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NOTICE TO READERS AND CONTRIBUTORS

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

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 In addition, we will be publishing compilations of published *and unpublished* dates along with interpretative text for these dates on a regional basis.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

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

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

For	*Date*
Vol 30, No. 1, 1988	Sept 1, 1987
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Half life of ^{14}C. In accordance with the decision of the Fifth Radiocarbon Dating Conference, Cambridge, 1962, all dates published in this volume (as in previous volumes) are based on the Libby value, 5570 ± 30 yr, for the half life. This decision was reaffirmed at the 11th International Radiocarbon Conference in Seattle, Washington, 1982. Because of various uncertainties, when ^{14}C measurements are expressed as dates in years BP the accuracy of the dates is limited, and refinements that take some but not all uncertainties into account may be misleading. The mean of three recent determinations of the half life, 5730 ± 40 yr, (Nature, v 195, no. 4845, p 984, 1962), is regarded as the best value presently available. Published dates in years BP can be converted to this basis by multiplying them by 1.03.

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

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

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

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

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RADIOCARBON AGE ANOMALIES IN SHELL CARBONATE OF LAND SNAILS FROM SEMI-ARID AREAS

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ABSTRACT. Radiocarbon age anomalies, resulting from ingestion of old carbonate, were measured in shell carbonate of live-collected snails from arid and semi-arid areas of Israel and the West Bank. The age anomalies were found to be similar to those in land snails from other climatic regions and averaged ca 1600 yr in *Trochoidea seetzeni*, 2200 yr in *Sphincterochila* spp, 800 yr in *Levantina* sp, and 1700 yr in coastal dune species. The differences are associated with ecological differences among taxa. The uncertainties of the age anomalies average several hundred years within each group. This renders radiocarbon dates of late Holecene snails relatively imprecise, whereas it has almost no effect on the age uncertainties of relatively old samples (*ie,* those with large errors of measurement). Procedures for correction for fractionation are discussed.

INTRODUCTION

Land snails have a habit that is unfortunate for one wishing to radiocarbon date their shells: they ingest calcium carbonate, which is digested to CO_2, dissolved in the body fluids, and subsequently incorporated into their shells. Since the carbonate available to land snails is generally old (depleted in ^{14}C), it confers an age anomaly to the shell carbonate (Goodfriend & Stipp, 1983). This age anomaly has been shown to occur in land snails from temperate regions (Tamers, 1970; Burleigh & Kerney, 1982; Evin *et al,* 1980) as well as tropical regions (Tamers, 1970; Goodfriend & Stipp, 1983) and has a maximum of ca 3000 yr (Goodfriend & Stipp, 1983). The age anomaly in fossil land snail shell carbonate can be corrected for by estimation of the age anomaly in live-collected shells of the same or similar species from a similar substrate. However, the variability of the age anomaly may result in dates with low precision (Goodfriend & Stipp, 1983).

In the present study, ^{14}C concentrations in live-collected land snails from the Negev Desert in Israel and Judean Desert in the West Bank (mean annual rainfall 80–200mm) and from the Mediterranean coastal dunes of Israel (rainfall 400–500mm) were analyzed in order to estimate the carbonate age anomalies and their variabilities. For most of the species, calcium carbonate is available from sediments—loess (or redeposited loessial sediments) in the case of the desert snails and sand in the case of the dune snails. *Levantina* sp lives on limestone, which may serve as a carbonate source.

MATERIALS AND METHODS

Most of the land snail shells analyzed here were collected before thermonuclear bomb tests raised atmospheric ^{14}C to unnatural levels (ca 1960).

Such material is preferred since precise estimates of age anomalies require precise information on atmospheric ^{14}C at the time of shell formation. Since the early 1960s, atmospheric ^{14}C levels have been decreasing steadily (currently at the rate of ca 2%/yr). For snails that live more than one year, the exact age of the snail must be known in order to estimate atmospheric levels at the time of shell deposition. Furthermore, for species with continuous growth, atmospheric carbon may be integrated over many years. Analysis of postbomb samples was therefore limited to species that have annual life cycles (*Theba pisana* and *Xeropicta vestalis*) (Heller, 1982; Heller & Volokita, 1981) and to juveniles (≤1 yr old) of multi-annual species (*Trochoidea seetzeni,* sample RT-675). Radiocarbon measurements of the annual species were provided by Dr A Kaufmann of the Weizmann Institute of Science.

Shells were scrubbed thoroughly on the outside with a toothbrush and broken open; the inner whorls were then removed and the shells scrubbed on the inside. Sonication was used in some cases to remove adhering organic material. The cleaned shells were briefly washed with dilute HCL, then rinsed with distilled water and dried. The shells were reacted with HCL under vaccum and the CO_2 generated was collected and converted through acetylene to ethane. ^{14}C was measured by gas counting (Carmi, Noter & Schlesinger, 1971; Carmi, in press).

Age anomalies were calculated in the following manner. The relative ^{14}C activity of shell carbonate (uncorrected for fractionation) was calculated as the ratio of the measured ^{14}C activity (corrected for decay of ^{14}C between the time of collection and the time of measurement) to the estimated ^{14}C activity of atmospheric CO_2 at the time of shell formation.

CORRECTION FOR FRACTIONATION

In order to correct the relative ^{14}C activity for isotopic fractionation, we need to know 1) the proportion of shell carbonate carbon derived from non-carbonate sources (*ie,* from plant matter and atmospheric CO_2) and 2) the $\delta^{13}C$ of this fraction. This is because the correction for fractionation applies only to this fraction and not to that derived from ingested carbonate (Goodfriend & Hood, 1983) (assuming no fractionation between dissolved bicarbonate and the shell carbonate precipitated from it; see Goodfriend & Hood (1983) for discussion of this assumption).

The proportion of non-carbonate-derived carbon is approximately equal to the relative ^{14}C activity, assuming the carbonate is devoid of ^{14}C (not strictly true—see discussion below). Formally,

$$A_m \approx P_{nc}(A_a) + (1 - P_{nc})(A_c), \quad (1)$$

where A_m = measured ^{14}C activity of shell (decay-corrected), P_{nc} = proportion of shell carbonate not derived from a carbonate source, A_a = contemporary atmospheric ^{14}C activity (corrected for fractionation), and A_c = ^{14}C activity of ingested carbonate. This result is only approximate since the A_m value is not (yet) corrected for fractionation. If $A_c = 0$, then

$$P_{nc} \approx A_m/A_a, \quad (2)$$

which is the relative ^{14}C activity of the shell.

The measured $\delta^{13}C$ of the shell carbonate represents a mixture of the $\delta^{13}C$ of the carbonate-derived and non-carbonate-derived carbon:

$$\delta^{13}C_m = P_{nc}(\delta^{13}C_{nc}) + (1 - P_{nc})(\delta^{13}C_c), \tag{3}$$

where $\delta^{13}C_m$ is the measured ^{13}C value of the shells, and $\delta^{13}C_{nc}$ and $\delta^{13}C_c$ are the ^{13}C values of the non-carbonate and carbonate fractions, respectively. Rearranging this to solve for $\delta^{13}C_{nc}$, we get

$$\delta^{13}C_{nc} = \frac{\delta^{13}C_m - (1 - P_{nc})(\delta^{13}C_c)}{P_{nc}}. \tag{4}$$

Substituting for P_{nc} from Equation 2, we get

$$\delta^{13}C_{nc} \approx \frac{\delta^{13}C_m - (1 - A_m/A_a)(\delta^{13}C_c)}{A_m/A_a}. \tag{5}$$

The standard formula for correction for fractionation (Stuiver & Polach, 1977) can be expressed as

$$A'_m = A_m\left(1 - \frac{2(\delta^{13}C_{nc} + 25)}{1000}\right), \tag{6}$$

where A'_m is the ^{14}C activity corrected for fractionation. Substituting for $\delta^{13}C_{nc}$ from Equation 5, we have

$$A'_m \approx A_m\left(1 - \frac{2\left(\dfrac{\delta^{13}C_m - (1 - A_m/A_a)(\delta^{13}C_c)}{A_m/A_a} + 25\right)}{1000}\right). \tag{7}$$

If $\delta^{13}C_c = 0$ (not always true—see below), then Equation 7 simplifies to

$$A'_m \approx A_m\left(1 - \frac{2\left(\dfrac{\delta^{13}C}{A_m/A_a} + 25\right)}{1000}\right). \tag{8}$$

Note that if no shell carbonate is derived from ancient carbonate sources, then $A_m = A_a$ (*ie,* the shells show no age anomaly) and the expression reduces to the standard correction for fractionation.

