E) from isolation contact formed during regression following Tapes-transgression. Threshold alt +7.9m.

Lu-1357A. Sotra no. 6109, soluble **9150 ± 100**

$\delta^{13}C = -24.5‰$

Lacustrine dy from Klokkarvatnet (60° 15′ N, 5° 02′ E) from isolation contact formed during regression before Tapes-transgression. Threshold alt +6.9m. *Comment*: sample undersized; diluted; 89% sample.

Lu-1356A. Sotra no. 6199, soluble **3990 ± 60**

$\delta^{13}C = -29.0‰$

Lacustrine dy from Klokkarvatnet from isolation contact formed after Tapes-transgression.

Lu-1359A. Sotra no. 6281, soluble **4340 ± 60**

$\delta^{13}C = -27.3‰$

Lacustrine dy from Kaldavatn (60° 16′ N, 4° 58′ E) from isolation contact formed during regression following Tapes-transgression. Threshold alt +7.55m.

Lu-1360A. Sotra no. 6358, soluble **8060 ± 85**

$\delta^{13}C = -25.8‰$

Lacustrine dy from Kaldavatn from ingression contact formed during Tapes-transgression.

Lu-1361A. Sotra no. 6368, soluble **9340 ± 90**

$\delta^{13}C = -24.7‰$

Lacustrine dy from Kaldavatn from isolation contact formed during Pre-Boreal regression.

C. Greenland

East Greenland series (VI)

Bivalve shells from emerged marine sediments, and lake sediment samples from Hochstetter Forland, Shannon Ö, and Ardencaple Fjord, NE Greenland. Coll by the Swedish-Danish Expedition of 1976 (C Hjort, L Adrielsson, H Bruch, and J Mikaelsson) and subm as part of study of glaciation chronology, shore-line displacement, and vegetation history. For other East Greenland dates from this lab, see R, 1972, v 14, p 388-390; 1973, v 15, p 504-507; 1974, v 16, p 319-322; 1975, v 17, p 184-187; 1976, v 18, p 301-303. According to Hjort (1973) a sea correction of −550 yr should be applied to shell dates, below.

Lu-1288. Åsen **39,000 $^{+2400}_{-1800}$**

$\delta^{13}C = +1.1‰$

Shell fragments (*Mya truncata, Hiatella arctica*) from beach gravel overlying laminated silt and sand deposited in front of and dating

terminal moraine on S Hochstetter Forland (75° 13′ N, 19° 55′ W). Alt 90m. *Comment*: outer 40% of shells removed by acid leaching. (3 1-day counts.)

Lu-1289. Mönstedhus **9190 ± 90**

$\delta^{13}C = -4.7‰$

Shells (*Portlandia arctica*) from silt at 22m, underlying delta built up to 53m near Mönstedhus, N Hochstetter Forland (75° 43′ N, 19° 40′ W). Dates deglaciation of area. *Comment*: no surface leaching; small sample. Shells well preserved with periostracum intact.

Lu-1290. Ailsa, Sample 1 **13,970 ± 200**

$\delta^{13}C = -23.2‰$

Clay gyttja from lowermost part of sediment core from lake near Ailsa, S Hochstetter Forland (75° 19′ N, 19° 40′ W). Above Late Weichselian marine limit. *Comment*: pretreated with HCl. Undersized; diluted; 53% sample. (3 1-day counts.)

Lu-1291. Agnetesöelven, Lake A, Sample 1 **8900 ± 110**

$\delta^{13}C = -24.5‰$

Clay gyttja from lowermost part of sediment core from lake S of Agnetesöelven, N Hochstetter Forland (75° 35′ N, 19° 50′ W). Dates deglaciation of area. *Comment*: pretreated with HCl. Undersized; diluted; 71% sample.

Lu-1292. Ardencaple Fjord 1 **7450 ± 75**

$\delta^{13}C = +0.4‰$

Shell fragments (*Mya truncata, Hiatella arctica*) from base of 20m thick silt deposit 6km NW of Kap Buch, Ardencaple Fjord (75° 12′ N, 20° 35′ W). Coll at 3m. In same level were also some shells of *Portlandia arctica*. *Comment*: outer 26% removed by acid leaching.

Lu-1298. Kap Tramnitz **19,000 ± 190**

$\delta^{13}C = +0.8‰$

Shell fragments (*Hiatella arctica*) from silt deposit underlying beach-ridge at 55m ca 3km NE of Kap Tramnitz, S Shannon Ö (75° 02′ N, 18° 52′ W). *Comment*: outer 56% removed by acid leaching. (3 1-day counts.)

Lu-1299. Peters Bugt **>42,400**

$\delta^{13}C = +0.7‰$

Shell fragments (*Mya truncata*) from laminated silt and sand underlying terminal moraine parallel to but younger than that one dated by Lu-1288, above. Coll at ca 45m, Peters Bugt, S Hochstetter Forland (75° 18′ N, 20° 00′ W). *Comment*: outer 71% removed by acid leaching. (3 1-day counts.)

Lu-1300:1. Hochstetter east 1, inner fraction **9470 ± 90**

$\delta^{13}C = +0.3‰$

Thick shells (*Hiatella arctica*) from silt at 13m, SE Hochstetter Forland (75° 17′ N, 19° 28′ W). *Comment*: inner fraction (29% of shells) was used.

Lu-1300:2. Hochstetter east 1, outer fraction **9520 ± 90**

$\delta^{13}C = +0.7‰$

Outer fraction of shells used for Lu-1300:1. *Comment*: outer fraction was 32% of shells; outermost 39% removed by acid leaching.

Lu-1301. Peters Bugt Lake, Sample 1 **12,960 ± 235**

$\delta^{13}C = -22.3‰$

Clay gyttja from lowermost part of sediment core from lake at Peters Bugt, S Hochstetter Forland (75° 19′ N, 20° 03′ W). *Comment*: pretreated with HCl. Small sample; diluted; 40% sample. (3 1-day counts.)

Lu-1302. Hill 150 **$33{,}500\ ^{+1550}_{-1300}$**

$\delta^{13}C = +1.2‰$

Shells (*Hiatella arctica*) from silt on top of 150m high hill. Highest deposit of its kind on S Hochstetter Forland (75° 15′ N, 19° 48′ W). *Comment*: outer 53% removed by acid leaching.

Lu-1303. Kildedalen **8930 ± 90**

$\delta^{13}C = \pm 0.0‰$

Thin shell fragments (*Mya truncata*) from deltaic sand overlying silt. Coll at 20 to 25m but probably dates or closely postdates local marine limit at 50m and deglaciation of outermost Kildedalen, Ardencaple Fjord (75° 15′ N, 20° 55′ W). *Comment*: outer 53% removed by acid leaching.

Lu-1304. Agnetesöelven, Lake B, Sample 1 **7630 ± 120**

$\delta^{13}C = -27.2‰$

Clay gyttja from lowermost part of sediment core from lake S of Agnetesöelven, N Hochstetter Forland (75° 34′ N, 19° 53′ W). *Comment*: pretreated with HCl. Small sample; diluted; 45% sample. (3 1-day counts.)

Lu-1384. Nanok **9810 ± 95**

$\delta^{13}C = +1.0‰$

Large thick shells (*Mya truncata*) from silt at 30m 3km W of Nanok, S Hochstetter Forland (75° 10′ N, 19° 51′ W). Postdates part of same terminal moraine as predates by Lu-1299, above. *Comment*: outer 57% removed by acid leaching.

Lu-1385. Northern Shannon **40,200 $^{+1800}_{-1500}$**

$\delta^{13}C = +1.1‰$

Shells (*Hiatella arctica*) coll at 39m on silt-covered hill reaching 48m, ca 4.5km N of pt 54m on N Shannon Ö (75° 18′ N, 18° 32′ W). *Comment*: outer 52% removed by acid leaching. (4 1-day counts.)

Lu-1386. Hochstetter east 2 **9400 ± 90**

$\delta^{13}C = +0.8‰$

Shells (*Mya truncata*) from sand overlying silt at 30m, SE Hochstetter Forland (75° 19′ N, 19° 25′ W). *Comment*: outer 57% removed by acid leaching.

Lu-1387. Hochstetter east 3 **35,400 $^{+1200}_{-1050}$**

$\delta^{13}C = +0.3‰$

Shell fragments (*Mya truncata, Hiatella arctica*) from silt at 60 to 65m, SE Hochstetter Forland (75° 27′ N, 19° 23′ W). *Comment*: outer 40% removed by acid leaching. (4 1-day counts.)

Lu-1388. Hochstetter east 4 **>43,500**

$\delta^{13}C = +0.1‰$

Shells (*Hiatella arctica*) from sand overlain by till bed, SE Hochstetter Forland (75° 17′ N, 19° 27′ W). *Comment*: outer 48% removed by acid leaching. (4 1-day counts.)

Lu-1389. Kap Copeland **9370 ± 90**

$\delta^{13}C = +0.8‰$

Shells (*Hiatella arctica*) from silt reaching 41m at Kap Copeland, N Shannon Ö (75° 20′ N, 18° 55′ W). Postdating ice moving S along Shannon Sund. *Comment*: outer 64% removed by acid leaching.

Lu-1390. Ardencaple Fjord 2 **8570 ± 85**

$\delta^{13}C = +0.7‰$

Large shells (*Mya truncata*) from sandy silt at 30 to 40m, 11km NW of Kap Buch, Ardencaple Fjord (75° 13′ N, 20° 40′ W). Local marine limit 50m. *Comment*: outer 60% removed by acid leaching.

D. Finland

Merijänjärvi series

Eriophorum-Sphagnum peat from bog situated beside Lake Merijänjärvi, Ii parish, Oulu province, Finland (65° 17′ 30″ N, 25° 30′ 30″ E). Alt 30m. Coll 1975 and subm by M Hjelmroos, Dept Quaternary Geol, Univ Lund. Dating is part of study on vegetational development and human influence in area. Depths given are below bog surface. All samples pretreated with HCl.

Lu-1311. Merijänjärvi, 183 to 193cm **2790 ± 55**

$\delta^{13}C = -26.9‰$

First signs of human influence recorded in pollen diagram.

Lu-1312. Merijänjärvi, 169 to 175cm **2640 ± 55**
$\delta^{13}C = -27.5‰$

First *Picea* maximum; one grain of *Plantago lanceolata*.

Lu-1313. Merijänjärvi, 138 to 142cm **1790 ± 50**
$\delta^{13}C = -26.2‰$

Decrease of *Picea*.

Lu-1314. Merijänjärvi, 110 to 115cm **1770 ± 50**
$\delta^{13}C = -26.6‰$

Maximum of *Urtica*.

Lu-1315. Merijänjärvi, 72 to 78cm **2160 ± 55**
$\delta^{13}C = -26.7‰$

Maximum of heath components.

Lu-1316. Merijänjärvi, 66 to 70cm **2320 ± 55**
$\delta^{13}C = -26.7‰$

Further decrease of *Picea*.

Lu-1317. Merijänjärvi, 25 to 32cm **1430 ± 50**
$\delta^{13}C = -26.0‰$

Rational limit of Cerealia.

Pilpajärvi series

Sediment from Lake Pilpajärvi, Oulu province, Finland (64° 57′ N, 25° 49′ E). Alt 40m. Coll 1976 by M Hjelmroos and C Renaud; subm by M Hjelmroos. Part of same project as Merijänjärvi series, above. Depths given are below sediment surface. Water depth at sampling point ca 5m. All samples pretreated with HCl.

Lu-1369. Pilpajärvi, 194 to 200cm **4000 ± 60**
$\delta^{13}C = -27.2‰$

Clay gyttja. First pollen grains of Cerealia.

Lu-1370. Pilpajärvi, 179 to 187cm **3660 ± 60**
$\delta^{13}C = -28.3‰$

Gyttja. Maximum of herb components.

Lu-1371. Pilpajärvi, 156 to 164cm **3370 ± 55**
$\delta^{13}C = -29.0‰$

Gyttja. Decrease of *Urtica* and Cerealia.

Lu-1372. Pilpajärvi, 130 to 138cm **2420 ± 50**
$\delta^{13}C = -29.1‰$

Gyttja. Empiric limit of Cerealia.

Lu-1318. Kaakonlantto **920 ± 50**
$\delta^{13}C = -26.0‰$

Peat from 22cm below surface in small bog near archaeol excavations of Ylitornio, Tornio Lappland, Finland (66° 13′ N, 23° 46′ E).

Alt 50m. Coll 1975 and subm by M Hjelmroos. Dating is part of study on human settlement history by means of pollen analysis. Sample corresponds to level with earliest occurrence of pollen grains of Cerealia.

Lu-1248. Oravaisensaari **390 ± 70**

$\delta^{13}C = -24.1‰$

Small wood fragments from 45cm below surface on Oravaisensaari I., 8km N of Tornio, Finland (65° 55′ N, 24° 10′ E). Alt 5.9m above Tornio R. Coll 1974 and subm by M Hjelmroos. Sample comes from cultural layer, archaeol dated to Early Middle ages. Dated as part of study on human settlement history in area assoc with pollen analysis.

E. Poland

Lower Vistula valley series (II)

Marine mollusk shells from same stratigraphic level as shells previously dated in this series (R, 1976, v 18, p 303-304). Coll 1976 and subm by E Drozdowski, Inst Geog, Polish Acad Sci, Toruń, Poland. Dated to solve chronologic problem assoc with redeposited mollusk fauna in lower Vistula R valley (Galon, 1934).

Lu-1326. Mala Słońca 1, *Nassa* and *Cardium* **37,400 $^{+2000}_{-1600}$**

$\delta^{13}C = -0.6‰$

Shells (*Nassa reticulata, Cardium edule*) id by C Hjort, from intermorainic sandy-gravelly sediments between 2nd and 3rd morainic strata, 11 to 18m above floodplain, at Mała Słońca (54° 03′ N, 18° 48′ E). *Comment*: outer 43% of shells removed by acid leaching. (4 1-day counts.)

Lu-1327. Mala Słońca 1, thick fragments **>42,300**

$\delta^{13}C = -1.5‰$

Thick unidentifiable bivalve fragments from same sample as Lu-1326. *Comment*: outer 44% removed by acid leaching. (3 1-day counts.)

Lu-1328. Mala Słońca 2, *Nassa reticulata* **40,700 $^{+2650}_{-2000}$**

$\delta^{13}C = -1.0‰$

Shells (*Nassa reticulata*) id by C Hjort, from layer of fine gravel, 6 to 7cm thick, 5m below morainic stratum and ca 20m above floodplain at Mała Słońca. *Comment*: outer 29% removed by acid leaching. (3 1-day counts.)

Lu-1329. Biola Góra **>41,900**

$\delta^{13}C = \pm 0.0‰$

Shells and shell fragments (*Cardium edule, C echinatum, Macoma balthica, Cyprina islandica, Nassa reticulata,* and *Bittium reticulatum*) id by C. Hjort from sandy-gravelly sediments between 2nd and 3rd morainic strata at Biola Góra (53° 57′ N, 18° 55′ E). Shells were coll ca 2 to 8m above flood terrace. *Comment*: outer 28% removed by acid leaching. (3 1-day counts.)

Mammoth bone series

For other mammoth dates, see R, 1976, v 18, p 291-293 and Berglund *et al* (1976).

Lu-1346. Bzianka **14,080 ± 165**

$\delta^{13}C = -20.0‰$

Collagen from bone fragment from skull of *Mammuthus primigenius* from small stream near Bzianka, Rzeszów, S Poland (ca 50° N, 22° E). Coll 1851 by Lozinski; subm by H Kubiak, Inst Systematic and Experimental Zool, Polish Acad Sci, Cracow, Poland. For details about mammoth find, see Hauer (1851), Kulczycki (1955, Pl I), and Kubiak (1965, p 17-18). *Comment*: collagen extracted as described previously (R, 1976, v 18, p 290); no NaOH treatment. Organic carbon content: 3.3%. Sample undersized; diluted; 71% sample. (3 1-day counts.)

Lu-1347. Debica **25,300 ± 500**

$\delta^{13}C = -20.1‰$

Collagen from bone fragment of *Mammuthus primigenius,* id by H Kubiak, from river gravels of Wisłoka R near Dębica, S Poland (50° 10′ N, 21° 30′ E). Coll 1975 by schoolboys; subm by H Kubiak. Preliminary report about find pub by submitter (Kubiak, 1976). *Comment*: collagen extracted in same way as Lu-1346 but including NaOH treatment. Organic carbon content: 5.4%.

II. ARCHAEOLOGIC SAMPLES

Sweden

Ingelstorp series

Charcoal from settlement areas and grave fields at Ingelstorp, Scania. Coll March 1974 to Nov 1976 and subm by M Strömberg, Hist Mus, Univ Lund. Preliminary report pub by submitter (Strömberg, 1977). For other dates from Ingelstorp, see R, 1976, v 18, p 314; 1977, v 19, p 435-436. All samples pretreated with HCl and NaOH.

Lu-1250. Ingelstorp 10, Sample 11:75-76 **3760 ± 60**

$\delta^{13}C = -24.8‰$

Charcoal from coffin in Grave 2 (1974), Ingelstorp 10 (55° 25′ N, 14° 03′ E). Assoc with flint objects. *Comment* (MS): date as expected.

Lu-1293. Ingelstorp 13, Sample 13:75-76 **2830 ± 55**

$\delta^{13}C = -23.4‰$

Charcoal from Hearth No. 24, Ingelstorp 13 (55° 25° N, 14° 02′ E). Assoc with pottery. *Comment* (MS): on new map property designation changed to Ingelstorp 110:1.

Lu-1294. Ingelstorp 13, Sample 14:75-76 **2890 ± 55**

$\delta^{13}C = -23.9‰$

Charcoal from Hearth No. 6, Ingelstorp 13.

Lu-1295. Ingelstorp 13, Sample 15:75-76 **2920 ± 55**

$\delta^{13}C = -23.3‰$

Charcoal from Hearth No. 18, Ingelstorp 13. *Comment* (MS): 3 dates from Ingelstorp 13 agree well mutually and are of expected age judging from archaeol evidence.

Lu-1321. Ingelstorp 32[5], Prov 1:HT76 **3100 ± 60**

$\delta^{13}C = -24.7‰$

Charcoal from pit near Grave 40 (urn grave), Ingelstorp 32[5] (55° 25′ N, 14° 03′ E). Report from study of other Bronze age graves in area pub by submitter (Strömberg, 1975, p 67-69). *Comment* (MS): ca 700 yr older than expected.

Lu-1322. Ingelstorp 32[5], Sample 2:HT76 **4580 ± 60**

$\delta^{13}C = -26.8‰$

Charcoal from fire pit (Grave 41), Ingelstorp 32[5]. *Comment* (MS): expected to be of same age as Lu-1321.

Lu-1323. Ingelstorp 32[5], Sample 3:HT76 **3150 ± 65**

$\delta^{13}C = -24.7‰$

Charcoal from Grave 43 (oak trunk grave), Ingelstorp 32[5]. Assoc with helically ornamented bronze object. *Comments*: sample undersized; diluted; 82% sample (MS): somewhat older than expected.

Lu-1324. Ingelstorp 32[5], Sample 4:HT76 **1980 ± 50**

$\delta^{13}C = -24.0‰$

Charcoal from fire pit (Grave 49), Ingelstorp 32[5]. Assoc with pottery. *Comment* (MS): somewhat younger than expected.

Lu-1325. Ingelstorp 32[5], Sample 5:HT76 **2720 ± 55**

$\delta^{13}C = -24.0‰$

Charcoal from fire pit (Grave 54), Ingelstorp 32[5]. Assoc with pottery. *Comment* (MS): ca 400 yr older than expected.

Lu-1348. Ingelstorp 32[5], Sample 6:HT76 **3180 ± 60**

$\delta^{13}C = -23.6‰$

Charcoal from stratum above Grave 63. Assoc with earthenware pots. *Comments*: only mild pretreatment with NaOH and HCl. Sample undersized; diluted; 92% sample. (MS): date is reasonable for this Late Neolithic grave, presence of which may explain unexpected old dates for some samples from Ingelstorp 32[5]. Samples were originally all expected to be from Late Bronze age or Early Iron age.

Lu-1249. Ingelstorp 32[8], Sample 10:75-76 **3010 ± 55**

$\delta^{13}C = -26.0‰$

Charcoal from Grave 32 (cremation grave), Ingelstorp 32[8] (55° 25′ N, 14° 03′ E). Assoc with pottery. *Comment* (MS): date much older than expected.

Lu-1251. Ingelstorp 32[8], Sample 12:75-76 **1910 ± 50**

$\delta^{13}C = -24.6‰$

Charcoal (25%) and soot (75%) from fire pit (Grave 34:1975), Ingelstorp 32[8]. Assoc with earthenware pots and spindle whorl. *Comment* (MS): date agrees with assoc finds.

Lu-1349. Hagestad 98[1]A, Sample 7:1976 **4700 ± 65**

$\delta^{13}C = -27.0‰$

Charred food remains from inside of earthenware pot (No. 18) from Early Neolithic TRB culture settlement at Hagestad 98[1]A, Löderup parish, Scania (55° 24′ N, 14° 11′ E). Coll 1968 and subm by M Strömberg. Assoc with flint objects and other pottery. No pretreatment due to small sample size. *Comment* (MS): date is reasonable.

Lu-1365. Simris 2[3] **1960 ± 50**

$\delta^{13}C = -27.2‰$

Resin from Grave 1972:2 (inhumation burial), Simris 2[3], Simris parish, SE Scania (55° 32′ N, 14° 19′ E). Coll 1972 and subm by B Stjernquist, Hist Mus, Univ Lund. For details about settlement sites and grave fields in Simris area, see Stjernquist (1955, 1961, 1965). Other samples from Simris were dated by Uppsala lab (R, 1959, v 1, p 98; 1960, v 2, p 125). Pretreated with HCl. *Comment* (BS): somewhat older than expected.

Brunn series

Seal bones, id by E Iregren, from Pitted Ware site Brunn, Ösmo parish, Södermanland (58° 55′ 50″ N, 17° 47′ 50″ E). Coll 1928 by I Schnell; subm by S Welinder, Univ Oldsaksamling, Oslo. All samples probably from Test Sq H18 (Schnell, 1930). Collagen extracted as described previously (R, 1976, v 18, p 290), including NaOH treatment.

Lu-1282. Brunn 1 **4640 ± 65**

$\delta^{13}C = -15.6‰$

Collagen from ribs of seal. *Comment*: organic carbon content: 4.0%.

Lu-1283. Brunn 2 **4610 ± 65**

$\delta^{13}C = -15.8‰$

Collagen from ribs of seal. *Comment*: organic carbon content: 4.1%.

Lu-1284. Brunn 3 **4650 ± 65**

$\delta^{13}C = -15.5‰$

Collagen from ribs of seal. *Comment*: organic carbon content: 3.5%.

Korsnäs series

Bones from Sq No. 106 579 on Pitted Ware site Korsnäs, Grödinge parish, Södermanland (59° 09′ 20″ N, 17° 48′ 30″ E). Coll 1970 by E Baudou; subm by S Welinder. Collagen extracted in same way as for Brunn series, above. Bone id by K Sörensen, Zool Mus, Copenhagen.

Lu-1285. Korsnäs 1 **4190 ± 60**

$\delta^{13}C = -20.8‰$

Collagen from bone of terrestrial animals from Layer I, 0 to 10cm below surface. *Comment*: organic carbon content: 3.4%.

Lu-1286. Korsnäs 2 **4270 ± 60**

$\delta^{13}C = -19.5‰$

Collagen from bone of terrestrial animals and seal (*Phoca groenlandica*) from Layer II, 10 to 20cm below surface. *Comment*: organic carbon content: 3.4%.

Lu-1287. Korsnäs 3 **4560 ± 60**

$\delta^{13}C = -17.9‰$

Collagen from bone, mainly of seal, from Layer III, 20 to 30cm below surface. *Comment*: organic carbon content: 3.7%.