This new, approximately corrected estimate of ^{14}C activity, A'_m, is then substituted for the original uncorrected activity, A_m, in Equation 8 (or 7) to obtain a new, more accurate estimate, A''_m. This iterative process is continued until the ^{14}C activity converges to a constant value. In practice, the values converge rapidly, and only three iterations (estimation of A'''_m) are required to estimate the corrected ^{14}C activity to 0.01% modern. The relative ^{14}C activity is then estimated as A'''_m/A_a.

If $\delta^{13}C_c \approx \delta^{13}C_m$, then $\delta^{13}C_m \approx \delta^{13}C_{nc}$, and the correction for fractionation can be made (from Eq 6) as:

$$A'_m = A_m\left(1 - \frac{2(\delta^{13}C_m + 25)}{1000}\right), \tag{9}$$

which requires no interation for solution.

The age anomalies of the shells were calculated from the depletion in relative ^{14}C activity $(1 - A_m'''/A_a)$, which is converted to years by the usual formula.

AGE ANOMALIES IN MODERN SNAILS

Age anomalies in the 14 samples analyzed range from ca 700 to 2800 yr (Table 1), similar to the anomalies in land snails from limestone areas in the humid tropics (Goodfriend & Stipp, 1983) and moist temperate zone (Burleigh & Kerney, 1982). These results further support previous findings that indicate a maximum carbonate age anomaly of ca 3000 yr in land snails (Goodfriend & Stipp, 1983).

Differences in average age anomalies are seen among taxa: *Sphinctero-chila* spp have relatively large age anomalies, whereas *Levantina* sp has a small age anomaly, with *Trochoidea seetzeni* and the two coastal dune species having intermediate values. These differences correspond closely to the ecology of the snails. *Sphincterochila* spp eat the alga and lichen crusts on the surface of the sediments and consequently ingest very large amounts of carbonate-containing sediment, which would lead to larger age anomalies. All of the species showing intermediate values live on plants (although *T seetzeni* may also live under rocks) and descend to the ground to feed on dead plant material when conditions are moist. Gut content analysis of *T seetzeni* indicates that it occasionaly ingests sediments. *Levantina,* showing the smallest age anomalies, lives on limestone rocks and feeds on dead plant material on the ground. Gut content analysis has failed to reveal sediment. Carbonate uptake apparently occurs by dissolution and subsequent uptake of carbonate by the foot, which in some land snails is known to produce acidic secretions (Frick, 1965). This habit of these snails is apparently responsible for creation of large pits observed in limestone rocks (Danin, 1986). Carbonate might also occasionally be scraped from rocks and ingested by these snails. It is not clear why *Levantina* should have small age anomalies but a possible explanation is that the continual availability of calcium carbonate does not require the snails to take up as large an amount as in the plant-dwelling species, to which it is available only when on the ground feeding.

Within these ecological groupings of snails, variability of the age anomalies (as measured by their standard deviation) is relatively low, ca 200–500 yr (Table 2). The variance $[(SD)^2]$ of the age anomalies within a group is the sum of the variance due to the analytical uncertainty of the measurements plus the variance due to real differences in age anomalies among samples. Since the error of measurement is different for different samples, the residual variance among samples cannot be calculated exactly. However, the mean error of measurement within the group can be used to calculate the residual variation among samples approximately. Alternatively, the maximum possible variation among samples can be estimated by choosing the lowest error of measurement within the group as representative of each sample. For *T seetzeni,* the error introduced by the variability of the age anomaly is calcualted as ca ± 230 (Table 2) and is not more than 250 yr, whereas for *Sphincterochila* spp it is ca ± 490 and not more than 500 yr. For

TABLE 1

Radiocarbon analyses of shell carbonate of live-collected land snails from Israel and the West Bank. PMC = % modern carbon. Contemporary ^{14}C values for comparison to pre-bomb shells were taken from Stuiver (1982), for 1974 shells from Barrette *et al* (1980), and for 1984 shells from extrapolation of data in Segl *et al* (1983). For pre-bomb shells, a correction was made for the decay of ^{14}C that occurred between the time of collection and the time of measurement (1985–1986).

Species	^{14}C Lab no	Colln yr	^{13}C (‰)	Shell ^{14}C ± SD (PMC)*	Contemporary ^{14}C (PMC)**	Relative shell ^{14}C (PMC)**	Age anomaly ± SD (yr)
Negev and Judean Deserts							
Trochoidea seetzeni	RT-675	1984	−5.50	96.9 ± 2.6	120	77.7	2030 ± 220
	RT-712C	1949	−4.42	85.7 ± 2.6	98	83.9	1410 ± 240
	RT-712D	1955	−5.16	85.9 ± 1.7	98	84.2	1380 ± 160
	RT-755	1946	−4.20	83.7 ± 1.7	98	81.9	1610 ± 160
Sphincterochila zonata	RT-693	1942	−2.41	79.5 ± 2.3	98	77.5	2050 ± 180
	RT-712E	1941	−1.90	83.3 ± 1.4	98	81.1	1680 ± 140
	RT-751A	1946	−0.06	74.8 ± 1.0	98	72.5	2590 ± 110
	RT-752	1946	−0.10	72.3 ± 1.0	98	70.3	2840 ± 110
Sphincterochila fimbriata	RT-712B	ca 1950	−3.52	82.2 ± 1.7	98	80.3	1760 ± 170
Levantina sp	RT-712A	1949	−3.51	91.7 ± 2.4	98	89.6	880 ± 200
	RT-756	ca 1950	−7.53	93.5 ± 1.3	98	92.1	660 ± 110
Coastal dunes							
Theba pisana	RT-474C	1974	−9†	117.4 ± 2.4	144	78.9	1900 ± 200
	RT-474D	1974	−9.52	120.5 ± 5.1	144	81.1	1680 ± 420
Xeropicta vestalis	RT-474E	1974	−8.32	122.5 ± 2.8	144	82.2	1570 ± 230

* Uncorrected for fractionation
** Corrected for fractionation
† Estimated value, no measurement available

TABLE 2

Mean and standard deviation of radiocarbon age anomalies of shell carbonate (corrected for fractionation) for various groups of land snails

Group	Source of data	N	Mean relative ^{14}C activity	Mean age anomaly ± SD (yr)	Mean error of measurement (yr)	Residual SD of age anomaly (yr)
T seetzeni, Israel	This study	4	0.819	1610 ± 300	195	230
Sphincterochila spp, Israel and West Bank	This study	5	0.763	2180 ± 510	140	490
Coastal dunes, Israel	This study	3	0.807	1720 ± 170	280	(0)
Jamaica*	Goodfriend & Stipp (1983)	5	0.799	1800 ± 1180	80	1180
England**	Burleigh & Kerney (1982)	3	0.871	1110 ± 310	80	300

* With the correction for fractionation recalculated as described here. Data included for pre-bomb samples of various species from limestone areas plus one sample of immature post-bomb shells.