General Comment for Brunn and Korsnäs series: dates on collagen from marine animals must be corrected because of apparent ^{14}C age of such animals during their lifetime. Size of correction is not yet known for seals in this area, but −200 to −400 yr may be a fair estimate of expected range.

Hjulberga series

Charcoal and carbonized hazel-nut shells from Early Neolithic TRB site Hjulberga 1, Eker parish, Närke (59° 21′ N, 15° 07′ E). Coll 1976-77 and subm by S Welinder.

Lu-1319. Hjulberga 1:A, Sample 7 **4830 ± 65**

$\delta^{13}C = -22.2‰$

Carbonized hazel-nut shells coll from excavated trench. *Comment*: pretreated with HCl and NaOH.

Lu-1320. Hjulberga 1:A, Sample 8 **2460 ± 95**

$\delta^{13}C = -24.8‰$

Charcoal and bark of *Pinus*, id by T Bartholin, from Pit W18, containing also main part of Sample 7, above. *Comment*: no pretreatment; sample undersized; diluted; 33% sample. (3 1-day counts.)

Lu-1434. Hjulberga 1:A, Sample 9 **4340 ± 80**

$\delta^{13}C = -22.4‰$

Carbonized hazel-nut shells sieved from large sample from basal part of culture layer. *Comment*: no pretreatment; sample undersized; diluted; 48% sample. (3 1-day counts.)

General Comment (SW): Lu-1320 much too late like 3 other dates on charcoal from same site dated at Stockholm lab: St 5396, 1985 ± 100; St 5397, 3370 ± 100; St 5398, 590 ± 105. Excavations unpub (cf Bagge, 1949).

Lu-1350. Nordansjö 1:5 **1060 ± 135**

$\delta^{13}C = -24.9‰$

Wood fragments (*Betula* sp) id by T Bartholin from hole for handle in iron-ax exposed by wave action at shore of Lake Malgomaj, Site Raä 756, Nordansjö 1:5, Vilhelmina parish, Lappland (64° 42′ N, 16° 22′ E; Sw Grid Ref x7177,2; y1527,0). Shore erosion caused by storage-capacity regulation of lake. Coll 1975 by B Eriksson; subm by A Huggert, Västerbottens Mus, Umeå. *Comment*: no pretreatment; very small sample; diluted; 15% sample. (4 1-day counts.)

Karlsbacka series

Charcoal from Site Raä 572, Karlsbacka 1:2, Vilhelmina parish, Lappland (64° 41′ N, 16° 27′ E; Sw Grid Ref x7175,8; y1530,6). Coll 1976 by K Wijkander; subm by A Huggert.

Lu-1351. Karlsbacka 1:2, Sample 1 **160 ± 45**

$\delta^{13}C = -25.5‰$

Charcoal from hearth above layer of cracked stones. *Comment*: no pretreatment; small sample.

Lu-1352. Karlsbacka 1:2, Sample 2 **220 ± 70**

$\delta^{13}C = -26.4‰$

Charcoal from upper part of rust-colored soil below layer of cracked stones. *Comment*: no pretreatment; undersized; diluted; 51% sample.

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MARINE RESOURCES RESEARCH INSTITUTE RADIOCARBON DATES II*

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Samples reported in this date list are primarily geologic specimens collected from coastal locations in South Carolina and Florida. Sample material was predominantly shells, with emphasis on single shell dates rather than multiple shell dates. Archaeologic samples from sites either directly above or adjacent to the geologic sampling location were collected whenever possible to provide an upper time limit on the shell deposits.

The main goal of the work was to illustrate the wide range of ages encountered in barrier island shell deposits due to the mixing and reworking of beach deposits in general. Apparently shells older than the barrier island are frequently incorporated into shell deposits at the time of island formation. As a result, many Holocene beach deposits contain shells ranging in age from 1000 yr to infinite with respect to ^{14}C.

It is also possible that a portion of the observed range in ages, perhaps a few hundred years, may be attributable to species differences, *eg* isotopic fractionation. However, due to a relative lack of some species, *eg Doscina discus,* as compared to *Mercenaria* sp, it is not possible to determine the influence of isotopic fractionation at this point. If species-controlled fractionation is, in fact, significant in age variations, it may be possible to detect as more data are gathered.

Analytic procedures were as previously reported (R, 1976, v 18, p 202-204). Whenever feasible, large samples were divided into two aliquots for duplicate dating.

Age calculations were based on a ^{14}C half-life of 5570 years, using 0.95 NBS oxalic acid as the modern standard. Each sample was counted at least 2000 min, with calculations based on sample, standard, and background statistics to $\pm 1\sigma$. All $\delta^{13}C$ values were estimated, *ie,* 0‰ for carbonate and −25‰ for wood samples. Ages were calculated with the equation of Williams, Oeschger, and Kinney (1969).

ACKNOWLEDGMENTS

Field work was conducted primarily by F W Stapor, Jr. Thanks are extended to M A Carson and M A Schramm for typing the manuscript.

A. South Carolina Coastal Samples

Crow's Island

Samples coll from large shell midden on Crow's I. (32° 50′ N, 79° 45′ W). Subm by R L Stephenson, Inst Archaeol & Anthropol, Columbia, South Carolina.

* Contribution No. 151 from the South Carolina Marine Resources Center.

MRRI-25.	Shell (*Mercenaria* sp)	3030 ± 380
MRRI-26.	Shell (*Mercenaria* sp)	1780 ± 160

Fripp Island

Samples coll from a canal on Fripp I. (32° 19′ N, 80° 29′ W).

MRRI-33.	3 shells (*Anadara brasiliana*)	1860 ± 190
MRRI-35.	Shell (*Mercenaria* sp)	1000 ± 90
MRRI-36.	4 shells (*A brasiliana*)	1040 ± 100
MRRI-37.	7 shells (*Anadara* sp)	2360 ± 100
MRRI-38.	12 shells (*Anadara* sp)	3050 ± 110

Edisto Beach

Samples coll at a series of sites on Edisto Beach, from shell bearing quartz sand, 1 to 2m below MSL.

Series A. Edisto Beach

(32° 29′ 25″ N, 80° 19′ 30″ W)

MRRI-56.	Shell (*Mercenaria* sp)	1610 ± 120
MRRI-57.	Shell (*Busycon carica*)	1620 ± 90
MRRI-59.	Shell (*Anadara* sp)	26,700 ± 1110
MRRI-60.	Shell (*Mercenaria* sp)	2450 ± 160

Series B. Edisto Beach

(32° 29′ 20″ N, 80° 19′ 50″ W)

MRRI-47.	Shell (*Mercenaria* sp)	3620 ± 100
MRRI-48.	Replicate of MRRI-47	4460 ± 280
MRRI-49.	Shell (*Mercenaria* sp)	3000 ± 210
MRRI-50.	Replicate of MRRI-49	2310 ± 90
MRRI-52.	Replicate of MRRI-47	3090 ± 80
MRRI-54.	Replicate of MRRI-47	3810 ± 100

Series C. Edisto Beach

(32° 29′ 15″ N, 80° 20′ 05″ W)

MRRI-53.	Shell (*Mercenaria* sp)	2220 ± 80
MRRI-55.	Shell (*Mercenaria* sp)	2300 ± 80
MRRI-58.	Shell (*Mercenaria* sp)	2320 ± 90
MRRI-61.	Shell (*Mercenaria* sp)	4600 ± 190
MRRI-62.	Replicate of MRRI-61	4130 ± 160

Series D. Edisto Beach

(32° 29′ 23″ N, 80° 20′ 30″ W)

MRRI-41.	Shell (*A brasiliana*)	24,140 ± 1670
MRRI-42.	Shell (*A brasiliana*)	1490 ± 150
MRRI-43.	Shell (*A brasiliana*)	22,780 ± 1410
MRRI-44.	Shell (*A brasiliana*)	1170 ± 140
MRRI-45.	Shell (*A brasiliana*)	1590 ± 140
MRRI-46.	Shell (*A brasiliana*)	>45,000

Eddingsville Beach

Samples coll at Eddingsville Beach (32° 31′ N, 80° 16′ W). Samples washed ashore from submarine exposure ca 400m offshore, 4 to 5m below MSL.

MRRI-63.	Reef (*Dodecaceria* sp)	2080 ± 100
MRRI-64.	Replicate of MRRI-63	2060 ± 100
MRRI-77.	Reef (*Dodecaceria* sp) 2cm above substrate	2640 ± 110
MRRI-76.	Reef (*Dodecaceria* sp) 3cm above substrate	2550 ± 170
MRRI-78.	Reef (*Dodecaceria* sp) 7cm above substrate	2130 ± 170
MRRI-79.	Replicate of MRRI-78	1900 ± 80
MRRI-75.	Reef (*Dodecaceria* sp) 9cm above substrate	2360 ± 100
MRRI-65.	Reef (*Dodecaceria* sp) 10cm above substrate	2740 ± 140
MRRI-66.	Replicate of MRRI-65	2450 ± 90
MRRI-69.	Reef (*Dodecaceria* sp) 20cm above substrate	2260 ± 100
MRRI-70.	Replicate of MRRI-69	1860 ± 80
MRRI-67.	Reef (*Dodecaceria* sp) 40cm above substrate	1370 ± 80
MRRI-68.	Replicate of MRRI-67	1310 ± 90

Kiawah Island

Samples coll at 2 construction sites on Kiawah I. from shell bearing quartz sand, 1 to 2m below MSL.

Series I. Kiawah I.

(32° 35′ 28″ N, 80° 07′ 38″ W)

MRRI-82.	Shell (*Polinices duplicatus*)	1080 ± 90
MRRI-84.	Shell (*A brasiliana*)	3150 ± 320
MRRI-85.	Shell (*B carica*)	940 ± 80
MRRI-87.	Shell (*B carica*)	1070 ± 80
MRRI-90.	Shell (*A brasiliana*)	1510 ± 230
MRRI-91.	Shell (*B carica*)	1810 ± 160
MRRI-92.	Shell (*B carica*)	1200 ± 120
MRRI-93.	Shell (*B carica*)	990 ± 70
MRRI-94.	Shell (*B carica*)	970 ± 90
MRRI-95.	Shell (*B carica*)	1230 ± 120

Series J. Kiawah I.

(32° 36′ 33″ N, 80° 03′ 20″ W)

MRRI-80.	Shell (*A brasiliana*)	1830 ± 140
MRRI-81.	Shell (*A brasiliana*)	1700 ± 100
MRRI-83.	Shell (*P duplicatus*)	1780 ± 180
MRRI-86.	Shell (*B carica*)	830 ± 90
MRRI-96.	Shell (*Doscina discus*)	1210 ± 120
MRRI-97.	Shell (*Dinocardium robustum*)	820 ± 70
MRRI-98.	Shell (*Oliva sayana*)	1420 ± 100

Ft Johnson

Samples coll from archaeol site (32° 45′ N, 79° 54′ W) at Fort Johnson. Subm by R L Stephenson.

MRRI-88.	Shell (*Crassostrea virginica*)	2130 ± 100
MRRI-89.	Shell (*C virginica*)	2100 ± 60

B. Florida Coastal Samples

Samples coll at Northwest Cape Sable (25° 14′ N, 81° 10′ W), from shell bearing carbonate sand, 0 to 1m below MSL.

MRRI-27. Wood (*Avicennia germinans*). 350 ± 180

Comment: id 1975 by P B Tomlinson, Harvard Univ.

MRRI-28. Replicate of MRRI-27 260 ± 150

MRRI-128. Replicate of MRRI-27 280 ± 120

MRRI-129. Replicate of MRRI-27 240 ± 70

MRRI-34. Shell (*Mercenaria* sp) 1800 ± 80

Comment: 2 aliquots of this shell were dated by Univ Miami, UM-457 and -458 at 1915 ± 85 and 1790 ± 70, respectively (J J Stipp, written commun).

MRRI-39. Replicate of MRRI-34 1790 ± 100

Samples coll at East Cape Sable (25° 07′ N, 81° 05′ W).

1. Archaeologic samples coll from shell midden, 0 to 1m below MSL.

MRRI-71. Shell (*Mercenaria* sp) 1880 ± 100

MRRI-72. Shell (*Mercenaria* sp) 2480 ± 90

MRRI-107. Shell (*Mercenaria* sp) 1810 ± 100

MRRI-109. Shell (*Mercenaria* sp) 1200 ± 70

MRRI-110. Shell (*Mercenaria* sp) 1890 ± 70

MRRI-111. Shell (*Noetia ponderosa*) 2280 ± 80

MRRI-112. Shell (*N ponderosa*) 2300 ± 100

MRRI-113. Shell (*Mercenaria* sp) 1880 ± 70

MRRI-114. Shell (*N ponderosa*) 2000 ± 80

MRRI-116. Shell (*N ponderosa*) 2740 ± 120

MRRI-117. Shell (*Mercenaria sp*) 2380 ± 70

MRRI-118. Shell (*N ponderosa*) 2910 ± 170

2. Geologic samples coll from shell bearing carbonate sand, approx MSL.

MRRI-73. Shell (*Anadara* sp) 2250 ± 110

MRRI-74. Shell (*Anadara* sp) 2180 ± 70

MRRI-99. Shell (*N ponderosa*) 1820 ± 110

MRRI-105. Shell (*N ponderosa*) 2620 ± 110

MRRI-108. Shell (*N ponderosa*) 3030 ± 130

MRRI-115. Shell (*N ponderosa*) 3450 ± 200

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[RADIOCARBON, VOL. 20, No. 3, 1978, P. 441-448]

TARTU RADIOCARBON DATES VII

ARVI LIIVA, ILPO EKMAN and TOIVO RINNE

Institute of Zoology and Botany, Academy of Sciences, Estonian SSR
Institute of Geology, Karelian Branch of Academy of Sciences, USSR

The present list contains dates of geologic samples from the southern part of the Karelian ASSR and partly from the northwest Leningrad Region, USSR, made in 1969-1975.

Measurement of the activity of ^{14}C was performed by liquid scintillation with the use of benzene. All dated samples were measured in parallel on two single-channel units. Radiocarbon dates have been calculated using 5568 ± 30 as the half life of ^{14}C, with 1950 as the reference year. $^{13}C/^{12}C$ measurements have not been made and results not corrected for ^{13}C fractionation.

Karelian ASSR

TA-487. Golikovka **43,900 ± 900**

Wood peat buried by moraines from excavation on SW outskirts of Petrozavodsk, 500m S of RR Sta Golikovka. Alt of peat layer ca 118m. Sample coll from 170 to 190cm depth.

Pollen analysis by A Kolkanen of a peat sample indicates presence of pine forests with admixture of birch and permanent presence of broad-leaved tree species (oak, elm, hornbeam) and hazel. *Comment*: date agrees with time of climatic optimum of Second Late Pleistocene of inter-Glacial period (mid-Valdai). Sample coll and subm 1972 by A Liiva and I Ekman.

Uuksunlahti series

Samples coll from excavation on terrace of Lake Ancylus, surface alt 18 to 21m, on SE shore of Uuksunlahti Bay of Lake Ladoga 2km SE of Ala-Uuksu, Pitkäranta Dist. Pollen analysis by A Kolkanen, diatom analysis by M Traving. Samples coll and subm 1970-1971 by I Ekman and A Liiva.

TA-411. Uuksunlahti I a **8760 ± 100**

Wood from large sunken tree trunk, from sand layer at 150 to 160cm depth formed in shallow water, according to diatom analysis. Pollen analysis attributes sample to Boreal period (prevalence of pine and birch).

TA-379. Uuksunlahti I b **8170 ± 80**

Well-preserved lake grasses over reeds and sedges from sand layer of Lake Ancylus at 125 to 130cm depth. According to composition of diatoms, grasses developed in period of maximum Ancylus transgression in Ladoga basin.

TA-417. Uuksunlahti I c **7500 ± 90**

Strongly decomposed peat passing over to gyttja. Sample coll from lower layer of peatbog at 65 to 70cm depth.

TA-256. Uuksunlahti I d **4860 ± 80**

Wood (birch), diam ca 6cm. Sample coll from leeward slope of sand dune at 70 to 90cm depth of aeolian sands, which disclosed fine-grained sands of Lake Ancylus.

General Comment: 1st stage of largest aeolian formations in the Holocene started on the boundary of Atlantic and Sub-Boreal periods (ca 4900 to 4700 BP), brought about by the development of Sub-Boreal transgression of Lake Ladoga on its N shore.

TA-362. Uuksunlahti II **2175 ± 120**

Wood from excavation 320km S of Uuksunlahti I profile (nearer to the shore of Ladoga). Sample coll 1970 at 50 to 110cm depth from layered sands covered by embankment of sand and pebble (alt 15 to 16m) of 2nd early-Sub-Atlantic Ladoga transgression. Subm by I Ekman.

Uuksunlahti Series III

Wood and peat from shallow prospecting hole (alt 7 to 9m) 300 to 310m S of Uuksunlahti II profile, ca 200m from present-day scarp of Lake Ladoga. In the outcropping beneath lake sands were 2 layers of peat and wood. According to pollen analysis, subm by M Guman, peat and underlying sands accumulated in 1st half of Sub-Atlantic transgression period.

General Comment: dates confirm existence of a 2nd, later Sub-Atlantic transgression period whose maximum occurred ca 2000 BP (*cf* TA-362). It was preceded by chief, Sub-Boreal, stage of transgression of Lake Ladoga with maximum rise of water level in N part of basin in 3000 to 3100 BP (*cf* TA-354, -355). Samples coll and subm 1970 by I Ekman.

TA-363. Uuksunlahti III a **2280 ± 70**

Peat from depth 36 to 42cm.

TA-364. Uuksunlahti III b **2240 ± 80**

Wood from trunk lying at depth 32 to 40cm.

TA-285. Ristioja **8690 ± 100**

Wood peat from a boring lying at 4km SE of town Pitkäranta. In the profile, layered sands are underlain by 6cm peat overlying sand.

Pollen analysis indicates that accumulation of lower layer of sand and peat proceeded in 1st half of Boreal period, whereas accumulation of upper sand bed took place in 2nd half of Boreal period and ended at beginning of Atlantic period. Deposits of transgressive and regressive stages of development of lake (Lak and Ekman, 1975) were found in profile of lake sands at base of composition of diatoms.

General Comment: samples confirm existence of bay of Lake Ancylus in Ladoga basin of ancient Baltic area (2nd half of Boreal period). Regression of water ended on boundary of Boreal and Atlantic periods. Depth of maximum water level of Ancylus transgression in dist of town Pitkä-

ranta did not exceed 21 to 23m. Sample coll 1969 at 155 to 161cm depth and subm by I Ekman.

TA-587. Heposelkä I **7870 ± 110**

Herbaceous peat from boring 5km SSE of town Pitkäranta; surface alt ca 18m. Sample coll from lower part of peat bed at 265 to 270cm depth from surface. According to pollen analysis by A Kolkanen, sample is attributed to layer formed on boundary of Boreal and Atlantic periods. *Comment*: dates end of regression of Lake Ancylus and transition of lake stage into swamp stage. Sample coll and subm 1973 by H Goryunov and I Ekman.

Heposelkä Series II

Well-preserved organogenous materials from profile 5km SSE of town Pitkäranta, buried under ancient beach barrier. Thickness of organogenous deposits ranges from 85 to 90cm, alt 18.5m. Pollen analysis by A Sarv. Samples coll and subm 1969 to 1970 by I Ekman.

TA-353. Heposelkä II a **5970 ± 80**

Wood and reed peat from 330 to 340cm depth. *Comment*: dates peat accumulation on outskirts of swamp, beginning of whose formation followed regression of Lake Ancylus (*cf* TA-587) on boundary of Boreal and Atlantic periods.

TA-286. Heposelkä II b **4150 ± 90**

Wood peat from 280 to 290cm depth.

TA-354. Heposelkä II c **3070 ± 70**

Peat from uppermost layer of organogenous bed; depth varies from 255 to 260cm. *Comment*: 2nd half of Sub-Boreal period. Dates maximum Ladoga transgression on N shore ca 3000 to 3050 yr BP (Liiva *et al*, 1971; Ekman *et al*, 1975).

TA-355. Heposelkä II d **3245 ± 80**

Wood from tree trunk buried in upper peat bed at 255 to 265cm depth. *Comment*: date confirms maximum Ladoga transgression determined earlier (*cf* TA-354).

Lysinvaara Series I

TA-590. Lysinvaara I **7950 ± 110**

Arboreal-herbaceous peat from paludified lagoon of Lake Ancylus 1.6km NW of mouth of Uuksunjoki R (on outskirts of Ala-Uuksu, Pitkäranta Dist). Alt of peat bed ca 21 to 22m. Sample from lowermost peat horizon at 172 to 177cm depth. Palynologic analysis by A Kolkanen attributes sample to Boreal period (short-lived local prevalence of birch in stands). *Comment*: dates beginning of drying up of lagoon as result of regression of Lake Ancylus. Sample coll 1973 and subm by I Ekman.

Lysinvaara Series II

Peat from excavation 100m E of Lysinvaara I profile on top of beach barrier formed in period of maximum Sub-Boreal Ladoga transgression. Alt of peat ca 19m. According to pollen analysis by A Kolkanen, buried peat was formed in Sub-Boreal period. Sample coll and subm 1973 by I Ekman.

TA-588. Lysinvaara II a **4250 ± 100**

Peat coll from 135 to 140cm depth. *Comment*: dates approach to high level of lake transgression, which was close to its maximum.

TA-694. Lysinvaara II b **3590 ± 80**

Peat coll from 120 to 125cm depth.

TA-589. Lysinvaara II c **3560 ± 60**

Peat coll from 100 to 105cm depth, underlain by sand at 105 to 120cm depth. *Comment*: dates short break in peat accumulation (*cf* TA-694).

TA-695. Lysinvaara II d **3350 ± 80**

Peat from 95 to 100cm depth. *Comment*: date confirms approx maximum of Ladoga transgression.

Uuksunjoki Series I

Buried organic materials from profile of Holocene deposits on left bank of Uuksunjoki R 1km N of estuary and 150 to 200m below RR bridge (Pitkäranta Dist); alt of embankment is 13.5m. Sample coll 1971 and subm by I Ekman.

TA-418. Uuksunjoki I a **5230 ± 70**

Wood from large tree trunk coll from lower layers of delta deposits at 182 to 195cm depth.

General Comment: date confirms lower limit of development of Ladoga transgression on N shore of lake (*cf* TA-256). Date agrees with data obtained by M Saarnisto (1970) concerning beginning of transgresion.

TA-419. Uuksunjoki I b **7300 ± 100**

Wood from a trunk fragment buried in N part of delta deposits at 145 to 155cm depth. *Comment*: date does not agree with result of a pollen-analysis (Sub-Boreal period). Fragment of tree trunk was obviously redeposited from earlier formations.

TA-422. Uuksunjoki I c **2615 ± 70**

Peat with fragments of wood from upper horizon of delta deposits (depth 130 to 135cm). *Comment*: dates end of chief stage of Ladoga transgression, followed, after a break of 200 to 400 yr, by another rise in lake level similar in scope and duration (*cf* TA-362-364).

TA-452. Uuksunjoki II **5215 ± 70**

Fragments of wood from outcropping on bank of Uuksunjoki 80 to 85m downstream from profile of Uuksunjoki I (*cf* TA-422). Samples coll

at 265 to 270cm depth from lower bed of lake deposits. *Comment*: dates initial stage of development of Ladogatransgression on N bank (*cf* TA-418). Samples coll and subm 1971 by I Ekman.

Uuksunjoki Series III

Outcropping on left bank of Uuksunjoki R 25m downstream from profile of Uuksunjoki I (see above). Deposits are similar to outcropping of Uuksunjoki II. Samples coll and subm 1971 by I Ekman.

TA-451. Uuksunjoki III a **2810 ± 80**

Peat from organogenous layer at 220 to 225cm depth in lower reaches of deltaic deposits. Date does not agree with pollen-analytic and radiocarbon data of adjacent profiles (*cf* TA-418, -452). For unknown reasons, age of sample is rejuvenated.