** With the correction for fractionation recalculated as described here. Data include 1 pre-bomb and 2 post-bomb samples of two species. For post-bomb samples, age anomalies were calculated in relation to plant values of the year prior to collection (data in Barrette *et al*, 1980). Age anomalies of the post-bomb samples are underestimated if the shell carbonate is >1 yr old (by ca 200 yr/yr of shell age).

the coastal dune snails, the variation among samples is actually less than the error of measurement of any of the samples, thus indicating no measurable variability in age anomalies among samples. All of these estimates must be considered approximate because of the small number of samples (3–5) on which they are based.

CORRECTION FOR FRACTIONATION: EVALUATION OF ASSUMPTIONS

As discussed above, the procedure for correction for fractionation assumes that the carbonate source that produces the shell carbonate age anomaly has no ^{14}C and has $\delta^{13}C = 0$ (typical values for limestones) in the simplified version (Eq 8). The effect that deviations from these assumed values have on the calculated ages is now considered.

If the old carbonate source has some ^{14}C activity, then the proportion by which the relative shell ^{14}C activity is depleted is an underestimate of the proportion of shell carbonate derived from old carbonate. The correction for fractionation is therefore correspondingly less. Carbonate in sand collected from the surface at the same site as the coastal dune snail samples RT-474D and E was found to have a ^{14}C activity of 4.1 ± 0.5% modern (RT-720), corrected for fractionation. The difference between this and 0% modern is negligible for calculations of the proportion of non-carbonate-derived shell carbonate for correction for fractionation. However, carbonate in loessial sediments in the Negev shows significant ^{14}C activity. A sample of the surface crust carbonate from the same site as *S zonata* sample RT-693 gave a value of 27.8 ± 0.5% modern (RT-719). In order to produce the 22.9% depletion in ^{14}C measured in this *S zonata* sample, 31.7% of its shell carbonate would have to have been derived from loess carbonate. This reduces the correction for fractionation for the non-carbonate-derived portion of the shell carbonate from 3.6% to 3.0%, equivalent to a 50-yr increase in the estimated ^{14}C age or decrease in the estimated age anomaly. This amount is small in relation to the uncertainty of the age anomaly of a sample of any of the species. Other Negev surface crust samples show similar (28.0 ± 0.6% modern; RT-785C) or lower (13.4 ± 0.5% modern; RT-785A) ^{14}C activity.

The $\delta^{13}C$ of the surface crust carbonate may deviate from the value of 0‰ used in the age anomaly calculations because of pedogenic alteration (reprecipitation of carbonate). In the Negev, surface crust carbonate $\delta^{13}C$ ranges from 0‰ in drier areas (receiving 100mm mean annual rainfall) to −6‰ in wetter areas (300mm rainfall) (Magaritz & Goodfriend, unpub data). To examine the effect of values of $\delta^{13}C_c < 0$‰ on the age anomaly estimates, $\delta^{13}C_{nc}$ was recalculated from Equation 3 using the extreme value of $\delta^{13}C_c = -6$‰. For the *S zonata* sample RT-752, with the very high $\delta^{13}C_m$ of −0.1‰, the use of the extreme value of $\delta^{13}C_c$ increases the calculated age anomaly by ca 40 yr, whereas for the *T seetzeni* sample RT-675, with a low $\delta^{13}C_m$ of −5.50‰, the age anomaly is increased by ca 20 yr. As with the assumption of no ^{14}C activity of the old carbonate source, deviation from assumed value of $\delta^{13}C_c = 0$ makes little difference to the age anomaly calculations and is in the opposite direction of that due to ^{14}C activity >0. Values of $\delta^{13}C_c < 0$ should occur in pedogenetically altered carbonates. Such carbonates will also tend to show ^{14}C activity >0. Thus the small errors in calculated shell age anomalies due to each will tend to cancel each other.

RADIOCARBON AGE CORRECTIONS IN FOSSIL LAND SNAIL SHELLS

From data on the relative ^{14}C activity of live-collected samples, estimates of the mean age anomaly and its standard deviation and the mean proportion of shell carbonate derived from non-carbonate sources (A_m/A_a) can be made, as above (Table 2). These correction factors may then be applied to apparent radiocarbon ages of fossil specimens of the same or similar species from a similar substrate. Equation 7, 8, or 9 is used (according to the assumptions concerning $\delta^{13}C_c$) to obtain the fractionation-corrected apparent age of the fossils. The age anomaly is then substracted from the apparent age to obtain the best estimate of the true age of the fossils.

However, a possible problem should be borne in mind: carbonate substrates that have some ^{14}C activity (*ie,* that contain some non-ancient carbon) may change their apparent ^{14}C ages over time. Consequently, the carbonate age anomalies of land snail shells resulting from ingestion of these materials might vary over time. In such a case, a correction for the age anomaly based on modern shells may not be strictly applicable to fossils. Substrate ^{14}C activity will tend to decrease over time as a result of aging (decay of ^{14}C) or it may increase as a result of addition of new carbonate. In loessial sediments in the Negev new carbonate is added as a result of pedogenic activity (dissolution-reprecipitation of carbonate) (Magaritz, 1986). It is not clear how the ^{14}C activity of the surface of the loess may change over time as a result of variation in the intensity of pedogenic activity.

The true standard deviation of the corrected age estimates of fossils can be calculated as the square root of the sum of the variance (SD^2) reported by the laboratory plus the residual variance of the age anomaly for the taxon, as calculated above. As discussed above, the standard deviation of this latter term varies between ca 200–500 yr for the semi-arid and arid zone land snail taxa analyzed here. English land snails (Burleigh & Kerney, 1982) have a similar variation in their age anomalies (Table 2). However, Jamaican land snails from limestone areas show considerably more variable age anomalies. This may be in part the result of ecological diversity among the taxa included in the analysis, eg, both rock-scrapers and leaf litter eaters are included.

Of the two error terms that together contribute to the uncertainty of the estimated age of a fossil (*ie,* error of measurement and uncertainty of age anomaly), the larger of the two terms will greatly predominate over the smaller in the combined error. For relatively young fossil material, it will be the uncertainty in the age anomaly that predominates. In older material and/or small samples in which the error of measurement exceeds the several hundred years of the age anomaly uncertainty, the error of measurement will largely determine the uncertainty of the corrected age. Thus, for older deposits, land snail shell carbonate can give radiocarbon dates as precise as preferred materials such as charcoal or wood, given appropriate corrections for age anomaly and fractionation. For late Holocene samples from carbonate areas, shell carbonate radiocarbon analysis will not yield precise age estimates. For such material, amino acid racemization/epimerization dating (Goodfriend, in press) may give more precise results. Accelerator mass spectrometer radiocarbon dating of shell organic matter might also give more precise dates but problems have been encountered with this method as applied to marine shells (Gillespie, Hedges & Humm, 1986).

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THE IMPACT OF BIOTURBATION ON AMS ^{14}C DATES ON HANDPICKED FORAMINIFERA: A STATISTICAL MODEL

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ABSTRACT. When single species of foraminifera picked from marine sediments are ^{14}C dated with Accelerator Mass Spectrometry (AMS), bioturbation puts limits on the minimal sample size to be used, as uncertainty is added to the result by statistics of the picking process. The model presented here simulates the additional statistical uncertainty introduced into the measurement by the coupling of bioturbation and small sample amounts. As there is no general solution for this problem, we present two simple cases only. The model can also be used to simulate more complicated situations occurring in sediments.

INTRODUCTION

With the advent of AMS it became possible to date much smaller amounts of sample material than with conventional decay-counting methods. In oceanography it became possible to ^{14}C date single species of foraminifera (Andrée *et al,* 1984). Applications are described by Broecker *et al* (1984) and Duplessy *et al* (1986). A problem with dating marine sediments originates from bioturbation, the mixing of the top few centimeters of the sediment by bottom dwelling organisms (Peng, Broecker & Berger, 1979; Berger & Killingley, 1982). The problem of statistic limitations to sampling of foraminifera has been demonstrated for chemical and stable isotope data by Boyle (1984). In this paper, the scatter introduced in radiocarbon dates by the combination of bioturbation with small sample amount is investigated.

THE PROBLEM OF SMALL SAMPLES

For AMS measurements, ca 10mg of carbonate (*ie,* a few hundred shells of a single foraminifera species) are needed. Depending on the weight of a shell, this amount of carbonate corresponds to 150 (eg, *P obliquiloculata*) to 700 (eg, *G ruber*) individual shells. If we assume homogeneous, infinitely rapid mixing of the sediment in the bioturbated layer, shells of all ages between 0 and ∞ years are, in principal, present in this layer. The number of particles of a given age will decrease exponentially with increasing age. The "decay" constant for this decrease is given by the ratio of accumulation rate to thickness of bioturbated layer. Figure 1 shows, for example, the distributions of simulated ages of single foraminifera shells for three different accumulation rates and a bioturbated layer thickness of 8cm each for constant abundance with time (Fig 1A) and for an abrupt abundance increase by a factor of five 10,000 years BP (Fig 1B). From this entity, a fraction is taken to determine the age. The question is how well the age of the fraction represents the age of the entity. With the model described below, a multiple sampling of a layer with a given age distribution can be simulated and the error of a single measurement can be estimated.

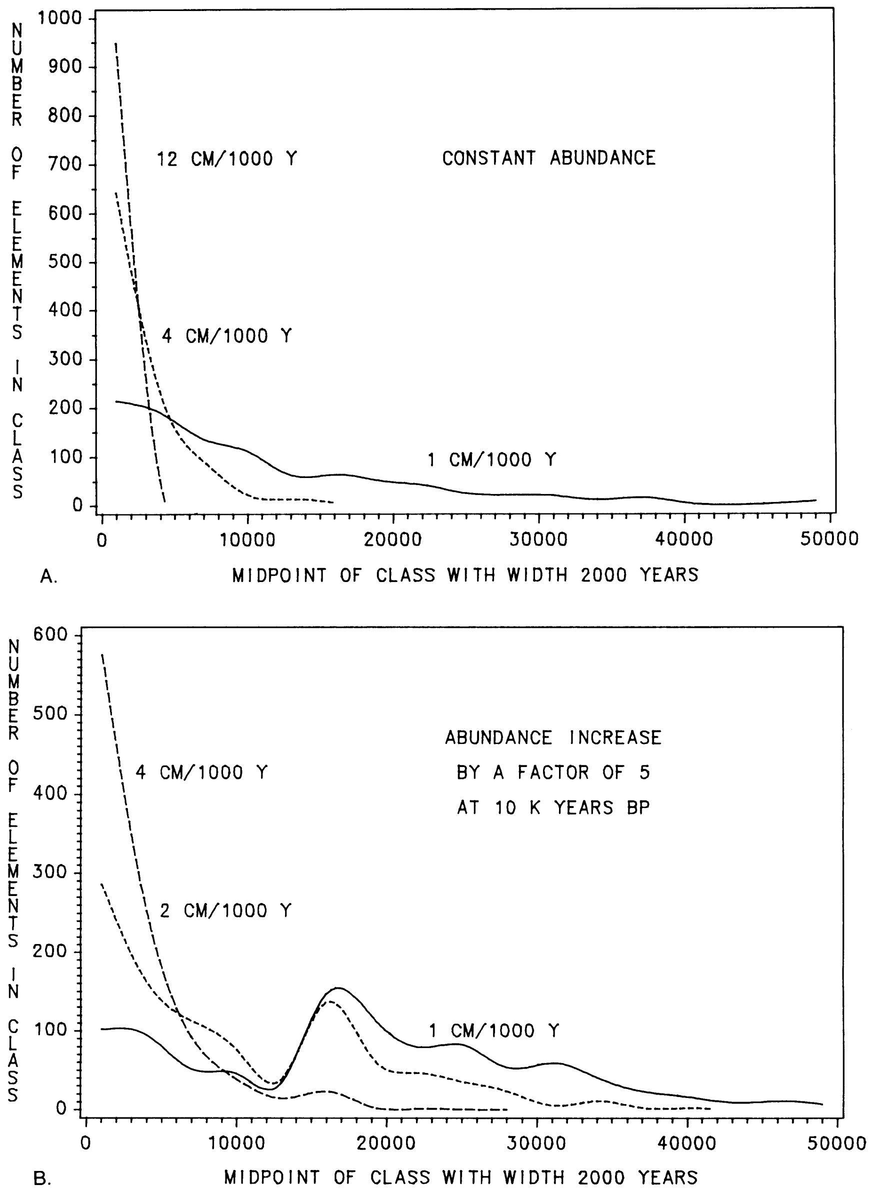

Fig 1. Distribution of simulated ages for three different accumulation rates: A. For constant abundance with time. B. For an abrupt change increasing the abundance by a factor of five before 10 ky BP.

THE STATISTICAL MODEL

The basic idea of the model is that the picking of a given number of shells from a given age distribution is simulated by random number generation.

The basic age distribution is exponential (Fig 1A) as required by the assumption of infinitely fast mixing in a reservoir with a given mean residence time of the particles, in this case, of the shells in the bioturbated layer. Slightly modified, the same model can also be applied to other tracers in sediments, eg, $\delta^{18}O$. This basic age distribution corresponds to constant abundance of a given species for all times. Then the mean age of the bioturbated layer can be calculated (Broecker & Peng, 1982):

$$t = -8033 \ln (1 + h/8.033A)$$

h is the thickness of the bioturbated layer in cm (in our case 8cm), A the accumulation rate in cm/ky and 8033 the e-folding time of radiocarbon.

The model can also be used when the abundance changes with time. In this case, changes can be defined by a discrete probability density function according to which FORTRAN library routines (IBM Numerical Algorithms Group MK10, 1983, routines G05EXF and G05EYF) select at random points from the basic exponential age distribution. An example of resulting age distributions is shown in Figure 1B.

The procedure followed by the program can be described by the following steps:

1a) Generation of random numbers according to a given probability density function.
1b) Summation of the first k_i of these random numbers according to the amount of shells needed for a given species. In this program, i allows for three different numbers per run.
1c) Calculation of the age and standard deviation defined by the sum of k_i random numbers.
2) Repetition of steps 1a to 1c 100 times and calculation of mean age and standard deviation of a single measurement from the 100 samples simulated for each species.

The printout lists all 100 individual mean ages with the asymmetric errors for all three species and the mean of the 100 measurements with the standard deviation of a single measurement.