TA-450. Uuksunjoki III b **1710 ± 60**

Wood from tree stub, buried in upper horizon of deltaic deposits at 170 to 185cm depth. Rejuvenation of sample age may be due to contamination by rootlets of present-day trees.

Verkhnyi Konets series

Outcropping on right bank of Megrega R 1.7km SW of estuary of Sambatuksa R, at former Verkhnyi Konets (Upper End) Olonets Dist. Samples coll 1973 and subm by I Ekman.

TA-602. Verkhnyi Konets **4680 ± 100**

Peat from 325 to 330cm depth from lower horizon of peat deposits. *Comment*: dates overgrowth of small lake in middle reaches of Negrea R in Sub-Boreal period, according to A Kolkanen.

TA-603. Verkhnyi Konets II **2940 ± 120**

Peat from 195 to 200cm depth from uppermost horizon of peat deposits. *Comment*: dates end of accumulation of peat as result of maximum level of Ladoga transgression on E bank of Ladoga.

Megrega series

Buried organic formations from profile on right bank of Megrega R, 1.1km NE of bridge in centre of profile of same name, Olonets Dist. Outcropping is within limits of underdeveloped delta (surface alt ca 13m) at time of regresion of Lake Ladoga. Samples coll and subm 1973 by I Ekman. Pollen analysis by A Kolkanen; diatom analysis by H Lak.

TA-604. Megrega I **5510 ± 120**

Wood from large alder stump, buried at 320 to 340cm depth in zone of contact with underlying aleurite. *Comment*: date confirms short flooding of depression in Megrega R valley in 2nd half of Atlantic period.

TA-605. Megrega II **4950 ± 120**

Peat from 315 to 320m depth, 2nd half of Atlantic period. *Comment*: dates beginning of peat accumulation in depression in middle reaches of Megrega R.

TA-606. Megrega III **2540 ± 120**
590 BC

Peat from beneath sediments of Ladoga transgression at 250 to 255cm depth.

TA-607. Megrega IV

Wood from a large fragment of tree trunk from 1.3m depth. *Comment*: date apparently confirms existence of late Sub-Boreal stage of transgression in history of development of Lake Ladoga (Ekman *et al*, 1975).

TA-608. Megrega V **1600 ± 150**

Finely scattered organic substance from 105 to 110cm depth. *Comment*: obvious rejuvenation of sample from unknown causes.

Rauda series

Outcropping on steep right bank of Rauda streamlet close to confluence with Obzhanka R, Olonets Dist in its lower reaches. Alt of brow of scarp is 8 to 9 m. Pollen analysis by A Kolkanen; diatom analysis by H Lak. Samples coll and subm 1973 by H Goryunov and I Ekman.

TA-611. Rauda I **4920 ± 100**

Wood from 205 to 220cm depth buried in contact layer between aleurite (Atlantic period) and peaty gyttja (transitional interval of Sub-Boreal period). *Comment*: evidently dates decline of water level and beginning of overgrowth of isolated lake in lower reaches of Obzhanka R.

TA-609. Rauda II **4600 ± 120**

Peat from contact zone with underlying gyttja from 180 to 185cm depth. *Comment*: dates beginning of peat accumulation after disappearance of lake in Sub-Boreal period.

TA-610. Rauda III **1310 ± 80**

Peat from 160 to 165cm depth. Undoubtedly, rejuvenation of sample.

TA-416. Koirinoja **470 ± 80**

Wood coal from quarry in region of lower reaches of Koirinoja R right bank, near bridge, Pitkäranta Dist. Sample coll 1971 from 100 to 110cm depth, subm by A Liiva and I Ekman.

Leningrad Region

TA-517. Burnaya **9450 ± 150**

Peaty gyttja from 122 to 126cm depth of lowest horizon of bog and lake deposits on right bank of Burnaya R, formerly Taipalenjoki, 1.5km

from estuary, Priozyorski Dist. Alt of river bank ca 14m. Gyttja apparently accumulated in isolated lake in Pre-Boreal period, according to pollen-analysis by A Kolkanen. Sample coll and subm 1972 by H Lak and I Ekman.

Vyun Series I

Buried organic formations from outcropping of former lacustrine terrace, surface alt 14m, on right bank of Vyun R, formerly Viisijoki R, 150m below hwy bridge between Zaporozhckoye and Pyatireshye, Priozyorsky Dist. According to literature (Znamenskaya and Ananova, 1967; Znamenskaya *et al*, 1970) lower layer of sediments was formed in Atlantic period in Sub-Boreal while upper layer was formed in Sub-Atlantic period. Sample coll and subm 1972 by H Lak and I Ekman.

TA-488. Vyun I a **7215 ± 160**

Wood from buried aleurite horizon coll at 580 to 590cm depth from alder trunk. Deposits accumulated in shallow lake near mouth of ancient streamlet.

TA-512. Vyun I b **3510 ± 100**

Wood peat from 420 to 425cm depth. *Comment*: dates beginning of peat accumulation after disappearance of lake in lower reaches of Vyun R.

TA-489. Vyun I c **2530 ± 70**

Peaty gyttja and peat from 313 to 318cm depth of contact zone. Acmulation of deposits of Lake Ladoga occurred in bay, a kind of lagoon, isolated from open Ladoga. *Comment*: date confirms maximum of Ladoga transgression in SW part of lake.

Vyun Series II

Buried lacustrine and boggy deposits from profile on left bank of Vyun R 100m upstream from profile of Vyun I.

TA-513. Vyun II a **6570 ± 70**

Fragments of wood from depth of ca 500cm. Dates accumulation of lower layers of profile in Atlantic period of Holocene.

TA-514. Vyun II c **2540 ± 110**

Gyttja from depth of 200 to 210cm depth. Date confirms time when Ladoga transgression reached maximum shore line in SW part of Ladoga (*cf* TA-489).

Syaskie Ryadki series

Buried organic formations from outcropping on right bank of Syas R, on E outskirts of Syakie Ryadki, Volkhov Dist. Alt of bank ca +13m. Samples coll and subm 1972 by H Lak and I Ekman.

TA-515. Syaskie Ryadki I **5025 ± 100**

Peat coll from peat layer at 227 to 232cm depth. *Comment*: dates end cessation of sedimentation in lower reaches of Sääs R at end of Atlantic period, according to pollen analysis by A Kolkanen.

TA-516. Syaskie Ryadki II **4400 ± 70**

Wood from 150 to 160cm depth from upper part of gyttja bed. Date conforms to early Sub-Boreal transgression stage in S part of Ladoga, with smooth and slow rise in level of earth, which preceded maximum rise (Ekman *et al*, 1975).

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TARTU RADIOCARBON DATES VIII

E ILVES

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The present list includes 66 dates of geologic samples determined using the liquid-scintillation ^{14}C metod at the Geobiochemical Laboratory of the Institute of Zoology and Botany, Academy of Sciences, Estonian SSR. Benzene synthesized from wood dating from 1850 ± 10 yr served as a reference standard. All radiocarbon dates have been calculated using 5568 ± 30 yr before AD 1950 as the half-life of ^{14}C.

Senno Bog series

Senno bog lies in Pskov region, 5km SW of Izborsk RR Sta. Sample coll 1970 by E Ilves, A Sarv, and T Rinne; pollen analyses by A Sarv.

TA-460. Senno **1580 ± 60**

Sphagnum peat from depth 60 to 70cm. Pollen Zone SA2.

TA-454. Senno **1970 ± 60**

Phragmites peat from depth 90 to 100cm. Boundary of Pollen Zones SA1 and SA2.

TA-455. Senno **3220 ± 60**

Phragmites peat from depth 160 to 170cm. Sub-Boreal and Sub-Atlantic contact.

TA-456. Senno **3750 ± 70**

Phragmites peat with admixture of lake lime from depth 190 to 200cm. Transition from lake stage to swamp.

TA-461. Senno **5090 ± 70**

Lake lime with mollusk shells from depth 200 to 210cm. Pollen Zone AT2.

TA-457. Senno **6660 ± 90**

Lake lime with mollusk shells from depth 250 to 260cm. Boreal-Atlantic contact.

TA-519. Senno **7300 ± 70**

Lake lime with mollusk shells from depth 260 to 270cm. Boundary of Pollen Zones BO2 and BO1. Empirical boundary of spruce pollen, rational boundary of alder and broad-leaved tree pollen.

TA-458. Senno **9070 ± 90**

Sapropel with admixture of lake lime from depth 280 to 290cm. Pre-Boreal and Boreal contact.

TA-459. Senno **9430 ± 90**

Sapropel with plant remains (reed) and with admixture of sand from depth 290 to 300cm. Dryas and Pre-Boreal contact.

Mõksi Bog series

Mõksi bog lies 3km SW of Kilingi-Nõmme, in SW of Estonian SSR. Sample coll 1970 by E Ilves, A Sarv and T Rinne. Pollen analyses by A Sarv, botanic determination by M Ilomets (Sarv & Ilves, 1976).

TA-404. Mõksi **1730 ± 50**

Sphagnum peat from depth 170 to 180cm. Boundary of Pollen Zones SA1 and SA2.

TA-405. Mõksi **2750 ± 60**

Sphagnum peat from depth 320 to 330cm. Sub-Boreal and Sub-Atlantic contact.

TA-406. Mõksi **2990 ± 60**

Sphagnum peat from depth 390 to 400cm. Pollen Zone SB2. Culmination of spruce pollen.

TA-407. Mõksi **4220 ± 60**

Sphagnum peat from depth 450 to 460cm. Pollen Zone SB1.

TA-408. Mõksi **6100 ± 70**

Peat-like sapropel from depth 570 to 580cm. Pollen Zone AT2. Rational boundary of spruce pollen.

TA-409. Mõksi **8160 ± 80**

Sapropel from depth 630 to 640cm. Boundary of Pollen Zones BO1 and BO2.

Kõivasoo Bog series

Kõivasoo bog is in S of Kõpu peninsula, Hiiumaa Dist, Estonian SSR. Thickness of peat 1.8m, thickness of lake sediments is 1.2m. Sample coll 1972 by E Ilves and A Sarv. Pollen analyses by A Sarv, diatomic analyses by M Pork.

TA-523. Kõivasoo **1060 ± 60**

Sphagnum cuspidatum peat from depth 0 to 10cm.

TA-524. Kõivasoo **2440 ± 60**

Sphagnum peat of transition type from depth 50 to 60cm. Pollen Zone SB2, 10cm above Sub-Boreal and Sub-Atlantic contact.

TA-525. Kõivasoo **4360 ± 60**

Sphagnum peat of fen type from depth 100 to 110cm. Pollen Zone SB1. Rational boundary of spruce pollen.

TA-526. Kõivasoo **4860 ± 70**

Sapropel from depth 180 to 190cm. Atlantic and Sub-Boreal contact. Empirical boundary of spruce pollen. Transition from lake stage to swamp.

TA-527. Kõivasoo **6580 ± 60**

Detritus sapropel from depth 200 to 210cm. Boundary of Pollen Zones AT1 and AT2.

TA-528. Kõivasoo **7440 ± 60**

Lake lime from depth 220 to 230cm. Pollen Zone AT1. Empirical boundary of oak and linden pollen. End of lake lime sedimentation.

TA-529. Kõivasoo **7850 ± 70**

Lake lime from depth 230 to 240cm. Boreal and Atlantic contact.

TA-530. Kõivasoo **8190 ± 90**

Lake lime from depth 270 to 280cm. Boundary of Pollen Zones BO2 and BO1. Rational boundary of alder and elm pollen.

Nigula Bog series

Nigula bog lies at SW border of coastal region of Estonian SSR, 35km S of Pärnu and 10km E of coast of Riga Bay. Bog stretches in N-S direction with length ca 9km and width 3 to 4km. W from longitudinal axis of bog rise 5 islets covered with wood flora. In general, mire sites of raised bog type are characteristic of this bog. Sample coll 1973 by E Ilves and A Sarv from E (Nigula 1) and W (Nigula 2) parts of mire complex. Pollen analysis by A Sarv, botanic determination by M Ilomets (Sarv & Ilves, 1976).

TA-562. Nigula 1 **1240 ± 60**

Complex emerged peat from depth 100 to 110cm. Pollen Zone SA2.

TA-790. Nigula 1 **2150 ± 70**

Complex emerged peat and Sphagnum cuspidatum peat from depth 160 to 170cm. Pollen Zone SA1.

TA-555. Nigula 1 **2820 ± 70**

Sphagnum and Eriophorum vaginatum peat from depth 220 to 230cm. Sub-Boreal and Sub-Atlantic contact.

TA-556. Nigula 1 **3480 ± 80**

Complex emerged peat from depth 280 to 290cm. Pollen Zone SB2.

TA-791. Nigula 1 **3900 ± 70**

Complex emerged peat from depth 320 to 330cm. Pollen Zone SB1.

TA-557. Nigula 1 **3960 ± 80**

Complex emerged peat from depth 340 to 350cm. Pollen Zone SB1.

TA-558. Nigula 1 **4330 ± 60**

Eriophorum-Scheuchzeria peat from depth 460 to 470cm. Pollen Zone SB1. Culmination of oak pollen.

TA-559. Nigula 1 **4720 ± 80**

Sedge-forest peat from depth 470 to 480cm. Atlantic and Sub-Boreal contact.

TA-566. Nigula 1 **6230 ± 70**

Eriophorum and Phragmites peat (contact) from depth 510 to 520cm. Pollen Zone AT2. Culmination of elm pollen.

TA-560. Nigula 1 **7040 ± 80**

Phragmites peat from depth 520 to 530cm. Pollen Zone AT1. Rational boundary of linden pollen.

TA-561. Nigula 1 **7840 ± 80**

Sapropel from depth 580 to 590cm. Boreal and Atlantic contact. Rational boundary of elm pollen.

TA-654. Nigula 2 **580 ± 60**

Woodland and wet pine peat from depth 50 to 60cm. Pollen Zone SA3.

TA-788. Nigula 2 **1100 ± 60**

Sphagnum fuscum peat from depth 120 to 130cm. Boundary of Pollen Zones SA2 and SA3.

TA-655. Nigula 2 **1430 ± 60**

Sphagnum fuscum peat from depth 160 to 170cm. Pollen Zone SA2. Culmination of spruce pollen.

TA-789. Nigula 2 **1420 ± 60**

Sphagnum fuscum peat from depth 200 to 210cm. Pollen Zone SA2.

TA-656. Nigula 2 **2130 ± 70**

Sphagnum fuscum peat from depth 240 to 250cm. Pollen Zone SA1.

TA-657. Nigula 2 **2410 ± 70**

Eriophorum with *Sphagnum fuscum* peat from depth 320 to 330cm. Pollen Zone SA1.

TA-658. Nigula 2 **2550 ± 70**

Eriophorum with *Sphagnum fuscum* peat from depth 350 to 360cm. Pollen Zone SA1.

TA-659. Nigula 2 **2950 ± 70**

Eriophorum with *Sphagnum fuscum* peat from depth 390 to 400cm. Pollen Zone SB2. Culmination of spruce pollen.

TA-660. Nigula 2 **3670 ± 70**

Sphagnum fuscum and *Eriophorum* peat (contact) from depth 430 to 440cm. Boundary of Pollen Zones SB1 and SB2.

TA-661. Nigula 2 **4870 ± 70**

Eriophorum peat from depth 480 to 490cm. Atlantic and Sub-Boreal contact.

TA-692. Nigula 2 **6190 ± 80**

Eriophorum peat from depth 540 to 550cm. Pollen Zone AT2. Rational boundary of spruce.

TA-662. Nigula 2 **6320 ± 80**

Eriophorum with *Sphagnum fuscum* peat from depth 570 to 580cm. Pollen Zone AT1. Culmination of elm pollen. Empirical boundary of spruce pollen.

TA-663. Nigula 2 **7150 ± 80**

Carex-Sphagnum peat from depth 640 to 650cm. Pollen Zone BO2. Rational boundary of alder pollen. Beginning of swamp formation.

TA-665. Nigula 2 **7770 ± 80**

Sapropel from depth 690 to 700cm. Pollen Zone BO2. Beginning of organic deposits.

Zosu Bog series

Zosu bog lies at W part of Luban plain, Latvian SSR, 5km E of Aickuja. Average thickness of organogenic deposits, 3m. Samples coll 1975 and subm by L Medne, botanic analyses by L Medne and A Guzlen, Latvian State Univ.

TA-881. Zosu **1820 ± 60**

Complex peat from depth 10 to 15cm. Pollen Zone SA2.

TA-880. Zosu **2210 ± 60**

Sphagnum medium peat from depth 30 to 35cm. Pollen Zone SA2.

TA-922. Zosu **2470 ± 70**

Sphagnum peat from depth 40 to 45cm. Boundary of Pollen Zones SA1 and SA2.

TA-921A. Zosu **4160 ± 70**

Forest mesotrophic peat from depth 60 to 65cm. Pollen Zone AT2.

TA-921B. Zosu **4570 ± 70**

Wood from depth 60 to 65cm.

TA-879. Zosu **5620 ± 70**

Forest mesotrophic peat from depth 85 to 90cm. Pollen Zone AT2.

TA-897. Zosu **6060 ± 70**

Forest sedge peat from depth 100 to 105cm. Pollen Zone AT2.

TA-898. Zosu **6560 ± 80**

Forest sedge peat from depth 125 to 130cm. Boundary of Pollen Zones AT1 and AT2.

TA-899. Zosu **7100 ± 80**

Forest sedge peat from depth 145 to 150cm. Pollen Zone AT1.

TA-900. Zosu **7450 ± 70**

Forest sedge peat from depth 180 to 185cm. Boreal and Atlantic contact.

TA-923. Zosu **7700 ± 70**

Forest sedge peat from depth 210 to 215cm. Boundary of Pollen Zones BO1 and BO2.

TA-878. Zosu **8160 ± 80**

Forest sedge peat from depth 220 to 225cm. Pollen Zone BO1. Boreal maximum of spruce pollen.

TA-877A. Zosu **8550 ± 80**

Forest sedge peat from depth 260 to 265cm. Pollen Zone BO1.

TA-877B. Zosu **8700 ± 80**

Repeat dating.

TA-876A. Zosu **8400 ± 80**

Forest sedge peat from depth 290 to 295cm. Pre-Boreal and Boreal contact.

TA-876B. Zosu **8360 ± 70**

Repeat dating.

TA-875. Zosu **8020 ± 80**

Sapropel from depth 295 to 300cm.

Reference

Sarv, A A and Ilves, E O, 1976, Stratigraphy and geochronology of Holocene lake and mire deposits from the southwestern part of Estonia (in Russian), *in*: Palynology in continental and marine geological investigations: Riga, p 47-59.

[RADIOCARBON, VOL. 20, NO. 3, 1978, P. 455-460]

TEXAS A&M UNIVERSITY RADIOCARBON DATES IV

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Organic and carbonate carbon in sediments deposited in the Cariaco Basin and on the Mississippi River Delta and the total dissolved inorganic carbon in four water column profiles comprise the samples in this list. Except as noted below the samples were processed using the benzene synthesis and other procedures described by Mathews, *et al* (1972).

The Mississippi Delta borehole samples contained low amounts of organic and inorganic carbon so that as little as 0.25g of carbon were obtained in combusting the maximum amount of sediment (typically 60g dry weight). The standard benzene synthesis procedure, with "normal" amounts of carbon (1-3g), results in a yield of 85 to 95% (carbon as benzene/carbon as CO_2). When processing smaller samples (less than 1g), the yield drops off rapidly with sample size. This loss of efficiency is due primarily to the volume within the vacuum system (designed to deal with several liters of gas), the inaccuracy of the vacuum gauges and evaporative losses of benzene during transfers. In an attempt to analyze these small samples, a dilution technique was used to bring the amount of carbon to be processed up to a minimum of one gram. As part of the technique, modifications were made to the system to 1) collect and use all of the sample CO_2 introduced into the system and 2) measure more accurately the amount of sample CO_2 obtained.

The necessary modifications, referred to in Figure 1, are 1) the addition of a cold finger (G in Fig 1) within the storage area to draw all of the sample CO_2 out of the collection traps, 2) the addition of a mercury manometer (C in Fig 1) to allow more accurate pressure measurement, and 3) the connection of tubing to allow the metering of CO_2 from a compressed gas tank through a needle valve (E in Fig 1). A second Hg manometer was connected to the collection trap area to assure complete transfer of CO_2 from the traps to the storage flask.

Only enough CO_2 was allowed to enter the system to bring the total amount of carbon to one gram. It was judged best to restrict the amount of dilution gas to minimize the effects in the statistical calculations.

Counting time was adjusted using the background level and sample activity so that the net count rate error was 2%, with a maximum counting time of 10,000 minutes. Ages were calculated using a ^{14}C half-life of 5568 years. Indicated errors for the ages are one standard deviation.

SAMPLE DESCRIPTIONS

1. OCEAN SEDIMENT SAMPLES

Cariaco Basin series

Sediments were coll by gravity coring at 3 locations within anoxic level of basin, ca 400m to basin floor. Unless otherwise noted, data is for combusted carbonate-free organic material within homogenized 10cm

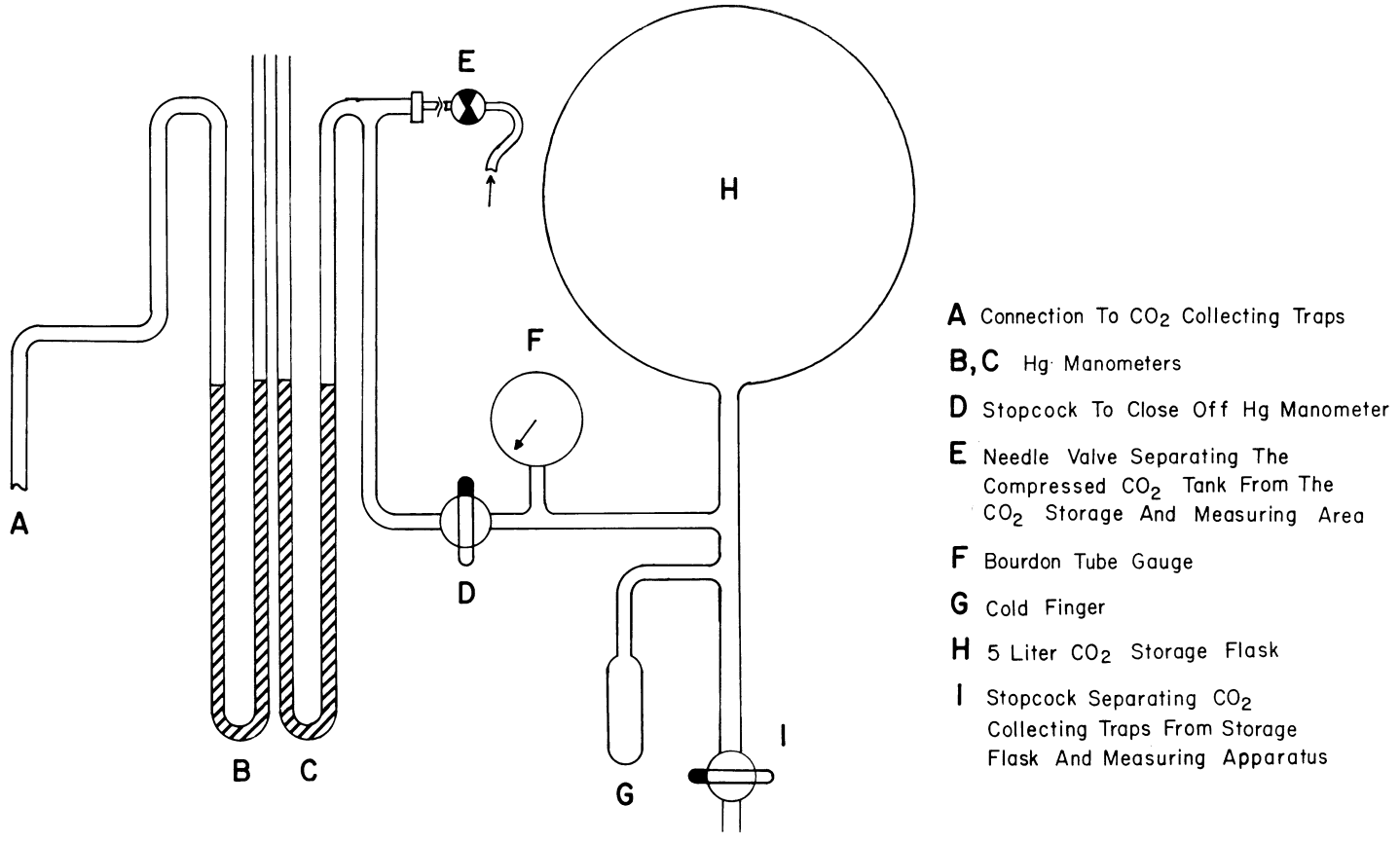

Fig. 1. Schematic of CO_2 storage and measuring section on the benzene preparation system showing modifications for handling small amounts of sample carbon.

interval. $\delta^{13}C$, relative to PDB, for top, middle and bottom samples in each core were determined by Gormly (1975). Values for samples listed here were interpolated assuming a linear change from datum point to datum point. Samples were coll 1972 by B J Presley, L Jeffrey, and J Gormly on Texas A&M Cruise 72-A-16.

Station 2, Median Ridge (10° 41′ N, 65° 04′ W), water depth 850m.

TAM-332. 20 to 30cm **1580 ± 180**
$\delta^{13}C = -19.9‰$

TAM-342. 40 to 50cm **2160 ± 180**
$\delta^{13}C = -20.0‰$

TAM-362. 50 to 60cm **2280 ± 160**
$\delta^{13}C = -20.1‰$

TAM-333. 80 to 90cm **3130 ± 170**
$\delta^{13}C = -20.2‰$

TAM-360. 100 to 110cm **4510 ± 150**
$\delta^{13}C = -20.3‰$

TAM-324. 100 to 110cm, carbonate **5010 ± 180**
Coarse (>62μm) calcium carbonate.

TAM-341. 120 to 130cm **5490 ± 240**
$\delta^{13}C = -20.2‰$

TAM-329. 130 to 140cm **5530 ± 190**
$\delta^{13}C = -20.5‰$

TAM-323. 130 to 140cm, carbonate **6475 ± 100**
Coarse (>62μm) calcium carbonate.

Station 3, Eastern Deep (10° 34′ N, 64° 45′ W), water depth 1330m.

TAM-343. 0 to 10cm **1390 ± 200**
$\delta^{13}C = -20.6‰$

TAM-364. 20 to 30cm **1750 ± 140**
$\delta^{13}C = -20.6‰$

TAM-330. 20 to 30cm, carbonate **1280 ± 150**
$\delta^{13}C = 0‰$
Coarse (>62μm) calcium carbonate.

TAM-348. 40 to 50cm **1580 ± 160**
$\delta^{13}C = -20.5‰$

TAM-345. 80 to 90cm **1650 ± 190**
$\delta^{13}C = -20.5‰$

TAM-349. 110 to 120cm **1690 ± 130**
$\delta^{13}C = -20.5‰$

TAM-363.	**120 to 130cm**	**2100 ± 170** $\delta^{13}C = -20.5‰$
TAM-344.	**140 to 150 cm**	**2380 ± 180** $\delta^{13}C = -20.5‰$

Station 4, Western Deep (10° 38′ N, 65° 37′ W), water depth 1350m.

TAM-358.	**10 to 20cm**	**710 ± 180** $\delta^{13}C = -20.2‰$
TAM-352.	**30 to 40cm**	**1010 ± 180** $\delta^{13}C = -20.0‰$
TAM-354.	**60 to 70cm**	**2430 ± 170** $\delta^{13}C = -19.9‰$
TAM-356.	**90 to 100cm**	**2370 ± 170** $\delta^{13}C = -20.1‰$
TAM-361.	**100 to 110cm**	**2440 ± 140** $\delta^{13}C = -20.2‰$
TAM-357.	**130 to 140cm**	**3210 ± 190** $\delta^{13}C = -20.3‰$
TAM-355.	**150 to 160cm**	**2990 ± 200** $\delta^{13}C = -20.4‰$

Mississippi Delta Borehole series

This borehole (BH-1A) was drilled as part of sediment mass movement study by US Geol Survey. Sediment was characteristically low in both organic and inorganic carbon except for shell hash layer at ca 37m (TAM-387). Borehole was in pro-delta facies, Block 47 of South Pass area (28° 52′ 38.05″ N, 89° 09′ 46.81″ W). All dates are for carbonate-free organic material except TAM-387. Samples were coll 1974 by Marine Geol Lab, USGS Corpus Christi, Texas and subm by W R Bryant, Texas A&M Univ, Dept Oceanog, College Station, Texas.

TAM-375.	**BH-1A-11 3.4m**	**3010 ± 140** $\delta^{13}C = -21.6‰$
TAM-383.	**BH-1A-23 7.0m**	**3980 ± 140** $\delta^{13}C = -23.3‰$
TAM-373.	**BH-1A-35 10.7m**	**4540 ± 170** $\delta^{13}C = -22.9‰$
TAM-382.	**BH-1A-47 14.3m**	**4350 ± 160** $\delta^{13}C = -23.2‰$
TAM-399.	**BH-1A-51 15.5m**	**4440 ± 170** $\delta^{13}C = -23.4‰$

TAM-377. BH-1A-61 18.6m **5200 ± 290**
$\delta^{13}C = -23.6‰$

TAM-423. BH-1A-96 29.3m **6270 ± 290**
$\delta^{13}C = -22.5‰$

TAM-432. BH-1A-121 36.9m **4680 ± 180**
$\delta^{13}C = -21.3‰$

TAM-387. BH-1A-121 36.9m, carbonate **7030 ± 130**
$\delta^{13}C = 0‰$ *EST*

Shell hash-small bivalves.

TAM-381. BH-1A-141 43.0m **16,970 ± 740**
$\delta^{13}C = -25.1‰$

TAM-378. BH-1A-178 54.2m **17,370 ± 1300**
$\delta^{13}C = -24.4‰$

II. SEA WATER SAMPLES

Water samples coll 1975 on Texas A&M Cruise 75-G-8 on *R/V Gyre* by D Reid.

Station 3 (28° 20.5′ N, 92° 36.5′ W).

TAM-301. 3m $\delta^{14}C = 83 \pm 12‰$
$\Delta = 27 \pm 12‰$

TAM-302. 18m $\delta^{14}C = 291 \pm 8‰$
$\Delta = 224 \pm 8‰$

TAM-305. 46m Barrel 2 $\delta^{14}C = 302 \pm 7‰$
$\Delta = 234 \pm 7‰$

TAM-306. 46m Barrel 1 $\delta^{14}C = 330 \pm 8‰$
$\Delta = 261 \pm 8‰$

East Cameron Bank Station (28° 31.2′ N, 92° 24.9′ W).

TAM-307. 4m $\delta^{14}C = 304 \pm 8‰$
$\Delta = 236 \pm 8‰$

Station 22 (28° 05.5′ N, 91° 05′ W).

TAM-308. SFC Barrel 2 $\delta^{14}C = 278 \pm 9‰$
$\Delta = 212 \pm 9‰$

TAM-308. SFC Barrel 3 $\delta^{14}C = 258 \pm 9‰$
$\Delta = 193 \pm 9‰$

Station 24 (28° 11.5′ N, 91° 28.1′ W).

TAM-310. SFC $\delta^{14}C = 243 \pm 8‰$
$\Delta = 179 \pm 8‰$

TAM-311. SFC No. 1 $\delta^{14}C = 255 \pm 8‰$
$\Delta = 190 \pm 8‰$

Water samples coll 1975 on Texas A&M Cruise 75-G-13 on *R/V Gyre* by W Sackett.

Station 18 (23° 28.2′ N, 92° 37.65′ W).

TAM-314. SFC $\delta^{14}C = 213 \pm 10‰$, $\Delta = 150 \pm 10‰$

East Cameron Bank Station (28° 31.2′ N, 92° 24.9′ W).

TAM-307. 4m $\delta^{14}C = 304 \pm 8‰$, $\Delta = 236 \pm 8‰$

Station 22 (28° 05.5′ N, 91° 05′ W.)

TAM-308. SFC Barrel 2 $\delta^{14}C = 278 \pm 9‰$, $\Delta = 212 \pm 9‰$

TAM-309. SFC Barrel 3 $\delta^{14}C = 258 \pm 9‰$, $\Delta = 193 \pm 9‰$

Station 24 (28° 11.5′ N, 91° 28.1′ W).

TAM-310. SFC $\delta^{14}C = 243 \pm 8‰$, $\Delta = 179 \pm 8‰$

TAM-311. SFC No. 1 $\delta^{14}C = 255 \pm 8‰$, $\Delta = 190 \pm 8‰$

Water samples coll 1975 on Texas A&M Cruise 75-G-13 on *R/V Gyre* by W Sackett.

Station 18 (23° 28.2′ N, 92° 37.65′ W).

TAM-314. SFC $\delta^{14}C = 213 \pm 10‰$, $\Delta = 150 \pm 10‰$

TAM-347. SFC #2 $\delta^{14}C = 252 \pm 21‰$, $\Delta = 187 \pm 21‰$

TAM-315. 150m $\delta^{14}C = 214 \pm 10‰$, $\Delta = 154 \pm 10‰$

TAM-320. 600m $\delta^{14}C = -22 \pm 9‰$, $\Delta = -70 \pm 9‰$

TAM-339. 900m $\delta^{14}C = -10 \pm 19‰$, $\Delta = -59 \pm 19‰$

TAM-368. 900m #2 $\delta^{14}C = -14 \pm 17‰$, $\Delta = -64 \pm 17‰$

TAM-346. 2500m $\delta^{14}C = -12.5 \pm 22‰$, $\Delta = -62 \pm 22‰$

References

Gormly, J R, 1975 Stable carbon isotope variations in marine organic matter: PhD thesis, Texas A&M Univ, 140 p.

Mathews, T D, Fredericks, A D, and Sackett, W M, 1972, Texas A&M University radiocarbon dates II: Radiocarbon, v 14, p 452-455.

[RADIOCARBON, VOL. 20, No. 3, 1978, P. 461-468]

TALLINN RADIOCARBON DATES V

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The following list comprises age measurements carried out during 1976 and 1977. The activity of ^{14}C was computed by one- and two-channel scintillation devices (Punning *et al,* 1976; 1977). Ages are calculated using a half-life of 5568 ± 30 years for ^{14}C with NBC oxalic acid as a reference standard. All dates are reported in years before 1950. $^{12}C/^{13}C$ measurements were not performed and results are not corrected for ^{13}C fractionation.

I. GEOLOGIC SAMPLES

Estonian SSR

Tln-200. Marikoja **6820 ± 70**

Carex/Phragmites peat from under beach barrier, NE of Kahala Lake, Harju Dist. In depression before glint near shore deposits of Littorina Sea overlying 0.5m complex organic deposits represented by *Carex/Phragmites* and wood peat. In transition zone wood remains. Pollen analyses by H Kesel refer accumulation of lacustrine deposits to Pollen Zone ATI. Coll 1971 and subm by H Kessel, Inst Geol, Acad Sci Estonian SSR (now Inst Geol).

Tln-201. Marikoja **7240 ± 90**

Wood peat from same complex as Tln-200. Coll 1975 and subm by H Kessel.

Tln-202. Uuri **9230 ± 80**

Wood (birch) remains underlying gravel of Ancylus Lake on foot of glint at Uuri, NE of Kahala Lake, Harju Dist. Lacustrine deposits overlay gravel and till. Coll 1975 and subm by H Kessel.

Tln-231. Tepanimägi **7660 ± 110**

Well-decomposed peat from funnel on N slope of Tepanimägi hill, Otepää elev, Valga Dist. Lake and bog deposits, 2.5m thick are embedded in deluvial deposits. From depth 2.45 to 2.50m. Coll 1973 and subm by R Karukäpp, Inst Geol.

Latvian SSR

Tln-239. Ozolnieki **9840 ± 160**

Wood remains from profile near settlement Ozolnieki, Jelgava Dist. Sample from sands overlying varved clays of Baltic Glacial Lake. Coll 1976 and subm by U Veinbergs, All-Union Research Inst Marine Geol.

Arkhangelsk and Murmansk Districts

Tln-192. Sija **31,380 ± 350**

Shells from exposure on right bank of Severnaya Dvina R, 300m upstream from port Sija, Arkhangelsk Dist. Sample from fine sand over-

lain by 2 tills at alt 4m from river level. Coll 1975 by R Rajamäe. *Comment*: outer 40% removed by acid leaching.

Tln-230. Sija **40,250 ± 650**

Shells from exposure ca 100m downstream from profile at Severnaya Dvina R where Tln-192 was taken. Sample from clayey aleurites at alt 2.6 to 3.6m from river level. Coll 1975 by R Rajamäe. *Comment*: outer 40% removed by acid leaching.

Tln-210. Verhne-Tulomsky **9030 ± 90**

Shells (*Hiatella arctica*) from deposits of sea terrace on left bank of outflow canal of Verhne-Tulomsky Hudropower Sta, Murmansk Dist. Sample from depth 0.10 to 0.15m. Coll 1975 and subm by B Koshetchkin, Geol Inst, Kola Branch Acad Sci USSR. *Comment*: outer 40% removed by acid leaching.

Tln-211. Paive **6180 ± 60**

Shells (*Cyprina islandica*) from profile of Middle Holocene sea terrace in valley of Paive R, Rõbatchji Peninsula, Murmansk Dist. Horizon, 0.5m of fine and medium sands rich in shells lies at depth 0.6m. Coll 1975 and subm by B Koshetchkin, Geol Inst. *Comment*: outer 25% removed by acid leaching.

Tln-212. Eina **6270 ± 70**

Shells (*Hiatella arctica*) from exposure on sea terrace on right bank of Eina R, Rõbatchji Peninsula, Murmansk Dist. Clays containing shells overlain by pebble and sandy loams. Sample coll and subm by B Koshetchkin, Inst Geol. *Comment*: outer 40% removed by acid leaching.

Pasva series

Exposures lie on right bank of Vaga R (tributory of Severnaya Dvina R, Arkhangelsk Dist) near village Pasva, ca 4km upstream from profile of Koleshki (Tln-49, -52, -71, Devyatova Punning, 1976). In profile 2 complexes of organic deposits are overlain by sandy-clayey deposits. Thermoluminescent dates on quartz showed accumulation of sediments in Pasva profile continued steadily from Mikulian up to Late Valdai period (Hütt *et al,* 1978). On basis of pollen evidence Devyatova correlates accumulation of organic deposits with Mikulian interglacial and Upper-Valdai interstadial (Devyatova *et al,* 1978). Samples coll 1975 by R Rajamäe.

Tln-215. Pasva **34,600 ± 1100**

Upper layer of well-decomposed wood peat, 0.7m thick. Sample from depth 11.85 to 12.05m.

Tln-216. Pasva **36,500 ± 750**

Central part of same layer where Tln-215 was taken. Sample from depth 12.05 to 12.25m.

Tln-217. Pasva **34,600 ± 750**

Lowermost part of same layer where Tln-215 was taken. Sample from depth 12.25 to 12.45m.

Tln-226. Pasva **≧49,700**

Compacted wood peat from depth 12.95 to 13.05m.

Tln-221. Verhnaya Telza **46,830 ± 1100**

Shells from exposure on right bank of Verhnaya Telza R (tributory of Onega R, Arkhangelsk Dist). Gravel-pebble sand abundant in shells underlies reddish brown till and medium sands at depth 8.5 to 10.0m. Coll 1975 by J M Punning and R Rajamäe. *Comment*: outer 40% removed by acid leaching.

Tln-222. Raibola **40,000 ± 800**

Well-decomposed peat from profile on right bank of Vaga R (tributory of Severnaya Dvina R, Arkhangelsk Dist). Peat in aleurites overlain by 3 tills. Previous date from same complex ≧49,000: Tln-77. Tln-222 apparently too young. Sample coll 1975 by R Rajamäe.

Tln-223. Lovozerskaya tundra **≧42,000**

Wood remains from borehole in foreland depression N of Lovozerskaya tundra, Murmansk Dist. Lake and bog deposits, 2m thick rest between cobble, gravel and sand deposits and are divided by interlayer of cobble and pebble loam into 2 complexes. Sample from depth 15.4 to 15.9m. Coll 1976 and subm by V Evzerov, Geol Inst.

Tln-224. Lovozerskaya tundra **21,630 ± 650**

Wood remains from lowermost organogenous complex of same borehole as Tln-223. Sample from depth 16.6 to 16.8m.

Tln-225. Lovozerskaya tundra **≧45,000**

Wood remains from same complex as Tln-224. Sample from depth 16.8 to 17.2m. According to Tln-223-225, age of lake and bog deposits in profile: ≧42,000 yr. Tln-224 apparently too young.

Tln-227. Pervomaiskji **39,000 ± 800**

Peat from profile on left bank of Severnaya Dvina R, ca 10km upstream from settlement of Pervomaiskji, Arkhangelsk Dist. Peat layer in aleurites buried under medium sands and gray aleurite. Sample coll 1975 by J M Punning and R Rajamäe.

Tln-229. Krasnaya Gorka **36,930 ± 700**

Shells from profile on right bank of Severnaya Dvina R near village Krasnaya Gorka, Arkhangelsk Dist. Shells of subfossil mollusks are embedded in medium sands on aleuritic till and are covered by clayey aleurites with interlayers of fine and medium sands. Sample from depth 1.6 to 1.8m. Coll 1975 by R Rajamäe. *Comment*: outer 40% removed by acid leaching.

Tln-240. Vajenga **3960 ± 70**

Wood remains from alluvial deposits on left bank of Vajenga R (tributory of Severnaya Dvina R) ca 1km upstream from settlement Ust-Vajenga. Coll 1975 and subm by E Devyatova, Geol Inst, Karelian Branch Acad Sci USSR.

Tln-248. Lodeinoye **6040 ± 110**

Shells (*Hiatella arctica*) from 22m sea terrace on E edge of settlement Lodenoye, Murmansk Dist. Sample from depth 2.3 to 4.7m. Coll 1976 and subm by B Koshetchkin, Geol Inst. *Comment*: outer 40% removed by acid leaching.

West Spitsbergen

Tln-194. Billefjord **34,120 ± 600**

Shells from profile on E coast of Billefjord near Cape Ekholm. Pleistocene deposits represented by complex of marine deposits lying between 2 tills and fluvioglacial deposits overlying carbonaceous sandstones. Uppermost till underlies marine deposits and terrace drifts. Terrace alt 30m. Coll 1975 and subm by L Troitski, Inst Geog. *Comment*: outer 40% removed by acid leaching.

Tln-219. Billefjord **8760 ± 90**

Shells from sands at depth 0.5m in deposits of 30m terrace on E coast of Billefjord near Cape Ekholm (see Tln-194). Coll 1975 and subm by L Troitski. *Comment*: outer 40% removed by acid leaching.

Tln-199. Billefjord **7370 ± 80**

Shells from surface of 20m terrace on E coast of Billefjord near Cape Ekholm. Coll 1975 and subm by L Troitsky. *Comment*: outer 40% removed by acid leaching.

Tln-195. Brögger **42,490 ± 550**

Shells from base of 30m-terrace on N coast of Brögger Peninsula. Bedrock overlain by cobble loam, sand, till, red clay, sand with shells and cobble-and-pebble beach deposits. Coll 1975 and subm by L Troitski. *Comment*: outer 40% removed by acid leaching.

Tln-252. Brögger **33,200 ± 550**

Shells from same complex as Tln-195. Based on Tln-195, -252, the following conclusions can be drawn: 1) because of contamination of samples, Tln-195 reflects min age of complex, 2) occurrence of younger shells in deposits is not excluded, 3) data obtained reflect interval of warming. Coll 1975 by J M Punning and L Troitski. *Comment*: outer 40% removed by acid leaching.

Tln-196. Gravsjoem **1760 ± 50**

Animal bones near lagoon Gravsjoem, Nordenskjöld Land. Sample from upper layer. Col and subm by V Korjakin, Inst Geog.

Tln-208. Homender **230 ± 60**

Animal bones from cultural layer near mouth of Homender R, Nordenskjöld Land. Sample from uppermost layer. Coll and subm by V Korjakin.

Tln-232. Agardalen **10,570 ± 360**

Peat layer from sands from crest of push moraine of Elfenbeinbreen glacier, Sabine Land. Sample from upper part of layer. Coll 1975 and subm by L Troitski.

Tln-233. Agardalen **9620 ± 120**

Central part of peat layer (see Tln-232).

Tln-234. Agardalen **9460 ± 110**

Lowermost part of peat layer (see Tln-232). Data obtained refer to reverse bedding of complex.

Tln-244. Kalypsobyen **16,720 ± 230**

Shells from surface of 16m-terrace near Kalypsobyen, Bay of Bellsund. Coll 1976 by J M Punning. *Comment*: outer 40% removed by acid leaching.

Tln-250. Kalypsobyen **17,070 ± 150**

Repeat analyses of shells from profile of Kalypsobyen (see Tln-244). *Comment*: outer 40% removed by acid leaching.

Tln-258. Kalypsobyen **10,380 ± 120**

Shells from surface of 30m-terrace near Kalypsobyen, Bay of Bellsund. Judging by dates, age of 16m-terrace is too old (see Tln-244, -250), which supposedly resulted from mixing of material used for dating with older material outwashed from base of terrace (see Tln-250). Sample coll 1976 and subm by J M Punning. *Comment*: outer 40% removed by acid leaching.

Tln-245. Nathorst **1380 ± 70**

Driftwood from marine deposits in distal part of E end of Nathorst moraine, Van Keulenfjord. Coll 1976 by J M Punning.

Tln-246. Kap Lyell **440 ± 70**

Driftwood from terrace deposits at alt 0.6m from sea level, 0.5km W of cape Kap Lyell (Bellsund). Coll 1976 by J M Punning.

Tln-247. Renarodden **230 ± 60**

Driftwood from surface of 60m-terrace near cape Renarodden (Bellsund). Judging by age driftwood is not of primary deposit. Coll 1976 by J M Punning.

Tln-251. Renarodden **31,910 ± 600**

Shells from intermorainic complex of sea deposits forming bases of 30m-terrace, cape Renarodden, Bellsund. Sample coll 1976 by J M Pun-

ning. From same complex previous date 30,750 ± 800: Tln-175 (Punning *et al*, 1976), which confirms good correlation with last date. *Comment*: outer 40% removed by acid leaching.

Tln-249. Blomstrand **9185 ± 120**

Shells from surface of 10m terrace (N coast of Kongsfjord). Coll 1976 and subm by L Troitski.

East Siberia

Tln-228. Tchaun-1 **35,300 ± 900**

Biodetrite from borehole on beach of estuary of Tchaun, 2km S of town Peven on coast of East-Siberian Sea. Ancient lagoon deposits lie between deluvial deposits at depth 3.2 to 4.8m. Coll 1975 and subm by F Kovalenko, All-Union Research Inst Marine Geol.

Tln-236. Techaun-2 **14,180 ± 350**

Well-decomposed peat from borehole in S part of estuary of Tchaun, East-Siberian Sea. Complex of lake deposits overlain by aleurite and fine sand. Sample from depth 1 to 1.2m. Coll 1975 and subm by F Kovalenko.

Tln-235. Aion-4 **7530 ± 250**

Peat from terrace of erosion coast of Aion I, estuary of Tchaun, East-Siberian Sea. Sample from lower part of peat from drained thermokarst funnel. Coll 1975 and subm by F Kovalenko.

Tln-238. Aion-3 **23,600 ± 800**

Plant remains from terrace on E abrasional coast of Aion I, estuary of Tchaun, East-Siberian Sea. Sample from under 13m complex of loess-like rocks alternating with horizontal layers of sandy and aleuritic deposits. Coll 1975 and subm by F Kovalenko.