RESULTS OF SIMULATIONS

For all simulation runs, a thickness of 8cm for the bioturbated layer was assumed. All model tests were done for two extremes of accumulation rate (1cm/ky and 12cm/ky) and all model runs additionally for the accumulation rates of 1.25, 1.6, 2.0, 2.5, 4, and 8cm/ky. These assumptions lead to mean residence times of particles in the bioturbated layer, *ie,* ratios of thickness of bioturbated layer to accumulation rate, between 8000 yr (accumulation rate 1cm/ky) and 667 yr (12cm/ky). Generalized, the results hold for all situations leading to the same mean residence times, eg, 8000 yr mean residence time is equivalent to a thickness of the bioturbated layer of

TABLE 1
Comparison of simulated bioturbated layer ages with analytically calculated ages for constant abundance

Mean residence time (yr)*	^{14}C age of bioturbated layer (yr) Calculated**	Modeled mean of repeated model runs	No. of model runs†
667	640	643 ± 4	18
1000	943	941 ± 4	3
2000	1786	1780 ± 9	3
3200	2694	2711 ± 6	3
4000	3246	3253 ± 12	18
5000	3887	3912 ± 6	3
6400	4707	4692 ± 14	3
8000	5552	5562 ± 21	21

* Ratio of thickness of bioturbated layer to accumulation rate
** Calculated with formula given in the text
† Each model run simulates the ages of $7 \cdot 10^5$ shells

TABLE 2
Reproducibility of simulated ages and errors for constant abundance

Run	150 shells mean age/error*		300 shells mean age/error*		700 shells mean age/error*	
Accumulation rate 1 cm/ky						
1	5547	354	5549	214	5532	173
2	5544	390	5566	274	5572	173
3	5566	343	5560	246	5564	172
4	5583	374	5579	269	5552	179
5	5571	371	5616	283	5596	188
6	5572	417	5547	275	5544	177
7	5531	359	5544	251	5562	193
Mean	5559	373	5566	259	5560	179
Error	19	25	25	24	21	8
Rel %	0.3	6.7	0.4	9.3	0.4	4.5
Accumulation rate 12 cm/ky						
1	645	57	643	34	644	25
2	643	49	644	34	646	23
3	638	50	641	30	643	21
4	653	59	649	41	647	24
5	636	50	641	38	641	25
6	637	46	642	34	642	24
Mean	642	52	643	35	644	24
Error	7	5	3	4	2	2
Rel %	1.1	9.6	0.5	11.4	0.3	8.3

* Mean age of 100 simulations of the age of the bioturbated layer with standard deviation from the mean

10cm and an accumulation rate of 1.25cm/ky as well as the situation presented here for 8cm and 1.0cm/ky.

Test of the Model

First the validity and performance of the model had to be checked. For this, the case of constant abundance through time was chosen, as then the

TABLE 3
Simulated uncertainties in years for different numbers of shells and accumulation rates*

Number of shells	Accumulation rate in cm/ky							
	1.0	1.25	1.6	2.0	2.5	4.0	8.0	12.0
	A. For constant abundance with time							
5							400	280
10							300	170
20							210	120
50	660	580	460	420	350	200	130	100
100	540	400	370	290	260	140	90	70
150	370	320	250	210	200	130	70	50
200	360	280	240	210	170	110	60	40
300	260	240	190	160	130	90	50	40
400	230	170	180	160	110	80	40	30
500	200	150	150	150	100	60	40	30
600	180	140	140	120	90	60	40	20
700	180	170	110	100	90	50	30	20
800	150	150	120	110	80	60	40	20
900	140	130	110	100	70	60	30	20
1000	140	130	110	90	60	50	30	20
	B. For an abrupt increase in abundance by a factor of five before 10 ky BP							
5							560	480
10							420	330
20					510	370	320	230
30					440	320		
40					380	270		
50					450	270	200	100
100					350	230	140	90
150					270	170	120	70
200	500	430	350	320	170	100	70	50
300	460	350	340	250	110	90	40	40
400	370	310	240	210	120	70	40	30
500	330	260	240	190	110	60	40	30
600	330	270	210	200	80	60	30	30
700	270	240	210	160	90	50	40	20
800	260	220	200	150	80	50	30	20
900	270	220	170	160	70	50	30	20
1000	230	200	170	130	70	50	30	20
1240				120				
1500	170		130					
1600				110				
1900		130	120	100				
2000	150							
2300		110	110					
2500	130							
2700		110						

* The values are rounded. One has to keep in mind that the uncertainty of the simulation is ca 10% of the values given here.

mean age of the bioturbated layer for a given accumulation rate can be calculated using the formula given above. As can be seen in Table 1, the model reproduces the expected mean ages of the bioturbated layer. No trend that the modeled ages would be systematically older or younger than the calculated ones is observed. Multiple runs were performed to determine the reproducibility of the results given by the model. As shown in Table 2, the standard deviation of an age determination is reproduced within ca 10% accuracy.

Simulated Situations

For eight accumulation rates and shell numbers, between 5 and 2700 (Table 3), the additional statistical uncertainty introduced into the measurement was simulated for constant abundance with time (Table 3A) as well as for an abrupt change increasing the abundance by a factor of five before 10 kyr BP (Table 3B). It was assumed that all shells have the same weight, *ie,* contribute with the same weight to the mean. It would be easy to include uneven weights into this model.

The results in Table 3 show a wide range of uncertainty which can be up to one order of magnitude larger than the measurement error of the ^{14}C date itself in unfavorable cases. Comparing Tables 3A and 3B, the difference between the two cases becomes the more pronounced, the less shells are used for a date, and the smaller the accumulation rate becomes. This is easy to understand qualitatively; as Figure 1 shows, the occurrence of old

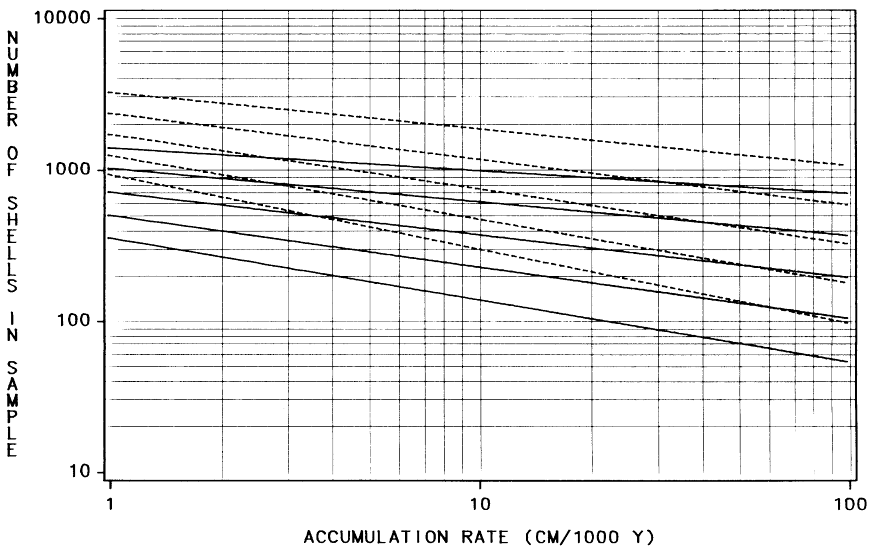

Fig 2. Plot of two sets of iso-standard deviation lines on a plot of the number of foraminifera shells per sample *vs* accumulation rate. Each set of lines indicates (from top to bottom) standard deviations of 50, 100, 150, 200, and 250 yr, respectively. A thickness of the bioturbated layer of 8cm is assumed (for generalization see text).
—— based on constant abundance with time.
----- based on an abrupt change increasing the abundance by a factor of five before 10 ky BP.

ages drops off very quickly for high accumulation rates; hence, an event in the old age tail of the age distribution is recorded only very weakly (*cf* the case of 4cm/ky accumulation, Figure 1A and 1B). On the other hand, this weak representation of the event is strong enough to show up as increased scatter when sampling only a few foraminifera shells. More detailed modeling shows that the influence on the age of the bioturbated layer becomes largest if the event occurs at the bottom of it, while the influence on the scatter in age determinations is largest if the event is placed at a depth of 1.6 times the bioturbated layer thickness.