Tln-242. Tchaun **13,460 ± 280**

Peat from subaqueous coastal slope in E Part of tributory Tchaun, East Siberian Sea. Clayey aleurites with peat layers at 4.5 to 5.4m, overlain by clayey aleurites. Sample coll 1975 and subm by M Rosenblats, All-Union Research Inst Marine Geol.

Central Asia

Tln-198. Suphan **180 ± 60**

Peat from central part of Suphan bog (Phergana Dist, Uzbek SSR). Sample from depth 0.2m. Coll 1974 and subm by L Serebryanny, Inst Geog.

Tln-203. Kerkidon-3 **5680 ± 80**

Plant remains from alluvial bog deposits on slope of 2nd terrace of Kuvasay R, 1km NW of village Kerkidon, Aravan Dist, Oshs region, Kirghiz SSR. Sample from depth 0.4 to 0.5m. Coll 1975 by G Pshenin and L Serebryanny, Inst Geog.

Tln-204. Kerkidon-4 **7430 ± 60**

Plant remains from alluvial bog deposits on slope of 2nd terrace of Kuvasay R (see Tln-203).

Tln-205. Kashkalan-1 **2470 ± 80**

Peat sapropel from slope of canal 1km S of village Kashkalan Alabuhinsk Dist, Oshs region, Kirghiz SSR. In profile peat sapropels at depth 1.60 to 1.65m and 2.60 to 2.70m. Sample from upper layer. Coll 1975 and subm by L Serebryanny.

Tln-206. Kashkalan-2 **2700 ± 120**

Peat from lowermost horizon from same profile as Tln-205.

Tln-241. Kulandy **745 ± 80**

Shells from surface of spit of ancient lagoon of Aral Sea 4km W of village of Kulandy (Aral Dist, Kõzol-Ordinsk region, Kazakh SSR. Sample coll 1976 and subm by I Veinbergs, All-Union Research Inst Marine Geol. *Comment*: outer 20% removed by acid leaching.

Tln-243. Kulandy **730 ± 80**

Shells from surface of spit of ancient lagoon of Aral Sea 5km S of settlement Kulandy. Sample coll 1976 and subm by I Veinbergs. *Comment*: outer 20% removed by acid leaching.

II. ARCHAEOLOGIC SAMPLES

Estonian SSR

Tln-207. Pajumóisa **1468 ± 80**

Remains of decomposed wood from ancient grave on I Saaremaa. Estimated age: 5th to 6th centuries AD. Sample from depth 0.6 to 0.7m. Coll 1975 and subm by T Hamla, Inst Hist.

Tln-209. Narva-Jõesuu **280 ± 50**

Remains of ancient ship from under old coast dunes near settlement Narva-Jõesuu (estuary of Narva R). Sample coll 1976 by V Lõugas, Inst Hist.

Tln-213. Kuressaare **960 ± 60**

Wood from wall of guard tower of castle Kuressaare, I Saaremaa. Sample coll 1975 and subm by K Aluvee, State Bldg Comm Council Ministers Estonian SSR, Restoration Office.

Tln-214. Kuressaare **690 ± 60**

Wood from defense wall of castle Kuressaare, I Saaremaa. Sample coll 1975 and subm by K Aluvee.

Tln-218. Kuressaare **630 ± 50**

Wood from earlier building stage of Kuressaare castle, I Saaremaa. Coll 1974 and subm by K Aluvee.

Tln-237. Kaali **2890 ± 90**

Wood from lacustrine deposits in main crater of Kaali, I Saaremaa. Coll 1976 and subm by V Lõugas, Inst Hist.

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UPPSALA NATURAL RADIOCARBON MEASUREMENTS XII

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The following list covers all bone sample measurements finished since the last list (R, 1972, v 14, p 247-271) until the end of 1977; the Egyptian samples were measured as an interlaboratory project and all shells were closely related to some of the bone samples.

The technique and the pretreatment are mainly the same as previously described (Olsson, 1958). In autumn 1970, we changed from bottles filled with saturated CrO_3 in conc H_2SO_4 to another solution (a mixture of 60g CrO_3, 60ml H_2O and 100ml conc H_2SO_4 dissolved in the same amount water as the mixture), as suggested by A Heikkinen, Finland. Grass and wood samples are heated to ca 100°C for some hours with HCl, 1 to 2%, left at least over night, washed with distilled water, transferred to NaOH, 1 to 2%, at +80°C over night, washed with distilled water and finally acidified to pH <3 before being dried. Combustion shortly follows pretreatment. Foraminifera and mollusk shells are leached with HCl. Fractions used for shell samples are given in per cent as a mean value. Since shell fragments usually are different in size, the fraction of shell samples does not give the fraction of individual shells.

Bone samples were treated to test different pretreatments (Olsson *et al*, 1974; El-Daoushy *et al*, 1978). Each method is indicated with the sample.

The reference sample is 95% of the $^{14}C/^{12}C$ ratio of the NBS oxalic-acid standard. Any corrections for apparent water ages are thus not included here, but are discussed in papers dealing with the samples. Corrections for deviations from the normal $^{13}C/^{12}C$ ratio (–25‰ in the PBD scale) are applied for unknown samples. Our 8 oxalic-acid samples did not show any significant difference according to measurements made in Stockholm (see also R, 1972, v 14, p 247).

The value, 5570 yr, has been used for the half-life of ^{14}C. Results in this list are given BP (before 1950). Errors include standard deviation (σ) of counted particles and uncertainties in corrections due to the $^{13}C/^{12}C$ ratio, filling pressure, temperature, working voltage, barometric pressure, etc, as described by Olsson (1966). When measured activity is lower than zero, 2σ has been used for calculation of minimum age. When it is between zero and 2σ, net activity is increased by 2σ for calculation of minimum age. Since results are physical measurements, no terms are included for the error in the half-life or previous $^{14}C/^{12}C$ variations. These errors are discussed elsewhere.

Several samples had to be diluted with CO_2 from an old source to bring them to normal working pressure of the counters. This has been ca 2000mmHg for most dates but ca 800 or 1300mmHg for some samples with numbers starting with U-5000 (PRF) measured with the new

counter (PRF) described by El-Daoushy and Olsson (1977). Samples measured with Counter No. 1 have date numbers U-770-899 and -4000-4049; No. 4, U-2200-2299 and -2400-2810; No. 5 (same construction as PRF) U-4050-4300.

Description of samples are based on information provided by those who collected and submitted them.

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SAMPLE DESCRIPTIONS

I. GEOLOGIC SAMPLES

A. Canada

U-2510. Cape Storm, Ellesmere I, North West Territories **9600 ± 120**

$\delta^{13}C = -17.2‰$

Collagen received by EDTA method from Whale (probably *Balaena mysticetus*) from Cape Storm, Ellesmere I., NWT (76° 25′ N, 87° 33′ W). Sample, part of mandible, embedded on raised beach, alt ca 118m. Coll 1970 by W Blake, Terrain Sc Div, Geol Survey Canada, Ottawa, Canada. *Comment*: sample dated by Canadian lab using method of Haynes (1967), GSC-1496-A,B and C, 8900 ± 60, 9080 ± 40, 9260 ± 45 with $\delta^{13}C$ values: −16.2, −15.9 and −15.4, respectively. Sample also apatite dated according to Haynes (1968), GSC-1496-2, 8590 ± 120 and 8860 ± 65, $\delta^{13}C = -13.5‰$, using same gas in 2 counters (Blake, 1975). Uncertainty given by Blake red to give $\pm\sigma$ here. Other dates from Arctic Canada given and discussed by Blake (1975). Sample subm by Blake for interlab check.

Amaroktalik, Bear Bay series

Whale vertebra from Amaroktalik, Bear Bay, Cumberland Pen, Baffin I., NWT (67° 48′ 36″ N, 64° 35′ 30″ W). Sample (CS-160874-1) consisted of chips in bad condition. Sample within beach boulder on surface of terrace, alt 10m. Coll 1974 and subm by C Schlüchter, Brock Univ, St Catharines, Ontario. *Comment*: 3 shell samples coll Aug 1974 from same locality to be dated at Brock Univ. Minor lichen growth seen. Sample believed to be ca 10,000 BP; thus, chosen by Uppsala for tests of different pre-treatment techniques. Although much later than thought dates of different fractions agree well.

U-4144. Bear Bay, c:1 **1440 ± 50**

$\delta^{13}C = -14.8‰$

Organic fraction obtained after EDTA treatment. *Comment*: gas obtained at degassing and 1st part of combustion.

U-4143. Bear Bay, c:2 **1250 ± 50**

$\delta^{13}C = -14.5‰$

Organic fraction obtained after EDTA treatment. *Comment*: same treatment as for U-4144 but gas from final part of combustion.

U-4141. Bear Bay, SOL, iso **1310 ± 50**

$\delta^{13}C = -15.0‰$

Organic fraction obtained after dissolving part of bone in 2-N HCl, neutralizing solution with NaOH, using iso-electric point, dissolving precipitate in HCl to pH ca 3.5, heating during extraction, dialyzed.

U-4140. Bear Bay, INS, iso:1 **1320 ± 90**

$\delta^{13}C = -17.6‰$

Organic fraction obtained from parts not dissolved at initial HCl treatment of bone yielding U-4141. Solution after further HCl treatment neutralized with NaOH, too little precipitate obtained. Liquid dried. *Comment*: gas obtained at degassing and 1st part of combustion.

U-4139. Bear Bay, INS, iso:2 **1280 ± 70**

$\delta^{13}C = -14.9‰$

Organic fraction obtained after EDTA treatment. *Comment*: same treatment as for U-4140 but gas from final part of combustion.

B. Svalbard

Vestspitsbergen series

Shells and whale bones from Vestspitsbergen coll for determination of land uplift but also used for testing different methods for pretreatment of bones. Alt given above mean sea level. Previous determinations in this series in Radiocarbon: 1960, v 2, p 115-116; 1961, v 3, p 82-83; 1964, v 6, p 296-298; 1965, v 7, p 317-318; 1967, v 9, p 456-457; 1969, v 11, p 521-524; 1972, v 14, p 255-257. Quaternary geology and land uplift disc by Birkenmajer (1960), Feyling-Hanssen (1955), Feyling-Hanssen & Olsson (1959-1960), and Birkenmajer & Olsson (1971). Samples from Hornsund coll 1970 and subm by K Birkenmajer, Polish Acad Sci, Krakow, and those from Isfjorden coll 1960 by D H Maling, R Feyling-Hanssen, Dept Geol, Aarhus Univ, Denmark, and I U Olsson. *Comment*: bone treatment with EDTA were shortly described (R, 1967, v 9, p 456) and in detail by Olsson *et al* (1974).

U-770. Wilczekodden E, 1st, Q7, B g, b **320**
4280 ± 310

$\delta^{13}C = -0.8‰$

Shell (*Buccinum glaciale*) from E coast of Wilczekodden (77° 00′ N, 15° 56′ E), Hornsund, Svalbard, alt 4m. Sample in shingle, fine, angular, 1 to 10cm diam, Bed "a" of 1st Terrace, Loc 3 (Birkenmajer, 1960, p 21; fig 5). *Comment*: innermost 45% was used.

U-771. Wilczekodden E, 1st, Q7, B g, a **4810 ± 340**
$\delta^{13}C = -2.0‰$

Shell layer surrounding U-770. *Comment*: layer corresponds to 50% of shell; 5% removed by washing.

U-772. Wilczekodden E, 1st, Q7, M+S, b **4980 ± 210**
$\delta^{13}C = +1.7‰$

Fragment (*Mya truncata*) 2.3g, and 3 shells (*Saxicava arctica*) 1.3g, from same bed as U-770, -771, -2251, -2240. *Comment*: innermost 55% was used.

U-773. Wilczekodden E, 1st, Q7, M+S, a **4660 ± 340**
$\delta^{13}C = -0.3‰$

Shell layer surrounding U-772. *Comment*: layer corresponds to 40% of shells; 5% removed by washing.

U-2251. Wilczekodden E, 1st, Q7, B, b **4740 ± 90**
$\delta^{13}C = -1.3‰$

Fragments (*Balanus* sp) from same bed as U-770-773. *Comment*: innermost 30% was used.

U-2440. Wilczekodden E, 1st, Q7, B, a **4820 ± 120**
$\delta^{13}C$ *assumed* $-1.3‰$

Shell layer surrounding U-2551. *Comment*: layer corresponds to 35% of shells; 35% removed by washing.

U-782. Isbjørnhamna, $2a_2$, Q2a, HCl, <250μ, r **9180 ± 390**
$\delta^{13}C = -19.0‰$

Insoluble remains after HCl treatment of whalebone from Fuglebergsletta, Isbjørnhamna (77° 00′ N, 15° 33′ 30″ E), 82m SW Polish Sta, Hornsund, Svalbard, alt 8m. Sample from lower jaw, 1.9m long, 17cm diam, 2/3 buried in tundra: mosses, lichens, *Saxifraga, Salix polaris,* and grass, $2a_2$ Terrace. *Comment*: grains <250μ used. pH of extracts same as HCl used for last 10 to 12 extractions (18 days); ca 30 extractions. 0.1-N HCl used. Bone dated previously (R, 1969, v 11, p 523) using more reliable EDTA-treatment.

U-783. Isbjørnhamna, $2a_2$, Q2a, HCl, <250μ, l **4190 ± 930**
$\delta^{13}C = -22.1‰$

First 9 extracts from HCl treatment of bone also used for U-782. *Comment*: liquid purified by dialysis.

U-778. Kapp Linné 6005, A2, R **285 ± 105**

$\delta^{13}C = -20.2‰$

Organic fraction of vertebra from Kapp Linné (78° 04′ N, 13° 40′ E), Isfjorden, Svalbard, alt ca 1m. Same vertebra as for U-2270. *Comment*: acetone-treated before EDTA treatment. Diluted.

U-758. Kapp Linné 6005, A2, A **3700 8700 ± 2500**

$\delta^{13}C = -25.6‰$

Acetone extract from bone used for U-778. *Comment*: probably contaminated with oil from radio sta. Diluted.

U-779. Kapp Linné 6005, A2, W **140 ± 140**

$\delta^{13}C = -25.9‰$

Wrong fraction of same vertebra as used for U-758. Diluted.

U-777. Kapp Linné, A1, W **440 470 ± 420**

$\delta^{13}C$ *assumed* $-20.2‰$

Wrong fraction of same vertebra as used for U-2270. *Comment*: diluted.

U-785. Kapp Linné, 6005, C1, SOL **480 ± 100**

$\delta^{13}C = -18.1‰$

Soluble fraction of same vertebra as U-778, received after HCl treatment. *Comment*: soluble fraction dialyzed.

U-786. Kapp Linné 6005, C1, INS **330 ± 130**

$\delta^{13}C = -16.6‰$

Insoluble remains after treatment to get U-785. *Comment*: diluted.

U-774. Gipshuken 6016 c:1 **5000 ± 160**

$\delta^{13}C = -17.8‰$

Organic fraction of whalebone from Gipshuken (78° 27′ N, 16° 24′ E), Isfjorden, Svalbard, alt 10m. *Comment*: EDTA treatment. Gas obtained at degassing and 1st part of combustion.

U-775. Gipshuken 6016 c:2 **4980 ± 120**

$\delta^{13}C = -17.0‰$

Organic fraction of same bone as used for U-774. *Comment*: gas obtained at final part of combustion.

U-784. Gipshuken 6016 c W **330 3540 ± 320**

$\delta^{13}C = -23.2‰$

Wrong fraction of same whalebone as used for U-774 and -775.

U-2538. Gipshuken 6017 c:1 **5430 ± 65**

$\delta^{13}C = -17.5‰$

Organic fraction of whalebone from Gipshuken, alt 12m. *Comment*: EDTA treatment including dialysis of extracted collagen.

U-2546. Gipshuken 6017 c:1 W **−830 ± 110**

$\delta^{13}C = -21.1‰$

Wrong fraction received at pretreatment of U-2538. *Comment*: diluted.

U-4056. Gipshuken 6017 c:2 **6370 ± 1250 1080**

$\delta^{13}C = -23.7‰$

Organic fraction of outer very porous parts, which normally should have been rejected, of same whalebone as used for U-2538. *Comment*: EDTA treatment including dialysis. Fraction soluble in cool water, pH ca 6. Diluted.

U-4057. Gipshuken 6017 c:2 R+W **2860 ± 80**

$\delta^{13}C = -26.3‰$

Wrong fraction mixed with parts of right fraction of same piece of bone as used for U-4056.

U-879. Gipshuken 6017 c:3 **8340 ± 760 670**

$\delta^{13}C$ *assumed* $-19.0‰$

Impure organic fraction of same whalebone as used for U-2538. *Comment*: Experiment by removing EDTA by dialysis of gelatinous sample. Not all EDTA removed. Date should not be used. Diluted.

U-2537. Gipshuken 6017 b:1a **5550 ± 100**

$\delta^{13}C = -18.0‰$

Organic fraction of same whalebone as used for U-2538. *Comment*: HCl treatment followed by neutralization with NaOH. Insoluble fraction from this treatment dissolved in HCl, pH ca 4. Solution purified by dialysis.

U-4051. Gipshuken 6017 b:2a **1220 ± 160**

$\delta^{13}C = -24.0‰$

Organic fraction of rather porous parts, which normally should have been rejected, of same whalebone as used for U-2538. *Comment*: HCl treatment. Soluble fraction used after dialysis. Diluted.

U-4032. Gipshuken 6017 b:1b **1620 ± 380 370**

$\delta^{13}C = -17.5‰$

Insoluble remains after HCl treatment to get U-2537. *Comment*: further extraction by HCl at elevated temperature. Neutralization with NaOH, pH ca 6.6, precipitate dialyzed, HCl added until pH 3 to 4,

heated, soluble fraction dialyzed, evaporated down and sample extracted at room temperature and pH ca 2.

U-4052. Gipshuken 6017 b:2b **1730 ± 100**

$\delta^{13}C = -22.5‰$

Insoluble fraction after HCl treatment to get U-4051. *Comment*: further washing in dialysis bag, dissolved in water, pH ca 5. Diluted.

U-4036. Gipshuken 6017 a:1 inorg **3935 ± 85**

$\delta^{13}C = -14.4‰$

Apatite CO_2 obtained after treatment of bone used for U-2538 with acetic acid for 2 days at slightly elevated temperature, careful washings with water for 2 weeks. CO_2 released by HCl in stream of oxygen.

U-4050. Gipshuken 6017 a:2 inorg **1910 ± 290**

$\delta^{13}C = -15.2‰$

Apatite CO_2 obtained after treatment of rather porous parts of whalebone used for U-2538 with acetic acid for 2 days at slightly elevated temperature, with new acetic acid under vacuum for 11 days, and careful washings with water. CO_2 released by HCl in stream of oxygen. *Comment*: diluted.

U-4033. Gipshuken 6017 a:1 s **4780 ± 270**

$\delta^{13}C = -19.6‰$

Soluble organic fraction obtained at HCl treatment to get U-4036. *Comment*: impurities removed by precipitation with NaOH, pH 3 to 4, liquid reduced in volume, dialyzed, evaporated down and used. Diluted.

U-4053. Gipshuken 6017 a:2 s **4050 ± 1390**

$\delta^{13}C = -27.3‰$

Soluble organic fraction obtained at HCl treatment to get U-4050. *Comment*: liquid reduced in volume, purified by dialysis and used. Diluted.

U-4034. Gipshuken 6017 a:1 ha **4580 ± 250**

$\delta^{13}C = -24.0‰$

In NaOH, 1%, soluble fraction of insoluble remains obtained at HCl treatment to get U-4036 and -4033. *Comment*: sample precipitated with HCl as for humic acid. Diluted.

U-4054. Gipshuken 6017 a:2 ha **3470 ± 1010 900**

$\delta^{13}C$ *assumed* $-24.0‰$

In NaOH, 1%, soluble fraction of insoluble remains obtained at HCl treatment to get U-4050 and -4053. *Comment*: sample precipitated with HCl as for humic acid. Diluted.

U-4035. Gipshuken 6017 a:1 INS **2180 ± 270 260**

$\delta^{13}C = -27.0‰$

Insoluble remains, washed and made acid, obtained at treatment to get U-4034. *Comment*: diluted.

U-4055. Gipshuken 6017 a:2 INS **1280 ± 470 440**

$\delta^{13}C$ *assumed* $-27.0‰$

Insoluble remains, washed and made acid, obtained at treatment to get U-4054. *Comment*: diluted.

U-4058. Gipshuken 6017 W **1805 ± 75**

$\delta^{13}C$ *assumed* $-25.0‰$

Fraction released at ultrasonic washing and boiling in water. *Comment*: slightly acidified.

U-4059. Gipshuken 6017 hpc SOL **4110 ± 460 440**

$\delta^{13}C = -22.7‰$

Fraction removed physically from ground samples used for dating. *Comment*: sample may contain pieces of bone as well as contaminants deriving from outer porous and very porous parts usually removed from samples before dating. Fraction soluble in HCl.

U-4064. Gipshuken 6017 hpc INS **1820 ± 400 380**

$\delta^{13}C = -27.9‰$

Insoluble remains obtained at treatment to get U-4059. *Comment*: diluted.

U-2436. Ekholmvika 6022, c 71 **9710 ± 100**

$\delta^{13}C = -17.1‰$

Whale rib from Ekholmvika (78° 35′ N, 16° 38′ E), Billefjorden, Svalbard; alt ca 50m. Deeply buried in fine gravel. Coll 1969 by D H Maling. *Comment*: EDTA treatment.

U-2406. Ekholmvika 6022, b HCl, < 500μm, SOL, H_2O SOL **9680 ± 90**

$\delta^{13}C = -15.6‰$

Same whale rib as for U-2436. Fraction <500μm ground to fine powder. Treated with 2-N HCl, left in acid for 1½ mos, filtrated, liquid evaporated, dissolved in water.

U-2407. Ekholmvika 6022, b HCl, <500μm, INS, H_2O SOL **9600 ± 90**

$\delta^{13}C = -17.4‰$

Same whale rib as for U-2406. Same treatment but fraction not dissolved by acid used. Extracted by acidic water.

C. Norway

U-2766. Toten tusk **>28,900**

U-4214. **30,600 ± $\begin{matrix}3800\\2600\end{matrix}$**

$\delta^{13}C = -24.4‰$

Collagen, obtained by EDTA method, but H_2O soluble and insoluble fractions, from tusk of *Mammutus primogenius* from Skreia, Oppland Co (60° 39½′ N, 10° 55½′ E). Sample from 1.5m below surface in moraine in ditch 2m deep (Heintz, 1956). Coll 1955, subm 1976 by N Heintz, Palentol Mus, Oslo Univ to Follestad, Norges geol undersøkelse, Trondheim, for age determination in Uppsala. *Comment*: intrusion of water-soluble compounds studied by Follestad (1977). Sample, 150g, from hard part. Porous parts of tusk dated 1962 by Nydal, T-359, 19,190 ± 1200. Sample, only 30g, was too small for thorough pretreatment and date regarded as too low because of contamination. Unpub by Nydal (pers commun) although used by others. Heintz (1965) used result to date mammoth from before end of last glaciation. New determination is underway in Trondheim. Present sample, pretreatment, age calculation and result $\left(\text{mean value } 32{,}100 \pm \begin{matrix}3100\\2300\end{matrix}\right)$ discussed by Follestad and Olsson (1979). Diluted.

Varangerfjord series

Whale rib from Makviken (Nesseby), Varangerfjord, Norway (70° 2′ 20″ N, 29° 07′ 43″ E). Sample from accumulation of shelly gravel and sand, 15.8m above present *Balanus* line (Donner *et al*, 1977). Subm 1975 by J Donner, Dept Geol Palaeontol, Univ Helsinki, Finland. *Comment*: *Mytilus edulis* shells from same accumulation, regarded as reliable dated as Hel-624, 4120 ± 130, $\delta^{13}C = +1.7‰$, but not normalized to $\delta^{13}C = -25‰$. After normalization radiocarbon age is 4560 yr without correction for reservoir effect. *Mya truncata* from same layer dated as Hel-625,

6430 ± 150, but not regarded as suitable for land uplift dating (Donner *et al,* 1977). Land uplift here corresponds to 1m in 160 yr.