In Figure 2 we try to summarize these results by plotting interpolated iso-uncertainty lines in a number of shells *vs* accumulation rate plot. If the accumulation rate is known and the allowable uncertainty chosen, the minimal number of shells needed can be determined.

CONCLUSION

As this work demonstrates, the interpretation of measurements on single foraminifera species is strongly affected by the sample picking strategy. For this reason, it is important to keep track of the numbers of foraminifera used for a measurement. As is evident, high accumulation rate cores are more favorable for such studies. Depending on the accumulation rate, the minimal number of shells to be picked per sample has to be estimated by modeling the deconvolved abundance trend (A C Mix, unpub model) in order to get this picking effect on the data under control. Thus, the planning of a study must include a reasonable compromise between the amount of material and work time available and the uncertainty in the results tolerable for the specific question.

ACKNOWLEDGMENTS

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[RADIOCARBON, Vol 29, No. 2, 1987, P 177–196]

BRITISH MUSEUM NATURAL RADIOCARBON MEASUREMENTS XX

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The following list consists of dates, obtained by liquid scintillation counting of benzene, for archaeologic samples mostly measured from June 1985 to June 1986.

Charcoal and grain samples were pretreated with 1M HCl followed by washing in water and, where considered necessary, with dilute alkali for the removal of humic acids. Wood samples were treated either in the same way, or, where large enough, were reduced to cellulose by the action of chlorine dioxide produced *in situ.* All antler and bone samples were treated with cold dilute acid. The term 'collagen' is used throughout to mean the acid insoluble organic fraction produced by this treatment. Peat samples were treated with dilute acid and alkali to separate the humin and humic acid fractions, which were dated separately.

The dates were obtained by liquid scintillation counting of benzene in low potassium glass vials, specially selected for similar backgrounds (Ambers, Leese & Bowman, 1986) in a Packard model 3255 scintillation counter, using PPO in toluene as a scintillator. The maximum sample size used was 5.5ml and smaller samples were made up to this volume with 'dead' benzene. Samples were counted for a minimum total period of 2000 minutes in trains containing at least 2 background and 2 modern samples. Each sample in the train was counted in successive 50-minute periods to achieve quasi-simultaneous counting. This procedure is basically the same as outlined in previous lists (see, eg, BM VIII, R, 1976, v 18, p 16).

Dates are expressed as suggested by Stuiver and Polach (1977), *ie,* in radiocarbon years relative to AD 1950, based on the Libby half-life for ^{14}C of 5570 yr, and corrected for isotopic fractionation ($\delta^{13}C$ values are given relative to PDB). The 1986 recommendations on the expression of calibrated and uncalibrated dates (R, 1986, v 28, no. 2A, p 799) have been followed. The modern reference standards are the NBS oxalic acids (SRM 4990 and RM 49).

Errors quoted are the counting error for the sample combined with an estimate of the errors contributed by the modern and background samples. This estimate includes both counting and non-counting errors, the latter being computed from differences in the overall count-rates observed among the individual backgrounds and moderns. The overall error is given as ± 1 standard deviation ($\pm 1\sigma$).

Descriptions, comments, and references to publications are based on information supplied by submitters.

Algeria

Sétif series

Samples from Islamic occupation of Roman city of Sétif, W of Constantine (36° 10′ N, 5° 20′ E). Coll 1982 and subm by T W Potter, Dept Prehist and Romano-British Antiquities, British Mus, for Elizabeth Fentress.

1230 ± 150

BM-2368. Sétif $\delta^{13}C = -20.3‰$

Charcoal, ref Th404, from layer representing destruction of Islamic structure.

1170 ± 50

BM-2369. Sétif $\delta^{13}C = -22.0‰$

Charcoal, ref Th339, from fill of deep pit, probably intended for grain storage.

General Comment (EF): BM-2368 derives from burning of Medieval house, assoc with apparently 9th century AD pottery. BM-2369, from fill of collective grain pit, confirms view that this is part of first Islamic activity on site.

British Isles

England

Chelm's Combe Shelter series

Collagen from bone samples from Chelm's Combe rock shelter (Balch, 1927), Cheddar, Somerset (51° 15′ N, 2° 50′ W, Natl Grid Ref ST 463545). Coll 1925 to 1926 by H E Balch for Somerset Archaeol Soc and subm 1985 by R M Jacobi, Univ Lancaster from colln of Wells Mus, as addition to series of dates for remains of reindeer in British Isles (see, eg, R, 1985, v 25, p 517) and as part of investigation of chronology of late glacial faunas of Cheddar area.

10,190 ± 130

BM-2318. Chelm's Combe Shelter $\delta^{13}C = -18.7‰$

Collagen from long bone (metapodial of *Rangifer tarandus*) id. by A P Currant and Juliet Clutton-Brock, British Mus (Nat Hist), from Spit 12 of excavation A in angluar limestone scree below rock-face.

10,220 ± 130

BM-2431. Chelm's Combe Shelter $\delta^{13}C = -18.9‰$

Collagen from long bone (right distal tibia of *Rangifer tarandus*) id. by A P Currant and Juliet Clutton-Brock, from Spit 7 of excavation A in angular limestone scree below rock-face.

General Comment (RJ): results provide first age estimates for one sp within rich mammal, small-mammal, and bird fauna which is presently being studied by A P Currant and C J O Harrison (British Mus (Nat Hist)). Contemporary human activity at site has still to be demonstrated.

Turnford series

Samples from Bronze Age site at Halfhide Lane, Turnford, W side of Lea Valley, Hertfordshire (51° 40′ N, 0° 00′ E, Natl Grid Ref TL 363043). Coll 1983 and subm by D S Stewart, Herts Archaeol Unit.

2650 ± 90
BM-2331. Turnford $\delta^{13}C = -24.9‰$

Charcoal, ref U40.011, (*Quercus* sp) id. by Janet Ambers, from fill of pit assoc with large group of pottery.

3320 ± 180
BM-2333. Turnford $\delta^{13}C = -25.4‰$

Charcoal, ref U72.010, from fill of shallow depression, close to possible ovens or metalworking hearths.

General Comment (DS): BM-2331 was assoc with post Deverel-Rimbury pottery and from strat was expected to date between 10th and 8th centuries BC. BM-2331 thus confirms dating based on pottery. Feature from which BM-2333 was taken is strat earlier than possible ovens or hearths; sample may be connected with scrub clearance or other activity on site.

2900 ± 70
BM-2339. Canewdon $\delta^{13}C = -27.7‰$

Wood, ref AS A7470, from broken ends of oar (estimated 17 growth rings across) found in Holocene estuarine clay deposit at Canewdon, Essex (51° 37′ N, 0° 45′ E, Natl Grid Ref TQ 924959). Coll 1983 and subm by T J Wilkinson, Archaeol Section, Essex Co Council to establish date for unique object with no assoc material. Comment by S V E Heal, Archaeol Research Centre, Natl Maritime Mus, Greenwich. *Comment* (SVEH): dates form of paddle and implied use of water transport on R Crouch. Found at contemporary high water mark, it also dates fixed point in study of tidal regime of area (Wilkinson, 1983).