U-4125. Varangerfjord, Nesseby, c:1 **5140 ± 170**
$\delta^{13}C = -17.2‰$

Organic fraction obtained after EDTA treatment. *Comment*: gas obtained at degassing and 1st part of combustion.

U-4126. Varangerfjord, Nesseby, c:2 **4710 ± 150**
$\delta^{13}C = -16.6‰$

Organic fraction obtained after EDTA treatment. *Comment*: same treatment as for U-4125 but gas from final part of combustion.

U-4128. Varangerfjord, Nesseby, SOL, iso **4095 ± 100**
$\delta^{13}C = -16.7‰$

Organic fraction obtained after dissolving part of bone in 2-N HCl, neutralizing solution with NaOH, using iso-electric point, dissolving precipitate in HCl to pH 3.0 to 3.5, heating during this extraction, dialysis.

U-4127. Varangerfjord, Nesseby, INS, iso **4320 ± 320**

U-2751. **4085 ± 190**
$\delta^{13}C = -12.5‰$

Organic fraction received from parts not dissolved at initial HCl treatment of bone yielding U-4128. Solution after further HCl treatment neutralized with NaOH, precipitate dialyzed and sample then treated as U-4128.

D. Sweden

Ageröd series

Collagen from bone fragments of red deer from white layer in raised bog, Ageröds mosse, Munkarp parish, Skåne, Sweden (55° 56½′ N, 13° 25′ E). Subm 1974 by S Håkansson, Radiocarbon Dating Lab, Dept Quaternary Geol, Univ Lund, after grinding. Other half of sample dated by Håkansson, Lu-872, 7220 ± 70, $\delta^{13}C = -22.9‰$ (Håkansson, 1976).

U-4081. Ageröd I:HC, Sample 6, CN **7750 ± 80**
$\delta^{13}C = -22.9‰$

Collagen obtained after EDTA treatment (Olsson *et al,* 1974), but fraction soluble in cool water, neutral soluble, used. Diluted.

U-4082. Ageröd I:HC, Sample 6, WA **7415 ± 115**
$\delta^{13}C = -23.5‰$

Collagen obtained after same treatment as U-4081, but fraction extracted after U-4081 using hot slightly acid water used. Diluted.

General Comment: mean value of present results lower than other results from Ageröd I:HC except Lu-872 (Håkansson, 1976).

II. ARCHAEOLOGIC SAMPLES

A. Egypt

Dra Abu El-Naga series

Samples from Dra Abu El-Naga S, on W bank of Nile R opposite Luxor, Egypt (25° 43′ N, 32° 38′ E). Samples from pyramidal tomb superstructures, built of courses of mud brick separated by beddings of halfa grass with occasional use of timber reinforcement. Coll April 13 to 15, 1970 by Lanny Bell, Univ Mus, Univ Pennsylvania, Philadelphia, USA. Subm by E Ralph and H N Michael, Univ Mus, Univ Pennsylvania as interlaboratory check and joint project. Description of provenience by Fishman *et al* (R, 1977, v 19, p 198). No details concerning provenience given directly to Uppsala. Samples classified as primary, secondary or tertiary samples by Bell. Historic ages related to Ramses II. His reign supposedly started in 1290 BC. Historical ages are: Nebwenenef, Tomb 157, High Priest, 1290-1273 BC; Bekenkhons I, Tomb 35, High Priest, 1273-1223 BC; Roma-Roy, Tomb 283, High Priest, 1244-1196 BC; Tjanefer, Tomb 158, 1267-1168 BC; Inhernakht, called Nakhtmin by Fishman *et al*, Tomb 282, Chief of Bowmen of Kush, 1290-1223 BC. Ages as given by T Säve-Söderbergh, Uppsala Univ, Uppsala, Sweden (pers commun). Small portions of reed samples id by Vivi Täckholm, Bot Dept, Fac Sci, Cairo Univ, Giza, Egypt. Portions of bulk reed samples also id by D F Cutler, Jodrell Lab, Royal Bot Gardens, Surrey, England. Wood samples id by B F Kukachka, Forest Prod Lab, US Dept Agric, Madison, Wisconsin. Details concerning treatment and results given by Olsson and El-Daoushy (1978) except 2 samples for which same gas was re-dated and another 2 samples for which NaOH soluble fraction was dated.

General Comment: all samples of *Desmostachya bipinnata* (L) Stapf, have yielded $\delta^{13}C$ values between −9.8 and −12.4‰, each with an uncertainty of ca 0.5‰, for NaOH insoluble fraction. This value is typical for C_4 plants. Samples dated at Pennsylvania, pretreated with HCl but not with NaOH (R, 1977, v 19, p 188), show a strange spread in their $\delta^{13}C$ values compared with present results. Comparison of results for U-862, -2462, -5002, -2800, -869, -2469, -5004, -870, P-1732, -1739, -1441, and BM-339 implies that insoluble fractions of tertiary reeds from Tomb 157 and primary reeds from Tomb 35 might have been interchanged. New measurements underway indicate that this is the case.

U-880. Nebwenenef, Dyn XIX, P R **2815 ± 140**

U-2460. **2970 ± 80**

U-5000. **2865 ± 110**

$\delta^{13}C = -21.2‰$

Primary reeds, *Desmostachya bipinnata* (L) Stapf and *Phoenix dactylifera*, from pyramid of Nebwenenef. *Comment*: sample dated as *Phoenix dactylifera*, P-1730, 3120 ± 50, $\delta^{13}C = -19.1‰$, and P-1730-A, 3210 ± 50, $\delta^{13}C = -15.7‰$.

U-881. Nebwenenef, Dyn XIX, S R **3060 ± 125**

U-2461. **3050 ± 60**

U-5001. **3240 ± 110**
$\delta^{13}C = -10.6‰$

Secondary reeds, *Desmostachya bipinnata* (L) Stapf, from pyramid of Nebwenenef. *Comment*: sample dated as (?) *Desmostachya bipinnata*, P-1731, 3010 ± 60, $\delta^{13}C = -11.1‰$. Another secondary sample, same species, P-1825, 2940 ± 50, $\delta^{13}C = -18.0‰$, also BM-658b.

U-862. Nebwenenef, Dyn XIX, T R **1390 ± 135**

U-2462. **1360 ± 60**

U-5002. **1480 ± 110**
$\delta^{13}C = -10.9‰$

Tertiary reeds, *Desmostachya bipinnata* (L) Stapf, from pyramid of Nebwenenef. *Comment*: sample dated as (?) *Desmostachya bipinnata*, P-1732, 3030 ± 60, $\delta^{13}C = -11.9‰$.

U-2800. Nebwenenef, Dyn XIX, T R SOL **2630 ± 190**
$\delta^{13}C = -16.5‰$

In NaOH soluble fraction from pretreatment yielding U-862, -2462 and -5002. Fraction SOL yielded 1/5 amount of gas from insoluble fraction.

U-869. Bekenkhons I, Dyn XIX, P R **2965 ± 135**

U-2469. **2975 ± 70**

U-5004. **2975 ± 70**
$\delta^{13}C = -10.7‰$

Primary reeds, *Desmostachya bipinnata* (L) Stapf, from pyramid of Bekenkhons I. *Comment*: sample dated as (?) *Desmostachya bipinnata*, P-1739-A, 1660 ± 50, $\delta^{13}C = -1.4‰$. Another sample coll by Martin dated as P-1441, 1120 ± 40 and as BM-339, 1210 ± 110 (R, 1971, v 13, p 162). A 3rd sample, (?) *Desmostachya bipinnata*, dated as secondary sample, P-1440, 3000 ± 60, $\delta^{13}C = -19.0‰$.

U-870. Bekenkhons I, Dyn XIX, P R SOL **1420 ± 80**
$\delta^{13}C = -15.9‰$

In NaOH soluble fraction from pretreatment yielding U-869. Fraction SOL yielded 1/3 amount of gas from insoluble fraction.

U-2495. Roma-Roy, Dyn XIX, P R **2915 ± 80**

U-5005. **2940 ± 80**
$\delta^{13}C = -12.4‰$

Primary reeds, *Desmostachya bipinnata* (L) Stapf, from pyramid of Roma-Roy. *Comment*: sample dated as (?) *Desmostachya bipinnata*, P-1735, 3130 ± 40, $\delta^{13}C = -9.6‰$.

U-5016. Roma-Roy, Dyn XIX, S R **2595 ± 105**
$\delta^{13}C = -11.5‰$

Secondary reeds, *Desmostachya bipinnata* (L) Stapf, from pyramid of Roma-Roy. *Comment*: same gas re-dated later as U-4166 and -5048. Sample dated as (?) *Desmostachya bipinnata*, P-1736, 3280 ± 50, $\delta^{13}C = -6.6‰$.

U-4166. Roma-Roy, Dyn XIX, S R **2680 ± 95**

U-5048. **2670 ± 140**
$\delta^{13}C = -11.5‰$

Same gas as for U-5016 re-measured.

U-2497. Roma-Roy, Dyn XIX, W 1 **2925 ± 80**

U-5017. **3005 ± 110**
$\delta^{13}C = -30.8‰$

Tamarix wood from branch protruding from pyramid of Roma-Roy. *Comment*: sample dated as P-1737, 3120 ± 50, $\delta^{13}C = -25.7‰$, P-1737-A, 3020 ± 80, $\delta^{13}C = -26.6‰$. Same wood dated, according to Fishman *et al* (1977), as BM-338, 3030 ±85, $\delta^{13}C = -28.3‰$ (R, 1971, v 13, p 162) and UCLA-1395, 2880 ± 60, $\delta^{13}C = -25.2‰$ (Berger, 1970).

U-5018. Roma-Roy, Dyn XIX, W 2 **2640 ± 135**
$\delta^{13}C = -25.8‰$

Tamarix wood from branch embedded in pyramid of Roma-Roy. *Comment*: same gas re-dated later as U-2693 and U-5049. Sample dated as U-2498 and U-5019 after new pretreatment, P-1738, 3060 ± 50, $\delta^{13}C = -25.7‰$.

U-2498. Roma-Roy, Dyn XIX, W 2 **3170 ± 70**

U-5019. **2735 ± 140**
$\delta^{13}C = -26.3‰$

Same *Tamarix* wood as used for U-5018 but new pretreatment.

U-2693. Roma-Roy, Dyn XIX, W 2 **3020 ± 70**

U-5049. **2760 ± 150**

Same gas as for U-5018 re-measured.

U-866. Tjanefer, Dyn XX, P R **2805 ± 90**
$\delta^{13}C = -11.1‰$

Primary reeds, *Desmostachya bipinnata* (L) Stapf, from pyramid of Tjanefer. *Comment*: sample dated as *Desmostachya bipinnata*, P-1696, 3080 ± 60, $\delta^{13}C = -13.4‰$. Other reed samples coll by Martin dated as BM-336, 2890 ± 100, $\delta^{13}C = -14.4‰$ and UCLA-1393, 3060 ± 60, $\delta^{13}C = -11.3‰$ (R, 1971, v 13, p 162; Berger, 1970).

U-868. Tjanefer, Dyn XX, S R **2800 ± 80**

U-5028. **2790 ± 130**
$\delta^{13}C = -11.3‰$

Secondary reeds, *Desmostachya bipinnata* (L) Stapf, from pyramid of Tjanefer. *Comment*: sample dated as primary sample *Desmostachya bipinnata*, P-1698, 2990 ± 50, $\delta^{13}C = -13.4‰$.

U-2499. Tjanefer, Dyn XX, W **2910 ± 70**

U-5029. **2755 ± 55**
$\delta^{13}C = -25.2‰$

Acacia wood from branch protruding from pyramid of Tjanefer. *Comment*: sample dated as P-1699, 3010 ± 50, $\delta^{13}C = -25.7‰$. Wood coll by Martin dated as BM-337, 3080 ± 75, $\delta^{13}C = -26.9‰$ (R, 1971, v 13, p 162). One wood sample dated as UCLA-1394, 3030 ± 60, $\delta^{13}C = -24.0‰$ (Berger, 1970).

U-863. Inhernakht, Dyn XIX, P R 1 **2830 ± 95**

U-5013. **2690 ± 120**
$\delta^{13}C = -11.0‰$

Primary reeds, *Desmostachya bipinnata* (L) Stapf, from within pyramid of Inhernakht. *Comment*: sample dated as U-2803 after new pretreatment, (?) *Desmostachya bipinnata*, P-1733, 2920 ± 50, $\delta^{13}C = -3.9‰$.

U-2803. Inhernakht, Dyn XIX, P R 2 **3020 ± 110**
$\delta^{13}C = -10.2‰$

Same reed sample as used for U-863 and -5013 but new pretreatment, 2 extractions with NaOH.

U-864. Inhernakht, Dyn XIX, S R 1 **2855 ± 115**

U-5014. **2370 ± 120**
$\delta^{13}C = -11.9‰$

Secondary reeds, *Desmostachya bipinnata* (L) Stapf, from pyramid of Inhernakht. *Comment*: sample dated as U-2802 after new pretreatment, and (?) *Desmostachya bipinnata*, P-1734, 3400 ± 60, $\delta^{13}C = -8.3‰$, P-1734-A, 3340 ± 50, $\delta^{13}C = -3.0‰$.

U-2801. Inhernakht, Dyn XIX, S R 1 SOL **3110 ± 170**
$\delta^{13}C = -13.3‰$

In NaOH soluble fraction from pretreatment yielding U-864 and -5014. Fraction SOL yielded 40% of amount of gas from insoluble fraction.

U-2802. Inhernakht, Dyn XIX, S R 2 **3090 ± 110**
$\delta^{13}C = -9.8‰$

Same reed sample as used for U-864 and -5014 but new pretreatment, 2 extractions with NaOH.

III. RESERVOIR EFFECT

Western Sweden series

U-4142. Morup 2097, c **415 ± 45**

$\delta^{13}C = -12.9‰$

Balaenoptera physalus along coast at Morup, 7 km long, Halland, Sweden (56° 59′ N, 12° 24′ E). Coll Nov 24 1875, subm to Naturhist mus in 1903 and subm to ^{14}C lab by C Fredén, Sveriges Geol Undersökning, Göteborg. *Comment*: EDTA treated. Another part of same bone, also EDTA treated, had $\delta^{13}C = -14.5‰$, but this part was lost. Liquid from same EDTA-treated bone but from initial boiling in water was recovered and measured as U-2650.

U-2650. Morup 2097, H_2O **200 ± 380**

$\delta^{13}C$ *assumed* $-17.0‰$

Water extract from initial treatment of bone before EDTA treatment.

U-4168. Lysekil 437, c **360 ± 100**

$\delta^{13}C = -12.5‰$

Orcinus orca from close to Lysekil, Bohuslän, Sweden (58° 17′ N, 11° 26′ E), killed Dec 18, 1868 and subm to Naturhist mus. Subm by J Lepiksaar, Naturhist mus, Göteborg to Fredén to forward it to ^{14}C lab. Description by Malm (1871, p 79). *Comment*: EDTA treated.

Eastern Sweden series

U-4211. Nätrafjärden, Älgön, c:1 **650 ± 55**

$\delta^{13}C = -18.2‰$

Whale from Nätrafjärden, Ångermanland, Sweden (63¼° N, 18½° E). Whale trapped in winter 1657 and found dead in 1658 (Nordlander, 1934). Subm to the ^{14}C lab with aid of Åke Hörnsten, Sveriges Geol Undersökning, Stockholm and Fredén. *Comment*: EDTA treated. Gas obtained at degassing and 1st part of combustion.

U-4167. Nätrafjärden, Älgön, c:2 **640 ± 55**

$\delta^{13}C = -17.0‰$

EDTA-treated but gas obtained at final part of combustion. *Comment*: expected ^{14}C age ca 200 yr.

U-4113. Caspian Sea 4614 c **455 ± 50**

$\delta^{13}C = -15.4‰$

Phoca caspica from Kulalai, Caspian Sea (45° N, 50° E). Coll 1899, subm to Naturhist Riksmus, Stockholm by Lönnberg. Rear extremity used. Subm to ^{14}C lab by G Westergren. *Comment*: EDTA treated.

U-4219. Trosa 7771, c **220 ± 90**

$\delta^{13}C = -22.0‰$

Alces alces from close to Trosa, (ca 58° 55′ N, 17½° E) Sweden. Coll 1881. Sample bought through Nordenskiöld, subm to Naturhist

Riksmus. Subm to ^{14}C lab by Westergren to date sample free from reservoir effect of sea. *Comment*: EDTA treated.

Tromsö whaling station series

Whales hunted June 1971. Subm by Stig Skreslet, Marinbiol stasjon, Tromsø, Norway. *Comment*: bones treated with acetone before EDTA treatment and collagen as well as extract dated (Olsson *et al*, 1974).

U-878. Fin whale 1 c **−685 ± 90**

$\delta^{13}C = -18.6‰$

Collagen fraction.

U-2467. Fin whale 1 f **−605 ± 60**

$\delta^{13}C = -18.6‰$

Extract obtained by acetone treatment before EDTA treatment to yield collagen for U-878. Acetone carefully removed.

U-2466. Fin whale 2 1c **−150 ± 60**

$\delta^{13}C = -16.0‰$

Collagen fraction from 2nd fin whale.

U-2294. Fin whale 2 2w **−340 ± 55**

$\delta^{13}C = -22.8‰$

Extract obtained by water treatment before acetone treatment to yield extract for U-4012. Another piece of whale used for U-2466.

U-4012. Fin whale 2 2f **−655 ± 100**

$\delta^{13}C = -25.1‰$

Extract obtained by acetone treatment. Acetone carefully removed.

U-2421. Sperm whale 1 c **−35 ± 45**

$\delta^{13}C = -13.8‰$

Collagen fraction.

U-860. Sperm whale 1 f **580 ± 90**

$\delta^{13}C = -17.8‰$

Extract obtained by acetone treatment. Acetone carefully removed.

U-2296. Sperm whale 2 c **−275 ± 60**

$\delta^{13}C = -13.4‰$

Collagen fraction from 2nd sperm whale.

U-861. Sperm whale 2 f **−520 ± 90**

$\delta^{13}C = -24.2‰$

Extract obtained by acetone treatment. Acetone carefully removed.

General Comment: samples subm on request to prove that sea mammals reflect activity of atmosphere. Because of age of whales, fat was supposed to have higher activity than collagen, which was indicated. One sample was selected to prove importance of careful removal of organic solvents when used in pretreatment of samples for radiocarbon dating.

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UNIVERSITY OF GEORGIA RADIOCARBON DATES VI

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The Geochronology Laboratory has recently changed its name to the Center for Applied Isotope Studies to reflect its steady and diversified expansion since its conception in 1969. Initially the laboratory was set up to offer age dating services to personnel at the University of Georgia. Subsequently, the laboratory expanded its activities so as to enable it to participate in studies of an applied and basic research nature.

The new name change will in no way alter the existing radiocarbon dating program. The Center will continue to use the benzene method of sample preparation, liquid scintillation counting and operational procedures as reported in our last date list (R, 1976, v 18, p 362-370). Ages quoted for this date list are calculated with a 1σ counting error which includes statistical variation of sample count as well as background and standard. Modern standard used is 95% of NBS oxalic acid with a reference date of AD 1950.

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We gratefully acknowledge the sample preparation and technical support of Donald F Smith. Our thanks also to those contributors of samples who supplied the descriptions for inclusion in this list.

SAMPLE DESCRIPTIONS

I. GEOLOGIC SAMPLES

Alabama

Tennessee-Tombigbee Waterway Survey

Shell and charcoal from floodplain deposits of Tombigbee R in which were found remains of Pleistocene mammals. Samples coll in 1974-75 by C B Curren, Jr, and subm by C W Copeland, Jr, Geol Survey Alabama, Univ Alabama.

UGa-1073. Bogue Chitto Creek **6375 ± 95**

Shell assoc with vertebrate specimens typical of Pleistocene epoch in yellow-orange clayey sand deposits along creek, Pickens Co (33° 5′ 39″ N, 88° 16′ 56″ W).

UGa-1074. Ringo Bluff **475 ± 70**

Wood from left bank bluff of Tombigbee R, Pickens Co, in near-surface deposit of blue-gray sand and clay of late Pleistocene—early Holocene age (33° 9′ 44″ N, 88° 16′ 24″ W). *Comment* (CWC, Jr): date indicated sample was probably tree root that penetrated deposit.

UGa-1075. Tombigbee R **8425 ± 145**

Wood from Pickens Co deposit of blue-gray sand and clay deposit of late Pleistocene—early Holocene age occurring on left bank of Tombigbee R (33° 7′ 42″ N, 88° 16′ 26″ W).

UGa-1076. Pickensville **2120 ± 70**

Wood from deposit of blue-gray sand and clay of late Pleistocene—early Holocene age on right bank of diversion channel at dam construction site on Tombigbee R at Pickensville, Pickens Co (33° 12′ 34″ N, 88° 17′ 22″ W). Date indicates more recent intrusion into deposit.

UGa-1105. Pickensville **4320 ± 75**

Carbonized leaves from deposit of blue-gray sand and clay and leaves occurring as lens in Holocene gravelly sand that forms present river bank on right side of diversion channel at dam construction site at Pickensville (33° 11′ 29″ N, 88° 17′ 21″ W.) *Comment* (CWC): seems to be more recent deposit.

UGa-1077. Deposit Station **8440 ± 105**

Wood from deposit of blue-gray sand anl clay of late Pleistocene—early Holocene age exposed on right bank of Tombigbee R below Demopolis Lock and Dam, Sumter Co (32° 31′ 22″ N, 87° 53′ 4″ W).

UGa-1100. Deposit Station **8365 ± 110**

Wood from location near UGa-1077.

UGa-902. Deposit Station **5515 ± 105**

Nut hulls, charcoal, bone fragments from lens of deposit near UGa-1077.

UGa-1104. Deposit Station **11,730 ± 135**

Wood from near UGa-1077.

UGa-1099. Gainesville Dam **9590 ± 110**

Wood from deposit of blue-gray sand and clay of late Pleistocene—early Holocene age exposed in excavation of Gainesville Dam on Tombigbee R, Sumter Co (32° 50′ 39″ N, 88° 9′ 4″ W).

UGa-901. Gainesville Dam **8045 ± 120**

Wood from similar strata near UGa-1099.

Georgia

Sapelo Island series

The following dates were made on shell samples as part of project to study age and growth of this Georgia coastal island. All were taken .8 to 1m below ground surface in a gray, medium-to-coarse-grained sand layer and consisted of *Donax, Tellina, Arca, Polinices* and other beach fauna, both whole and broken. Georgia I. samples coll 1969 and dated by Darwin Chapman, Dept Geol, Univ Georgia, Athens.

UGa-23. Shell **995 ± 85**

Coll 45m S of Beach Rd and 27m E of Lighthouse Rd (31° 23′ 20″ N, 81° 16′ 28″ W), S end of island.

UGa-24. Shell **495 ± 120**

27m S of UGa-23.

UGa-25. Shell **455 ± 80**

27m S of UGa-24.

UGa-48. Shell **795 ± 40**

27m S of UGa-25.

UGa-50. Shell **4820 ± 180**

27m S of UGa-48.

UGa-59. Shell **2720 ± 215**

27m S of UGa-50.

UGa-63. Shell **2400 ± 130**

27m S of UGa-59.

UGa-67. Shell **2355 ± 130**

27m S of UGa-63.

UGa-71. Shell **2365 ± 90**

27m S of UGa-67.

UGa-76. Shell **2910 ± 85**

27m S of UGa-71.

UGa-84. Shell **155 ± 140**

27m S of UGa-76.

UGa-86. Shell **715 ± 120**

27m S of UGa-84.

UGa-94. Shell **1000 ± 70**

27m S of UGa-86.

General Comment: in general, the older, the more elevated the sample above MLW.

Blackbeard Island series

Blackbeard I. lies NE of Sapelo I. and is separated from it by Blackbeard Creek. The following shell samples were taken as above.

UGa-26. Shell **3960 ± 200**

Coll 36m N of artesian well and 26m S of N-most beach MHW mark.

UGa-96. Shell **3055 ± 150**

26m SE of UGa-26.

UGa-118. Shell **1710 ± 225**

78m SE of UGa-96.

UGa-119. Shell **Modern**

26m SE of UGa-118. *Comment*: from area touched by storm action.

UGa-115. Shell **3260 ± 110**

26m SE of UGa-119.

UGa-101. Cabretta Salt Marsh shell **1025 ± 300**

From marsh on E Cabretta I. which is a small island E of Sapelo and separated by a tidal creek.

South Carolina

Titi Peat Bog series

Peat samples from Titi #3 core at 32° 39′ N, 80° 27′ W, U S Peat Corp, Fenwich 7 1/2 Quad, South Carolina. Subm by A D Cohen, Dept Geol, Univ South Carolina, Columbia.

UGa-1319. 170 to 180cm **3340 ± 65**

UGa-1320. 244 to 252cm **4040 ± 100**

II. ARCHAEOLOGIC SAMPLES

Alabama

UGa-1235. La Grange Bluff Shelter site **2035 ± 150**

Charcoal from Feature 20, Zone A, 1 Ct 90, Colbert Co (34° 39′ N, 87° 33′ W), pit of Late Woodland McKelvey series ceramics. Date slightly older than expected.

UGa-1127. White's Bottoms **1925 ± 135**

Charcoal from Feature 3, storage pit of 1 Ra 29, Randolph Co on Little Tallapoosa R (33° 20′ N, 85° 30′ W). Middle Woodland assoc.

Above samples subm by D L DeJarnette, Mound State Mus, Moundville, Alabama, as part of Rother L Harris Reservoir Archaeol Evaluation.

Alaska

Mt Hayes 111 site series

Tangle Lakes dist, central Alaska (63° 2′ N, 146° 4′ W). Samples subm by F H West.

UGa-572. Charcoal **10,150 ± 280**

Sample from B soil horizon of paleosol which occurs widely in this region. Artifacts from Denali Complex period found 2 to 3cm above, but occur in this horizon elsewhere in excavation. Coll 1973; subm by F H West, Dept Anthropol, Univ Wisconsin, Madison. *Comment* (FHW): date corroborates dating by typologic means.

UGa-927. Charcoal **8155 ± 265**

Sample from horizon containing Denali Complex material.

UGa-974. Charcoal **6735 ± 390**

Sample from some rather large pieces of charcoal in buried A horizon. Squirrel burrow was uncovered 10cm or less from sample. *Comment* (FHW): date is younger than Denali Complex materials as would be expected from stratigraphy older than dates (SI-2171, unpub) previously run on humic acid of buried A horizon. At present, dating is not clear.

Mt Hayes 72 site series

Tangle Lakes dist, central Alaska (63° 3′ N, 146° 3′ W). Samples subm by F H West.

UGa-530. Charcoal **5480 ± 300**

Sample coll near upper surface of A horizon of buried paleosol. *Comment* (FHW): sample stratigraphically overlay cultural deposit and thus age is only minimum.

UGa-531. Charcoal **4160 ± 175**

Sample from test square, scattered between A and B horizons. *Comment* (FHW): charcoal veins were traced to surface and possibly contamination from roots occurred.

Mt Hayes 149 site series

Site in Tangle Lakes dist, central Alaska (63° 1′ N, 146° 3′ W).

UGa-941. Charcoal **9060 ± 425**

Small flakes of charcoal occurring in B horizon of buried soil, where most artifacts were recovered. *Comment* (FHW): nearby "hearth" provided too little charcoal to date, but material coll from surroundings may be contemporaneous and date Denali Complex artifacts.

UGa-950. Charcoal **4310 ± 150**

Sample from A horizon of buried soil. A few artifacts occur in A layer but were probably pushed upward by frost action. Artifact assemblage belongs to Denali Complex. *Comment* (FHW): date may be of burial of lower soil horizon, and is close to several other dates on humic acid from A horizon from Mt Hayes 111 site; see Hadleigh-West (1967), and West (1975).

Portage site series

Tangle Lakes dist, central Alaska (63° 1′ N, 146° 3′ 30″ W), on storm ridge of Landlock Lake. Samples subm by F H West.

UGa-914. Charcoal **1380 ± 125**

From middle level of what appears to be 3 component site, assoc with a side scraper.

UGa-915. Charcoal **2025 ± 225**

From area of site where middle and lower levels are difficult to differentiate. Coll 1970.

UGa-519. Charcoal **2095 ± 225**

Sample from lowest level, assoc with a few fragments of projectile points, including a tip and a base, bone fragments, and burned rocks.

General Comment (FHW): site appears to provide link between protohistoric sites of area and earlier ones. Differentiation, of middle and lower layers, is emerging. UCLA-1875A (1050 ± 90, unpub) is from same area as UGa-914.

UGa-527. He 1, Teklanika River **3820 ± 115**

Charcoal from A horizon of test pit of site near Teklanika R, Mt McKinley Natl Park (63° 40′ 35″ N, 149° 45′ 20″ W). A horizon is reddish at some locations in site, indicating possible burning. Coll 1971. *Comment* (FHW): previously run dates on site have clustered ca 3500 BP. Cultural material, representing Denali complex core and blade industry, resembles sites dated from 8 to 10,000 yr ago. Possibly, these assays date natural burn. See UGa-253 (R, 1974, v 16, p 131), Hadleigh-West (1967), and West (1962).

UGa-529. Tm 1, Charcoal **5690 ± 210**

From top of lowest cultural layer of test pit of site (63° 10′ N, 148° 10′ W) on ridge overlooking a salmon stream flowing between Stephen L and Murder L in S central Alaska. Assoc with side-notched projectile point. Coll 1971; subm by F H West.

Long Lake site series

Anchorage quad (61° 50′ N, 148° 14′ W).

UGa-949. Charcoal **6605 ± 115**

Coll 1973 from small flakes in lower portion of B horizon. Artifacts were assoc with sample.

UGa-973. Charcoal **2930 ± 370**

Coll 1973 from small flakes in upper portion of B horizon where artifacts were also found.

General Comment (FHW): site yielded material of core and blade industry. Although material has not yet been extensively studied, it is believed that site is Upper Palaeolithic which first appeared in Alaska in late Pleistocene and probably extended some millennia into Holocene. UGa-949 date is reasonable for encountered assemblage of artifacts, but UGa-973 date is perplexing for what seems to be single component site. Hopefully, further assays will clarify situation.

UGa-634. Minchumina site **2365 ± 140**

Charcoal from site in central Alaska (64° 54′ N, 152° 6′ 30″ W), Denali Complex assoc. Coll and subm by C E Holmes, Lab Anthropol, Alaska Methodist Univ, Anchorage.

Arkansas

UGa-1263. 3 Cw 151 **485 ± 120**

Charcoal from Ozarks Bluffshelter in Crawford Co (35° 42′ 0″ N, 94° 18′ 52″ W). From depth 78cm in test pit, assoc with burned nut, stone flakes, and bone. Date is reasonable. Coll and subm by L M Rabb, Univ Arkansas, Fayetteville.

Colorado

Draper Cave series

Draper Cave, 5 Cr 1, is Rocky Mt foothills cave site (38° 14′ 27″ N, 105° 7′ 34″ W), in Custer Co, ca 8km SE of Hardscrabble Mt. Total fill during cave occupation: 214cm; 1 male burial, age 28 to 30, height 168cm; cause of death not determined. Subm by I K Hagar, Colorado Archaeol Soc, Denver.

UGa-736. Charcoal **3520 ± 70**

Recovered from a fire hearth in rear of cave, ca 137cm below cave floor before excavation. Lithic samples recovered at same level indicate McKean-Duncan-Hanna occupation, Middle Archaic age.

UGa-737. Charcoal **3480 ± 65**

Recovered from only burial level (71 to 76cm), 2 grids from burial and ca 1m from mouth of cave, stratigraphically indicates same Middle Archaic age for occupation.

Montrose County site

UGa-926. Charcoal **1045 ± 60**

From deep fire pit (.4m below surface) in Roc Creek Valley, Montrose Co site, Mn 367 (38° 26′ N, 108° 55′ W). *Comment* (JV): date provides evidence that recovered material is of Fremont affinity.

UGa-1132. Charcoal **1190 ± 355**

Hill 1, Site Mn 517, sample from living floor of shallow (45cm) dwelling SW Uncompahgre Plateau, Weimer Ranch.

UGa-1274. Bone **870 ± 70**

Near surface find in unstratified Site 5 Mn 368, Weimer Ranch IV, Locality Battleship (38° 15′ N, 108° 20′ W), SW Uncompahgre Plateau. Coll and subm by Jiri Vondracek, Dept Anthropol, Metropolitan State Coll, Denver.

UGa-1046. Burke site **1620 ± 195**

Site 5 Rb 123 is on right bank of Piceance Creek ca 17.7km upstream from juncture with White R in Rio Blanco Co (39° 53′ 13″ N, 108° 15′ 6″ W), Sample from ash and charcoal concentration 155cm below datum. Agrees with UGa-1045 (R, 1976, v 18, p 364), 30cm higher in excavation. Coll by T W Stout and J L Pierson; subm by C H Jennings, Dept Anthropol, Colorado State Univ, Fort Collins.

Spring Gulch site series

5 Lr 252 Larimer Co, Livermore (40° 50′ 12″ N, 105° 12′ 30″ W) is stratified site (UGa-664, 669-673, 829, R, 1976, v 18, p 365-366) described by Kainer (1974, 1976). Samples subm by E A Morris, Lab Public Archaeol, Dept Anthropol, Colorado State Univ, Fort Collins.

UGa-1047. Feature 33 **3700 ± 105**

Charcoal from basin-shaped hearth filled with angular and slab sandstone fragments (Type II), found near top of stratigraphic Level V, Loc I.

UGa-1048. Feature 29 **3855 ± 350**

Charcoal from "surface" hearth constructed of angular and slab sandstone fragments (Type I), found in lower half of Level IV, Loc I.

UGa-1049. Feature 18 **1485 ± 130**

Charcoal from "surface" hearth constructed of angular and slab sandstone fragments (Type I), found in upper half of Level III, Loc I.

UGa-1050. Feature 21 **935 ± 140**

Charcoal from "surface" hearth constructed of angular and slab sandstone fragments (Type II), found in upper half of stratigraphic Level II, Loc I, depth 60cm.

UGa-1051. Feature 44 **880 ± 180**

Charcoal from "surface" hearth constructed of angular and slab sandstone fragments (Type I), found in 10 to 20cm level in Test Trench E, Loc III.

Louisiana

Thibodaux site series

Site 16 As 35, Assumption Parish (29° 40′ 16″ N, 91° 15′ 53″ W), extends along E bank of Bayou Boeuf from ca 1.4km N of Southern Pacific RR bridge to 0.8km S of US 90 bridge. All samples are from Test Pit I, coll and subm by Katherine Brooks and Richard Weinstein, Coastal Environments, Inc, Baton Rouge. Further discussion in Weinstein *et al* (1977).

UGa-1740. *Rangia cuneata* **515 ± 60**

30 to 40cm level, upper of 4 distinct shell lenses in pit. Lenses are separated by noncultural deposits of silty clay from overbank flooding of Bayou Boeuf. *Comment* (KB&RW): age agrees with assoc ceramics of Delta Natchezan phase, especially a sherd of Maddox Engraved, var Emerald.

UGa-1741. *Rangia cuneata* **460 ± 60**

40 to 50cm level, 2nd lens. *Comment* (KB&RW): date is also good for Delta Natchezan phase of coastal Louisiana, including Fatherland Incised, vars Fatherland and Bayou Goula and sherd of Plaquemine

Brushed, var Plaquemine sherds found. Date is somewhat later than anticipated for Plaquemine sherd but not terribly so, and also shows that 1st and 2nd lens are probably nearly contemporaneous.

UGa-1742. ***Rangia cuneata*** **975 ± 60**

From 60cm level in upper 3rd lens. *Comment* (KB&RW): date is early Medora phase (early Mississippi) and helps date a Plaquemine sherd. Date is somewhat earlier than anticipated for Plaquemine but helps define early temporal range of variety.

UGa-1743. ***Rangia cuneata*** **1070 ± 55**

Sample from level 90 to 105cm, lowest in pit, heavily compacted and containing burned shells. No ceramics of equivalent age, late Coles Creek, Bayou Ramas, were found at site and no datable sherds in this lens.

Massachusetts

Bear Swamp 2 site

M 39 81 is near Berkley, Massachusetts (41° 49′ 43″ N, 71° 6′ 31″ W). Samples subm by Carol Barnes, Dept Anthropol & Geog, Rhode Island Coll, Providence.

UGa-386. Feature 190 **4180 ± 75**

Charcoal dispersed in pit, 107cm below plow zone.

UGa-387. Feature 65 **3445 ± 80**

Charcoal dispersed in possible garbage pit, 55cm below plow zone.

UGa-388. Feature 72 **2210 ± 70**

Charcoal concentration from pit 150cm below plow zone.

UGa-913. Feature 230 **4080 ± 85**

Charcoal from deep hearth on hill isolated from main occupation area.

General Comment (CB): UGa-386 and -387 compare well with dates of Squibnocket complex artifacts found on Martha's Vineyard (Ritchie, 1969) and a previous date of 3520 ± 180 (GX-2418, unpub) for Bear Swamp 2. UGa-388 date is unexpected as site yields no materials usually assoc with this time period, but Feature 72 was unique in site and apparently does not belong with rest of occupation.

UGa-389. Bear Swamp 1 **4145 ± 65**

Charcoal assoc with red ochre burial, 60cm below base of plow zone. This site, M 39 72, is .2km from Bear Swamp 2 and date is acceptable. Sample subm by Carol Barnes.

UGa-830. Peace Haven 2 site **6460 ± 75**

Charcoal from SE Massachusetts site M 39 74 (41° 46′ 10″ N, 71° 6′ 37″ W) from base of pit 80cm below plow zone. Pit filled with sand, red ochre and few calcined bone fragments, also a unique perforated stone

object with single central hole perforated by pecking from both sides. Date indicates correlation with Otter-Creek-like points which have been found in vicinity but not assoc with charcoal. Sample subm by Carol Barnes.

Read Farm B series

Site R2-94 is Archaic site (46° 29′ N, 71° 20′ W) in Seekonk, Massachusetts. Samples coll by Arthur Staples and T E Lux; subm by T E Lux, Dept Anthropol, Providence Coll.

UGa-635. Feature A-2, charcoal **3535 ± 130**

From hearth uncovered near plow zone.

UGa-921. Feature 18, charcoal **3475 ± 70**

From hearth in pit ca .6m deep.

UGa-922. Feature 47, charcoal **3145 ± 65**

From large shallow hearth 26cm deep.

UGa-912. Ponkapoag site **4960 ± 75**

From deep feature, 3.2m, Site M 35-7 near Ponkapoag Pond (42° 12′ N, 71° 7′ W) with much flaked debris. Coll 1974 by Joseph Marshall, South Shore Chap, Massachusetts Archaeol Soc; subm by John Rosser, History Dept, Boston Coll, Chestnut Hill, Massachusetts. Site discussed in Martin (1977).

Green Hill site series

Site M 35 NW on kame terrace along Neporset R at junction of I-95 and Rte 128, 180m N of end of I-95 and Rte 128 (42° 13′ N, 71° 8′ W). Samples coll Oct 1975; subm by John Rosser, South Shore Chap Massachusetts Archaeol Soc. Earlier Green Hill site dates in R, 1975, v 17, p 109.

UGa-1236. Charcoal **4390 ± 70**

From firepit ca 3cm below surface.

UGa-1237. Wood **Modern**

From presumed basket ca 3cm below surface.

UGa-932. Charlestown Meadows, Feature 2 **4365 ± 105**

Charcoal and charred wood from well-defined circular, bowl-shaped fire pit in Westboro, Massachusetts (42° 16′ 10″ N, 71° 38′ 57″ W), between Gleason and Fisher Sts. Top diam 1.9m, total vertical range 17.5cm, beginning 5cm below base of plow zone, and cutting into glacial gravel. Possibly assoc with nearby quartz scraper fragment. Coll Nov 1974 and subm by Curtiss Hoffman, South Shore Chap, Massachusetts Archaeol Soc. *Comment* (CH): date is relatively consistent with stylistic criteria from site, which appears at present writing to be a single-component Brewerton/Squibnocket complex site.

Montana

Pretty Creek site series, 24 Cb 4 & 5

Occupation site (45° 4′ 52″ N, 108° 15′ 24″ W). Subm by K N Good, Dept Anthropol & Archaeol, Univ North Dakota, Grand Forks.

UGa-957. Charred earth and charcoal **7685 ± 580**

Contains many bits of charcoal obtained at depth 80 to 100cm.

UGa-960. Charcoal **390 ± 65**

From surface depth 7.5cm.

North Dakota

Naze site series, 32 Sn 246

Composed of 2 components, both assoc with Woodland period (46° 41′ 7″ N, 98° 35′ 38″ W). Samples subm by K N Good.

UGa-1398. Charcoal **2035 ± 70**

From Unit A, 1 of 4 test units excavated at site, from lowest of the 2 components, Level 9, 80 to 90cm below surface. No cultural features were noted at site which was composed of fire cracked rock, fragmentary faunal remains, ceramics, and chipped stone tools.

UGa-1499. Charcoal **3405 ± 85**

Recovered from profile exposed in nearby cutback at depth 2.6cm.

UGa-961. Squash seeds **1145 ± 105**

Assoc with burial at Site 32 Rm 201 excavated near Lisbon, North Dakota on Cheyenne R. Subm by K N Good.

Hendrickson III site series, 32 Sn 403

Possible fortified village site with at least 6 probable house depressions and fortification ditch surrounding site (46° 43′ 29″ N, 98° 33′ 53″ W). Samples subm by K N Good.

UGa-1396. Charcoal **425 ± 65**

From Level 5 of 3 by 4m test unit (N15 W02) which was situated so as to quarter one of these depressions. Recovered from massive heap of faunal material at base of large trash pit.

UGa-1397. Charcoal **585 ± 60**

Combined sample from 1 by 2m test unit (N21 E06), part of 14m trench bisecting fortification ditch. Although from combined levels, 3, 4, and 5, charcoal is probably from one occupation and or component.

UGa-1498. Charcoal **570 ± 85**

From same units as UGa-1396, closer to surface.

UGa-1097. Quast site, 32 Lm 234 **705 ± 70**

Located on right bank of James R, LaMoure Co (46° 28′ 15″ N, 98° 23′ 41″ W). Identified as assoc with Stutsman focus (Wheeler, 1963). Charcoal from buried hearth which also contained ceramics, lithic debitage, and faunal debris. Subm by Fred Schneider, Dept Anthropol & Archaeol, Univ North Dakota, Grand Forks.

Ohio

UGa-579. Logan site, 33 Ct 30, Feature 8 **4115 ± 455**

Charred wood and nut hull fragments from refuse pit in Clermont Co, Ohio (38° 49′ 22″ N, 84° 13′ 17″ W). Pit is near top of midden accumulation but below plow zone 22cm below ground surface in small Late Archaic base camp. Coll and subm 1973 by K D Vickery, Dept Anthropol, Univ Cincinnati. *Comment* (KDV): date is in expected range and dates McWhinney Heavy Stemmed projectile point contained within feature. This projectile point type is diagnostic for Late Archaic at least in SW Ohio and adjacent portions of Kentucky and Indiana.

Bullskin Creek site, 33 Ct 29

A Late Archaic base camp (38° 46′ 39″ N, 84° 5′ 10″ W). Coll and subm 1974 by K D Vickery.

UGa-930. Charred nut hulls and wood charcoal **4550 ± 355**

Fragments from Feature 6, earth oven originating within but near base of midden deposit, .43m below ground surface.

UGa-931. Charred wood and nut hull fragments **4470 ± 75**

From shallow pit in Feature 12, containing cache of ceremonial objects, .74m below ground surface, below base of overlying midden deposit.

DuPont site series

A large Late Archaic base camp, 33 Ha 11, Hamilton Co, Ohio (39° 6′ 35″ N, 84° 48′ 40″ W). Site originally covered > 40 acres, now only 15.

UGa-928. Nut hulls **4485 ± 75**

From earth oven originating in non-midden cultural deposit ca 46m below ground surface and assoc with a flexed burial. Coll 1974 by T S Dalbey; subm by K D Vickery.

UGa-1342. Charred nut hulls and wood charcoal **4125 ± 65**

From a deeply stratified earth oven .3m below sheet midden. Assoc with 3 burials, various artifacts and tunnel leading to another feature .9m below surface. Subm by T S Dalbey, Dept Anthropol, Univ Cincinnati, Ohio.

UGa-1343. Charcoal **4100 ± 65**

From large, possibly communal, earth oven coll at depth .75m. Top of oven occurred in plow zone and was truncated by plow; has assoc artifacts. Subm by T S Dalbey.

UGa-1344. Charred nut hulls and wood charcoal **4435 ± 65**

From shallow basin earth oven at depth 36cm. Ten artifacts were assoc with feature and a burial. Coll Jan 1975 by T S Dalbey and B J Featherstone; subm by T S Dalbey.

General Comment (TDS): all ovens showed evidence of several distinct usages. There is also evidence that inhabitants were either from or related to people of Green R, Kentucky. 31 Late Archaic burials were found at this site, which also contains extinct Ohio R mussel shells.

Sand Ridge site, 33 Ha 17

Stratified multicomponent site, Hamilton Co, Ohio (39° 6′ 7″ N, 84° 24′ 15″ W). First occupation is Late Archaic component, followed by Early Woodland, Late Woodland, and Upper Mississippian, Fort Ancient component. For discussion see Griffin (1943) and Starr (1960).

UGa-929. Charcoal **1510 ± 100**

From Test Pit A, Level 12, midden cultural deposit 1.3m below ground surface. Coll 1974 by J L Theler; subm by K D Vickery.

UGa-1333. Charcoal **1135 ± 60**

From midden, Level 8, 85cm from surface in what is believed to be top of Late Woodland component. Coll by R E Riggs, J L Theler, and T S Dalbey; subm April 1976 by Charles Oehler, Cincinnati Mus Nat Hist, Cincinnati, Ohio.

UGa-1334. Charcoal **3370 ± 110**

From burial pit, Level 18, containing semi-flexed adult female, from what is believed to be basal occupation of Upper Mississippian component; there was no break in stratigraphy. Coll by R E Riggs, J L Theler, and T S Dalbey; subm by Charles Oehler.

Krill Rockshelter site series

Bath Township, Summit Co, Ohio (41° 11′ N, 81° 40′ W). Subm by D J Metzger, Dept Sociol, Univ Akron, Ohio.

UGa-1528. Charcoal **1705 ± 75**

Sample from ca 77cm below surface in prepared fireplace. Assoc with bone fragments, grit-tempered sherds, 2 bone awls, flint chips, miscellaneous stone, including slate, hematite, and sandstone. Coll Aug 1974.

UGa-1529. Charcoal **2095 ± 95**

From surface burn area 132cm below surface. Assoc with bone fragments, ground-stone axe, flint chips, miscellaneous stone. Coll Aug 1975.

UGa-1530. Charcoal **1795 ± 265**

From fire burn area ca 15cm below surface. Assoc with bone fragments, 2 bone awls and awl fragment, 2 antler punches, grit-tempered sherds, flint chips, 2 flint tools and tool fragment, and miscellaneous stone. Call Aug 1974.

UGa-1531. Charcoal **405 ± 80**

Sample from fire pit ca 46cm below surface. Assoc with bone fragments, 1 drilled bone fragment, 1 grit-tempered sherd, flint chips, 1 point fragment, and miscellaneous stone. Coll Aug 1975.

UGa-666. Spruce, 33 Da Br-2 **12,190 ± 215**

Beaver-chewed spruce wood found below partial skeleton of ground sloth (*Megalonyx jeffersonii*) in ground moraine between Bloomer and Union City end moraines in Darke Co (40° 12′ N, 84° 12′ W) Lowell Carter farm. Coll and subm Dec 1973 by R S Mills, Dayton Mus Nat Hist, Dayton, Ohio. *Comment* (RSM): age falls in expected range. Site and fossils are discussed in Mills (1975).