4120 ± 45
BM-2346. Giants' Hills 2, Skendleby $\delta^{13}C = -23.6‰$

Collagen from distal end and shaft of tibia of *Bos primigenius* (sample ref 355), id. by J G Evans, Dept Archaeol, Univ College, Cardiff, from Layer 4 in Cutting MN, late Neolithic horizon in ditch on S side Giants' Hills 2 Long Barrow, Skendleby, Lincolnshire (53° 15′ N, 0° 10′ E, Natl Grid Ref TF 429709). Coll 1976 and subm 1985 by J G Evans to provide date for Layer 4, and as part of post-Pleistocene mammalian extinctions program (R, 1983, v 25, p 39–41); charcoal, human bone, and red deer antler from other contexts at Giants' Hills 2 are being dated at Cardiff, Oxford, and Harwell labs. *Comment* (JGE): BM-2346 is late in series of ^{14}C dates for Neolithic activity on site which spans 5450 ± 80 BP (OxA-641) to 3830 ± 60 BP (CAR-816) and derives from period of late Neolithic re-use of site represented by CAR-818, 4450 ± 70 BP, CAR-817, 4370 ± 70 BP and

CAR-816, 3830 ± 60 BP (Evans & Simpson, 1986). BM-2346 overlaps at 2σ with dates from red deer antlers from Giants' Hills 1 Long Barrow, BM-192, 4320 ± 150 BP and BM-191, 4410 ± 150 BP (R, 1969, v 11, p 278–284).

9790 ± 180

BM-2350. Seamer Carr $\delta^{13}C = -24.1‰$

Collagen from fragmentary right mandibular ramus of wild horse, *Equus ferus*, id. by Juliet Clutton-Brock, British Mus (Nat Hist), from Mesolithic site preserved in peat deposits at Seamer Carr, 4.8km W of Scarborough, Vale of Pickering, N Yorkshire (54° 15′ N, 0° 30′ W, Natl Grid Ref TA 030835). Coll 1984 by T Schadla-Hall and subm by J Clutton-Brock as part of British late Pleistocene/early Holocene extinctions program (see, eg, R, 1983, v 25, p 39–41). Comment supplied by J Clutton-Brock and R Burleigh. *Comment* (JC-B & RB): remains of wild horse from Seamer Carr were assumed to be Late Glacial, but this late date confirms that horse survived into Boreal period and was component of Seamer Carr and contemporaneous nearby Star Carr mammal fauna (*cf* Q-14, 9557 ± 210 BP; R, 1959, v 1, p 69). At present there are only two other comparable late dates for remains of horse in Britain: OxA-111, 10,000 ± 200 BP (Gillespie *et al*, 1985; Burleigh *et al*, in press), accelerator date for decorated mandible from Kendrick's Cave, N Wales, and BM-1619, 9770 ± 80 BP (R, 1982, v 24, p 262) for metapodial from Darent gravels, Sevenoaks, Kent (Clutton-Brock & Burleigh, 1981; Harrison, Clutton-Brock & Burleigh, 1981). After this period horse was absent or very rare in Britain until reintroduced as domestic animal in late Neolithic, ca 4000 BP (Clutton-Brock & Burleigh, 1986; in press).

5160 ± 45

BM-2355. Thickthorn Down *Est* $\delta^{13}C = -21.0‰$

Collagen from antler, ref sample 3, (red deer) id. by J W Jackson, from group of bone and antler found together on surface of buried soil beneath N quadrant of long barrow (Drew & Piggott, 1936) at Thickthorn Down, Gussage St Michael, Dorset (50° 55′ N, 2° 00′ W, Natl Grid Ref ST 971123). Coll 1933 and subm 1983 by R Bradley, Univ Reading for Dorset Co Mus. Sample had been treated with PVA and was cleaned with acetone but there is slight possibility of some contamination surviving pretreatment. *Comment* (RB): sample should provide *terminus post quem* for long barrow aligned on S terminal of Dorset Cursus. Date seems anomalously early compared with those for long barrows of similar form, and some contamination is likely.

Grime's Graves series

Samples from area around Canon Greenwell's pit, 19th century excavation of one of shafts in large late Neolithic flint mining complex at Grime's Graves, Weeting, Norfolk (52° 30′ N, 0° 40′ E, Natl Grid Ref TL 816898). Coll 1984 during small-scale excavation for Historic Bldgs and Monuments Comm (England), following re-excavation by British Mus in 1972 to 1976, and subm by Frances Healy, Norfolk Archaeol Unit. Results for material from 1972 to 1976 excavation and further details are given in BM X (R, 1979, v 21, p 41–47).

4060 ± 90
BM-2377. Grime's Graves $\delta^{13}C = -23.9‰$

Charcoal, ref 5640G157, from hearth on old land surface, sealed by dump of upcast surrounding flint-mine shaft.

4150 ± 90
BM-2379. Grime's Graves $\delta^{13}C = -25.7‰$

Combined charcoal sample, ref 5640G121, 122, 123, 124, 155, 105, 103, from hearth sealed by dump of upcast surrounding flint-mine shaft.

3810 ± 60
BM-2380. Grime's Graves $\delta^{13}C = -23.0‰$

Collagen from antler, ref 5640G79, from old land surface sealed by dump of upcast surrounding flint-mine shaft, assoc with flint-knapping debris.

General Comment (FH): all three dates overlap with those obtained for antler picks abandoned during working of Greenwell's pit (R, 1979, v 21, p 43–44). Dates indicate that activity in area of pit preceded its excavation by only short interval.

Brixworth series

Samples from All Saints' Church, Brixworth, Northamptonshire (52° 20′ N, 0° 55′ W, Natl Grid Ref SP 745708). Subm by D Parsons, Univ Leicester.

1370 ± 60
BM-2387. Brixworth $\delta^{13}C = -25.8‰$

Charcoal, ref 600, from immediately below mortar layer assoc with construction of church. Coll 1981.

1560 ± 60
BM-2423. Brixworth $\delta^{13}C = -11.9‰$

Mortar, ref MS 298 (63μm fraction separated using Texas method, Folk & Valastro, 1976) from surface rendering in vault in turret. Coll 1983.

General Comment (JA): BM-2423 is too early and must be contaminated with geol carbonate. Sample is part of research in ^{14}C dating of mortar to be pub elsewhere.

Barrow Hills series

Samples from series of deliberate deposits in fill of ditches of double ditched oval long barrow at Barrow Hills, Radley, Oxfordshire (51° 40′ N, 1° 15′ W, Natl Grid Ref SU 514984). Coll and subm 1984 by R Bradley, Dept Archaeol, Univ Reading.

4320 ± 130
BM-2390. Barrow Hills $\delta^{13}C = -20.6‰$

Collagen from antler, ref 293, (red deer, base of tines) id. by Annie Grant, Univ Reading, from middle fill of outer ditch of barrow. Measured for *terminus ante quem* of initial fill of outer ditch and, indirectly, of primary burial assoc with polished knife and belt slider and for comparison with other similar deposits.

4330 ± 80
BM-2391. Barrow Hills $\delta^{13}C = -21.8‰$

Collagen from antler, ref 298, (red deer, base of antler with brow tine) id. by A Grant, from lowest fill of outer ditch. Measured for *terminus ante quem* of initial fill of outer ditch, primary burial, and comparison with material from other deposits in ditches.

4500 ± 60
BM-2392. Barrow Hills $\delta^{13}C = -20.0‰$

Collagen from antler, ref 299, (red deer, fragment of beam and tines) id. by A Grant, from lowest fill of inner ditch. Measured for *terminus ante quem* of fill of ditch and, indirectly, of primary burial, and comparison with material from other deposits in ditches.

4420 ± 70
BM-2393. Barrow Hills $\delta^{13}C = -22.1‰$

Collagen from antler, ref 302, (red deer, fragment of beam and base of tines) id. by A Grant, from middle fill of outer ditch of barrow in similar position to sample 293 (BM-2390) above. Measured for *terminus ante quem* of fill of ditch and, indirectly, of primary burial, and comparison with other deposits.