Ontario, Canada

UGa-1905. Pipeline site **545 ± 85**

Charcoal from midden in Site Ai Gx-12, Halton Co, Ontario (43° 26′ 55″ N, 79° 54′ 55″ W), depth 35cm, 4th level. Coll and subm by Melanie Busby, Dept Anthropol, Trent Univ, Peterborough, Ontario. *Comment* (MB): date supports belief that site is of early prehistoric Neutral phase.

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[RADIOCARBON, VOL. 20, NO. 3, 1978, P. 502-512]

UNIVERSITY OF MIAMI RADIOCARBON DATES XIII

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The following radiocarbon dates are a partial list of samples measured since Sept 1977. The chemical and counting procedures are the same as indicated previously (R, 1978, v 20, p 134-138).

Dates are conventional calculations based on the 5568-year Libby half-life, uncorrected for isotopic fractionation in nature. $\delta^{13}C$ is reported, however, for all samples analyzed for stable C isotope ratios. Errors are reported as one-standard deviation which include only the uncertainties of measurement of the modern NBS standard, background, and sample.

ACKNOWLEDGMENTS

Kim Rudolph instituted and carried out procedures for calcite-aragonite measurements in carbonate samples.

SAMPLE DESCRIPTIONS

I. ARCHAEOLOGIC SAMPLES

United States

Western Columbia County series

Charred wood from posts of Weeden Island ceremonial structure which date time of construction. Structure was razed and covered with Mound B cap after interment of an individual. Coll and subm Oct 1977 by J Milanich, Florida State Mus, Gainesville, Florida.

UM-1234. Charred Post II **1580 ± 80**

UM-1235. Charred Post I **1490 ± 80**

UM-1260. Pinellas Co, Florida **4050 ± 80**
$\delta^{13}C = -26.01‰$

Charcoal from 50cm deep in shell midden found under overturned whelk shell, used to date habitation of site on Boca Ciega Bay (27° 49′ N, 82° 50′ W). Coll and subm 1977 by C Braley, Florida State Univ, Tallahassee.

Newcomb Hearth series

Charcoal from 4 hearth sites in Newcomb, New Mexico (36° 16′ 39″ N, 108° 42′ 22″ W) were studied to correlate and define prehistoric agricultural activities in area. Coll 1977 and subm 1978 by S Koczan, Mus New Mexico, Santa Fe.

UM-1292. Grid 81 **1510 ± 80**

$\delta^{13}C = -12.64‰$

Charcoal from circular hearth, 65cm diam, containing 4 round stones with no diagnostic artifacts or assoc architecture.

UM-1293. Feature 11 **1520 ± 140**

$\delta^{13}C = -15.80‰$

Charcoal from hearth assoc with small habitation structure and ceramic assemblage of 800 BP.

UM-1294. Feature 14 **1090 ± 90**

$\delta^{13}C = -11.82‰$

Charcoal from circular hearth, 30cm diam, with no assoc architecture.

UM-1295. Feature 10 **1240 ± 60**

$\delta^{13}C = -12.39‰$

Charcoal from rectangular hearth definable by 4 upright sandstone slabs; no assoc architecture.

Hardee Co Firepit series

Charcoal from 2 aboriginal firepits in Baird Quad in NW Hardee Co, Florida (27° 38′ 45″ N, 81° 57′ 0″ W). Coll June 1977 by B Wharton, Univ South Florida and subm Sept 1977 by R Williams, Univ South Florida, Tampa. *Comment* (RW): useful in interpreting portion of Central Gulf Coast and Manatee archaeol regions.

UM-1198. 8Hr11/B59/2 **2070 ± 70**

Charcoal from top layer of firepit found 20cm below ground surface. Assoc potsherds of ceramic vessel.

UM-1199. 8Hr11/B59/3 **1730 ± 80**

From same zone as UM-1198. $\delta^{13}C = -25‰$

UM-1200. 8Hr11/B59/1 **1710 ± 130**

$\delta^{13}C = -26.58‰$

Charcoal from 28cm below surface in same firepit as UM-1198 and -1199.

UM-1201. 8Hr11/B1/1 **1270 ± 70**

$\delta^{13}C = -26.36‰$

Charred wood from 15cm below surface in firepit containing chipped stone and pottery fragments.

UM-1202. 8Hr11/B1/2 **1170 ± 90**

From same zone as UM-1201. $\delta^{13}C = -26.50‰$

II. GEOLOGIC SAMPLES

A. Iran

Makran Coast series

Studies using shell samples from sites on Makran coast indicate amount Quaternary deformation varies greatly geographically. Degree

of movement as well as rates of movement are being studied from age/height values (Vita-Finzi, 1975; 1978). Coll and subm 1976 by C Vita-Finzi, Univ College, London, England.

UM-1256. PP(a) **20,560 ± 250**
$\delta^{13}C = -1.45‰$

Anadara uropigmelana from fossil beach (25° 09′ N, 61° 13′ E) ca +50m for comparison to UM-1145 at similar height.

UM-1145. Beris 1A **27,990 $^{+980}_{-880}$**
$\delta^{13}C = +1.40‰$

Anadara uropigmelana from coquina layer, 1m thick (25° 11′ N, 61° 11′ E) ca +50m.

UM-1160. Beris 1G **28,560 $^{+560}_{-530}$**
$\delta^{13}C = -0.59‰$

Gastropods from coquina layer, 1m thick (25° 11′ N, 61° 11′ E) ca 55m above high water exposed by narrow gullies.

UM-1148. CB1 L **27,850 $^{+730}_{-670}$**
$\delta^{13}C = 0.00‰$

Oyster shell from beach deposit (25° 16′ N, 60° 37′ E) 10cm thick and 16.65m above high water.

UM-1149. K76C (G) **5720 ± 80**
$\delta^{13}C = +1.13‰$

Gastropod fragments from fossil beach (25° 19′ N, 60° 23′ E) in 25cm thick layer on exposed cliff face 17.75m above high water.

UM-1146. K76C (B) **24,590 $^{+850}_{-770}$**
$\delta^{13}C = -0.59‰$

Balanus from fossil beach (25° 19′ N, 60° 23′ E) in pebble layer, 25cm thick, under 3.6m cross-bedded sand 17.75m above high water.

UM-1147. K76 (O) **22,090 ± 400**
$\delta^{13}C = -1.52‰$

Oyster shell from fossil beach (25° 19′ N, 60° 23′ E) in pebble layer, 25cm thick, in cliff face 17.75m above high water.

UM-1150. E Jask (1) **6620 ± 130**

Anadara uropigmelana from fossil beach (25° 39′ N, 57° 46′ E) 1m above high water that grades upward into alluvial terrace.

UM-1151. E Jask (2) **4870 ± 100**
Oliva sp from same site as UM-1150. $\delta^{13}C = +0.09‰$

UM-1159. Jask 1G **19,170 ± 380**
$\delta^{13}C = +0.12‰$

Gastropods from coquina and sand, 10cm thick, surface layer in fossil beach (25° 39′ N, 57° 48′ E) 6m above high water.

UM-1255. Tujak III(x) **6160 ± 160**
$\delta^{13}C = -0.48‰$

Asaphis deflorata from pebbly marl layer, 1m thick (26° 01′ N, 57° 14′ E) +28.6m.

UM-1268. Tujak II(b) **3310 ± 90**
$\delta^{13}C = +0.79‰$

Anadara uropigmelana in pebbly marl (26° 01′ N, 57° 14′ E) +11.8m.

UM-1269. Tujak III(b) **6110 ± 100**
$\delta^{13}C = +0.46‰$

Anadara uropigmelana from pebbly marl layer (26° 01′ N, 57° 14′ E) +28.6m.

B. Mexico

Laguna Inferior series

Marine shells from barrier dune of Laguna Inferior (16° 15′ 30″ N, 94° 36′ 40″ W) coll Sept 1977 and subm Dec 1977 by A Carranza-Edwards, Univ Naci Autonoma Mexico, Mexico 20, DF, to study past sea level at site 20m E of Laguna Inferior and +7m. One sample was divided into 3 parts.

UM-1262. A **1150 ± 80**
$\delta^{13}C = -2.19‰$

UM-1263. C **1340 ± 90**
$\delta^{13}C = -1.82‰$

UM-1264. D **1030 ± 70**
$\delta^{13}C = -2.72‰$

Laguna Mar Tileme series

Marine shells from barrier dune of Laguna Mar Tileme (16° 14′ 10″ N, 94° 50′ 50″ W) coll Sept 1977 and subm Dec 1977 by A Carranza-Edwards to study past sea level. Sample taken S of Laguna Mar Tileme, at +7m; divided into 3 parts.

UM-1265. B **2090 ± 100**
$\delta^{13}C = -2.37‰$

UM-1266. E **2100 ± 90**
$\delta^{13}C = -1.21‰$

UM-1267. F **2380 ± 80**
$\delta^{13}C = -0.50‰$

C. Algerian Slope

Calcareous sediments from Algerian Slope for correlation of carbonate and temperature curves in Western Mediterranean Basin. Coll Sept 1976 and subm Oct 1977 by P Loubere, Oregon State Univ, Corvallis, Oregon.

UM-1187. TR 173-7P **26,300 ± 700**
From core (36° 56′ N, 2° 25′ E) 484cm long, −1719m.

UM-1212. TR 173-10P **38,450 $^{+1460}_{-1230}$**
From core (37° 34.9′ N, 00° 09.4′ E) 736cm long, −1108m.

UM-1213. TR 173-16P **22,060 ± 360**
From core (36° 10.1′ N, 1° 51.4′ W) 710cm long, −1904m.

D. Belize

Carrie Bow Cay series

Four cores containing peat, marine and, terrigenous sediments coll on Belize shelf. Peat, predominantly Rhizophora, was dated to determine submergence curve for Belize shelf. Cores CB7 (16° 54′ 15″ N, 88° 15′ 50″ W), CB6 (16° 54′ 15″ N, 88° 15′ 15″ W), CB5 (16° 50′ 10″ N, 88° 8′ 40″ W) and CB2 (16° 47′ 50″ N, 88° 06′ 30″ W) are piston cores obtained with scuba. Coll 1977 by E Shinn; subm 1977 by D S Introne, Univ Miami, Miami, Florida. Depths given are below present day mean sea-level.

General Comment (DSI): acid washing only due to nature and size of samples.

UM-1248. CB7-B-A **2860 ± 100**
5.19m. $\delta^{13}C = -29.16‰$

UM-1249. CB5-B-A **7640 ± 160**
13.97m. $\delta^{13}C = -27.90‰$

UM-1250. CB5-C-B **8240 ± 140**
14.86m. $\delta^{13}C = -29.62‰$

UM-1251. CB6-A-B **8850 ± 350**
NaOH pretreatment, −7.33m. $\delta^{13}C = -27.52‰$

UM-1252. CB6-A-A **6810 ± 80**
7.01m. $\delta^{13}C = -27.23‰$

UM-1310. CB2-A **6430 ± 70**
9.61m. $\delta^{13}C = -26.11‰$

UM-1311. CB2-B **7520 ± 70**
10m. $\delta^{13}C = -27.42‰$

UM-1312. CB2-C **7340 ± 80**
10.12m. $\delta^{13}C = -27.94‰$

UM-1313. CB2-A **5010 ± 70**
Shell material incorporated within UM-1310. *Comment* (DSI): younger age implies shell material to be of burrowing variety.

UM-1314. CB2-C **4250 ± 60**
Shell material. *Comment* (DSI): younger age implies shell material to be of burrowing variety since it is assoc with UM-1312.

E. Bahamas

Orange Cay series

Peliod sand cored from Orange Cay (24° 56′ 45″ N, 79° 8′ 03″ W) studied to determine if sand in marine shoal under aeolian dune is Holocene of late Pleistocene sea level high. Coll Aug 1977 and subm Sept 1977 by D Beach and R Ginsburg, Univ Miami, Fisher Island Sta, Miami Beach, Florida.

UM-1188. OJ-3-45 **34,830 ± 680**
14m from core surface.

UM-1189. OJ-3-60 **38,650 $^{+1120}_{-980}$**
18m from core surface.

Joulters Cay Bryozoan series

Several samples of bryozoan rock, lithothaminoid rock, and consolidated ooid rock hand-picked from submerged reef in Joulters Cay, Bahamas (25° N, 78° W). Samples coll to determine regional history, development, and diagenesis of bryozoan reefs. Coll by R J Cuffey, Penn State Univ; subm 1977 by M Yukon, Univ Miami, Florida.

UM-1214. OCR-D-4 **1740 ± 110**
Consolidated ooid, 5m depth.

UM-1215. NWN-A-1 **2590 ± 100**
Bryozoan rock encrusted upon consolidated ooid, 5m depth.

UM-1216. OCR-D-2 **2990 ± 100**
Bryozoan encrusting trepostomes and cyclostomes infilled with ooids. Coll 4m below high water.

UM-1217. OCR-A-1 **2120 ± 130**
Lithothamnioid rock coll 3m below high water.

UM-1218. OCR-D-1 **2060 ± 80**

Bryozoan knob coll 4m below high water.
Lithothamnioid rock coll from reef mass 3m below surface.

UM-1219. CMM-A-1 **1730 ± 90**

F. United States

Cluett Key series

Carbonate cores from Cluett Key (25° 01′ 54″ N, 80° 51′ 42″ W) in Florida Bay studied to determine sedimentation rate on island and to ascertain that proto-dolomite in sediments is Holocene (R, 1977, v 19, p 455-456). Coll June 1975 by R Halley, USGS, Miami Beach, R Steinen, Univ Connecticut, Storrs, and subm Mar 1978 by M Calvert.

UM-1296. C1-3-1-0 **1580 ± 90**

Top of core to 2cm; no dolomite.

UM-1297. C1-3-29-0 **2620 ± 100**

28 to 30cm; no dolomite.

UM-1298. C1-3-52-0 **2475 ± 80**

51 to 53cm; no dolomite.

UM-1299. C1-3-89 **3100 ± 100**

88 to 90cm; dolomite content not known.

UM-1300. C1-3-119 **2540 ± 70**

118 to 120cm; dolomite content not known.

UM-1301. C1-3-160 **3420 ± 100**

159 to 161cm; dolomite content not known.

UM-1302. C1-3-204-41 **3500 ± 90**

203 to 205cm; sediment contains 41% dolomite.

UM-1303. C1-3-212 **3810 ± 130**

211 to 213cm; dolomite content not known.

UM-1304. C1-3-214-32 **4020 ± 90**

213 to 215cm; sediment contains 32% dolomite.

UM-1305. C1-3-260 **4310 ± 90**

259 to 261cm; dolomite content not known.

UM-1306. C1-3-279-0 **6000 ± 260**

278 to 280cm; no dolomite found in sediments which were laced with mangrove peat.

Portsmouth Island series

Peat and wood fragments for stratigraphic correlation of Back Bar-

rier I., Diamond City and Core Creek sand formations, coll and subm 1977 by J Herbert, Duke Univ, Durham, North Carolina.

General Comment (PC): tops of cores are +1 to +1.5m. Depth measurements are from top of core.

UM-1191. PB-6 (9.5m) **7780 ± 370**

Wood chips in clay layer of Diamond City formation from site N of Isa Morris Camp (34° 54′ 30″ N, 76° 14′ 30″ W).

UM-1192. PB-13 (19.8 to 21.3m) **12,720 ± 470**

Fibrous organics in clayey sand of Diamond City formation (35° 3′ 7″ N, 76° 3′ 22″ W).

UM-1193. PB-4 (15.2m) **>33,950**

Peat in silty sand layer of Core Creek sand formation from site N of Drum Inlet (34° 53′ 45″ N, 76° 15′ 45″ W).

UM-1194. PB-2 (6.5m) **6500 ± 160**

Wood in silty sand layer of Back Barrier I. formation from site N of Drum Inlet (34° 52′ 15″ N, 76° 17′ 30″ W).

UM-1195. PB-26 (1m) **530 ± 80**

Peat in fine sand layer from site near Merkle Hammock (34° 59′ 45″ N, 76° 8′ 15″ W).

UM-1196. PB-13 (14 to 15m) **7230 ± 160**

Wood chips in silty, clayey sand layer of Back Barrier I. formation (35° 3′ 7″ N, 76° 3′ 22″ W).

UM-1197. PB-38 (17.7m) **25,220 ± 480**

Wood fragments in peaty layer of Diamond City formation (35° 2′ 30″ N, 76° 3′ 45″ W).

UM-1282. PB-11 (18.3m) **30,470 $^{+800}_{-730}$**

$\delta^{13}C = -29.88‰$

Wet peaty sand layer of Diamond City formation (35° 2′ 6″ N, 76° 4′ 50″ W).

UM-1283. PB-12 (12.5m) **6560 ± 260**

$\delta^{13}C = -29.05‰$

Wood chips in sandy layer of Back Barrier I. formation. Site (35° 3′ 8″ N, 76° 3′ 30″ W) is 1.37km from UM-1197 and 1.08km from UM-1196 and -1192.

UM-1284. PB-8 (19.8 to 21.3m) **22,760 +2890 −2120**

$\delta^{13}C = -28.16‰$

Wood chips in sandy layer of Diamond City formation (34° 58′ 42″ N, 76° 09′ 45″ W).

UM-1285. PB-21 (6.7 to 7.0m) **4830 ± 170**

Wood in silty sand layer 1.13km from UM-1194.

Carolina Shoreline series

Peat, shell, and wood, coll 1977 and subm 1978 by W J Cleary, Univ North Carolina, Wilmington, for sea-level curve and shoreline studies.

UM-1261. Caswell Pond 1 **3870 ± 60**

$\delta^{13}C = -18.14‰$

Freshwater peat, 4.9m into core taken in pond at Caswell Beach (33° 54′ 35″ N, 78° 04′ 35″ W) in Pleistocene dune fields.

UM-1274. Long Beach Motel **1510 ± 90**

$\delta^{13}C = -20.96‰$

Freshwater peat outcropping on beach face at low tide at Long Beach (33° 53′ 30″ N, 78° 07′ 00″ W).

UM-1275. Sample #4 Wood **2710 ± 80**

$\delta^{13}C = -27.10‰$

Bay/Magnolia, id by R Thomas, removed from stump forest on Yaupon Beach (33° 53′ 30″ N, 78° 07′ 00″ W) at low tide.

UM-1286. **2530 ± 70**

$\delta^{13}C = -26.99‰$

Duplicate run of UM-1275.

UM-1276. Sample #6 Wood **4060 ± 90**

$\delta^{13}C = -26.67‰$

Southern Yellow Pine, id by R Thomas, removed from stump forest on Yaupon Beach (33° 53′ 30″ N, 78° 07′ 00″ W) at low tide.

UM-1287. **3820 ± 80**

$\delta^{13}C = -26.18‰$

Duplicate run of UM-1276.

UM-1288. Onslo Bch So Peat **380 ± 50**

Salt-water peat (*Spartina alteom*), id by P Hosier, outcropping on Onslow Beach (34° 32′ 55″ N, 77° 19′ 28″ W) at low tide.

UM-1289. CBSB Line 3-1-160cm **2720 ± 70**

$\delta^{13}C = -0.51‰$

Oyster shells cored from below peat outcropping on beach face of Carolina Beach (34° 03′ N, 77° 53′ W).

UM-1290. CBSB 5-7 (145 to 150cm) **1930 ± 70**
$\delta^{13}C = -0.37‰$

Bulk carbonate shells from below present marsh surface at Carolina Beach (34° 03′ N, 77° 53′ W).

Safety Valve series

Several shell and *Porites divasticata* samples taken from hand push-piston Core E of Soldier Key, Biscayne Bay, Florida (25° 35′ N, 80° 10′ W), to determine beginning of formation of safety valve tidal bar belt (UM-V, R, 1976, v 18, p 119-120). Coll and subm by J Sloan, RSMAS, Miami, Florida.

UM-1236. JLS-2:218 to 205cm **2050 ± 120**

UM-1237. JLS-2:205 to 185cm **2380 ± 90**
$\delta^{13}C = +2.02‰$

UM-1238. JLS-2:125 to 141cm **1220 ± 80**
$\delta^{13}C = +2.10‰$

UM-1239. JLS-1:340 to 350cm **1900 ± 70**
$\delta^{13}C = -0.67‰$

UM-1240. JLS-1:275 to 290cm **1470 ± 100**

UM-1241. JLS-1:155 to 165cm **1540 ± 90**
$\delta^{13}C = +2.09‰$

UM-1242. JLS-1:40 to 50cm **560 ± 60**
Porites divasticata.

Card Sound series

Red mangrove peat taken from hand push-piston core just S of Turkey Point canal ca 10km W of Biscayne Bay (25° 20′ 35″ N, 80° 20′ W). Samples obtained for initial study to determine if peat accumulation destroys bedrock by physical and chemical processes. Coll and subm 1977 by J F Meeder, RSMAS, Miami, Florida.

General Comment (JMF): implications of study show that Red Mangrove peat overlying carbonate bedrock may not be used as paleo-sea-level indicator without rate of bedrock destruction; also, mangrove hammocks seem to cause depressions found beneath them rather than being caused by them.

UM-1226. JFM 3-1:220 to 222cm **1390 ± 80**
Basal peat layer. $\delta^{13}C = -26.51‰$

UM-1227. JFM 3-1A:210 to 217cm **2620 ± 270**
$\delta^{13}C = -26.04‰$

UM-1228. JFM 3-2:187 to 195cm **4050 ± 70**
$\delta^{13}C = -26.36‰$

UM-1229. JFM 3-3:175 to 183cm **3170 ± 90**
$\delta^{13}C = -26.67‰$

UM-1230. JFM 3-7:39 to 47cm **1330 ± 70**
$\delta^{13}C = -27.17‰$

UM-1231. JFM 3-8:3 to 11cm **4030 ± 160**

La Costa I series

Sub-soil shell hash from La Costa I., Florida (26° 41′ 30″ N, 82° 14′ 30″ W). Coll to determine relative sea-level changes in Florida and barrier island formation. Coll and subm by T Barron, Univ Miami, Florida.

UM-1220. SAM 1 **760 ± 80**
$\delta^{13}C = -0.26‰$

UM-1221. SAM 2 **1140 ± 90**
$\delta^{13}C = -0.52‰$

UM-1222. SAM 5 **1880 ± 90**
$\delta^{13}C = +0.03‰$

UM-1223. SAM 4 **2310 ± 80**
$\delta^{13}C = -0.02‰$

UM-1224. SAM 3 **2230 ± 90**
$\delta^{13}C = -0.17‰$

UM-1225. SAM 6 **1200 ± 110**
$\delta^{13}C = -0.33‰$

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LABORATORIES

* Inactive Laboratories have been removed from this list. They are available, separately, upon request from the Managing Editor.

[1] The ^{3}H—Laboratorium of this institute (directed by Klaus Fröhlich) should be addressed separately.

[1a] Lists from this laboratory have not been submitted to RADIOCARBON. See Gdansk I, Acta Physica Polonica, vol 22, p 189, 1962 Gdansk II, *ibid*, vol 32, p 39, 1967.

[2] This designation Gif supersedes both Sa (Saclay) and Gsy (Gif-sur-Yvette). The only Gsy date list to be published is Gsy I (Coursaget and Le Run, RADIOCARBON, v 8).

[3] From January 1, 1961 the Gro numbers have been replaced by GrN numbers. "New" dates are referred to the NBS oxalic-acid standard.

[4] Early dates from this laboratory were given a code designation that represents the name of the sponsoring institution, e g, I (AGS) for American Geographical Society (Heusser, RADIOCARBON SUPPLEMENT, v 1).

[5] Formerly Hazelton Nuclear: code designation HNS has been dropped.

[6] Some dates from this laboratory were published with the code designations S (Pringle *et al*, 1957, Science, v 125, p 69-70).

[7] See SM.

[8] See Gif.

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