General Comment (RB): dates confirm this to be late long barrow, commencing construction during lifespan of nearby Abingdon causewayed enclosure.

Wyke Down series

Samples from single-entranced pit circle henge (J Barrett, R Bradley & M Green, The prehistory of Cranborne Chase, ms in preparation) at Wyke Down, Down Farm, Woodcutts, Dorset (51° 00′ N, 2° 00′ W, Natl Grid Ref SU 006153). Coll and subm 1984 by R Bradley.

3460 ± 90
BM-2394. Wyke Down $\delta^{13}C = -23.1‰$

Collagen from bone, (fragment of right humerus of *Bos* sp) id. by A Grant, from Feature 1, Layer 3, lower fill of pit at center of henge, assoc with leaf-shaped arrowhead. Measured to check if pit is contemporary with rest of monument.

BM-2395. Wyke Down **4040 ± 90**
$\delta^{13}C = -22.5‰$

Collagen from antler (red deer), id. by A Grant, from Pit 1, Layer 5, from silt in rapidly filled pit, 1 of 27 in pit circle aligned on Dorset Cursus. Measured to date monument and for comparison with dates from Maumbury Rings (BM-2281, -2282; R, 1986, v 29, no. 1, p 64).

BM-2396. Wyke Down **4140 ± 80**
$\delta^{13}C = -22.9‰$

Charcoal (*Quercus* sp, heartwood) id. by M Robinson, Univ Mus, Oxford, from secondary recut of pit belonging to pit circle henge.

BM-2397. Wyke Down **4150 ± 50**
$\delta^{13}C = -24.1‰$

Charcoal (*Alnus,* >10 yr old, *Corylus,* >10 yr old, *Rhamnus,* up to 25 yr old, spp) id. by M Robinson from Tr K, Layer 3A, secondary recut in top of monument, apparently refilled immediately. Similar features on site contain Grooved Ware.

General Comment (RB): dates show site to be among earlier henge monuments in lowland Britain and some centuries earlier than superficially similar site at Maumbury Rings (BM-2281, -2282; R, 1987, v 29, no. 1, p 64). Wyke Down also provides some of earlier dates for Grooved Ware tradition in Wessex. BM-2394 shows central cremation to be secondary addition, most probably whilst nearby barrow cemetery was in use. Dates for Down Farm Neolithic Pits (see BM-2406, -2407, below) suggest that this settlement site, which was also assoc with Grooved Ware, was in use at same time as henge monument.

Lindow Moss series

Samples from peat close to preserved ancient male human body found in bog at Lindow Moss, Cheshire (53° 20′ N, 2° 10′ W, Natl Grid Ref SJ 812808). Coll 1985 and subm by I Stead, Dept Prehist and Romano-British Antiquities, British Mus, as part of research into age of body and surrounding environment.

BM-2398. Lindow Moss **2590 ± 170**
$\delta^{13}C = -26.1‰$

Humins, extracted from whole peat sample, ref 14, from column of weakly humified *Sphagnum* peat from underside of upper arm surface, close to skull.

BM-2399. Lindow Moss **2470 ± 250**
$\delta^{13}C = -27.7‰$

Humic acids, extracted from same whole peat sample as BM-2398, above.

2450 ± 80

BM-2400. Lindow Moss $\delta^{13}C = -25.1‰$

Humins, extracted from whole peat sample, ref 125, 16–19, from column of humified *Eriophonum* peat beside body.

2400 ± 100

BM-2401. Lindow Moss $\delta^{13}C = -26.0‰$

Humic acids, extracted from same whole peat sample as BM-2400, above.

General Comment (JA & SB): dates for humin and humic acid fraction from each peat sample agree well within counting error, indicating little mobility of humic acids within peat. Dates for 2 peat samples also agree well, as expected on strat grounds. Peat samples from above body (HAR-6562, 2290 ± 90 BP) and from upper part of peat column 125 (HAR-6565, 2280 ± 70 BP) give dates significantly later than BM dates using appropriate single-sided test, also as expected on strat grounds. Peat dates are earlier than dates for body produced by Oxford and Harwell labs. For full discussion of peat dates and details of dates for body, see Stead, Bourke & Brothwell (1986).

5890 ± 100

BM-2404. Stratford's Yard $\delta^{13}C = -22.5‰$

Collagen from 5 bone fragments (*Bos primigenius*) id. by Caroline Grigson, from Stratford's Yard, Chesham, Buckinghamshire (51° 40′ N, 0° 40′ W, Natl Grid Ref SP 960015) assoc with late Mesolithic flints. Coll 1969 by Bambi Stainton and subm by Caroline Grigson, Royal College of Surgeons, London, to provide date for assoc flint and to date *Bos primigenius* as part of late Pleistocene/early Holocene mammalian extinctions program (see, eg, R, 1983, v 25, p 39–41). *Comment* (CG): date confirms presence of *Bos primigenius* in S England in Atlantic period and id. of flint assemblage as Late Mesolithic.

1020 ± 50

BM-2405. Wansdyke $\delta^{13}C = -24.9‰$

Charcoal sample consisting of many fragments (*Quercus* sp, at least partly from young wood) id. by Jacqui Watson, English Heritage, from ditch of Wansdyke, late Roman or post-Roman linear earthwork sectioned by oil pipeline trench at Wernham Farm, Savernake, Wiltshire (51° 25′ N, 1° 45′ W, Natl Grid Ref SU 176668). Coll and subm 1985 by A J Clark on behalf of Trust for Wessex Archaeol and Esso Petroleum Co. *Comment* (AJC): layer containing sample represented stable phase in silting of ditch, prior to fill with plough soil. Beneath lay mass of large loose flints 0.5m deep, and late result indicates that these were probably derived from agric ground clearance after dyke had lost its significance, rather than from early collapse of possible bank revetment.

Down Farm Neolithic Pits series

Samples from two clusters of late Neolithic pits (Barrett, Bradley & Green, The prehistory of Cranborne Chase, ms in preparation) beside Dorset Cursus, at Down Farm, Woodcutts, Dorset (51° 00′ N, 2° 00′ W, Natl Grid Ref SU 000148). Coll 1977 and subm by R Bradley, Dept Archaeol, Univ Reading.

BM-2406. Down Farm Neolithic Pits **4140 ± 60**
$\delta^{13}C = -21.3‰$

Collagen from antler, ref 11A, (red deer, base of tine) id. by A Legge, Univ London, from upper fill of pit in one of clusters, assoc with Grooved Ware.

BM-2407. Down Farm Neolithic Pits **4080 ± 50**
$\delta^{13}C = -24.2‰$

Collagen from antler, ref 32, (red deer, base of tine) id. by A Legge, from bottom of pit in different pit cluster to BM-2406, above, assoc with Grooved Ware and complex group of artifacts.

General Comment (RB): dates suggest that this site was in use at same time as nearby Wyke Down henge monument (BM-2394 to -2397, above).

BM-2416. Down Farm **2450 ± 110**
$\delta^{13}C = -25.4‰$

Collagen from bone, ref PH12 L1 (*Bos* sp, long bone) id. by A Legge, from fill of post hole of oval structure between pond barrow and Dorset Cursus at Down Farm, Woodcutts, Dorset (51° 00′ N, 2° 00′ W, Natl Grid Ref SU 002137). Sample subm to determine *terminus ante quem* for structure and if structure is assoc with either pond barrow or cursus. Coll 1982 and subm by R Bradley. *Comment* (RB): date shows that this group of otherwise undated post holes is assoc with neither pond barrow nor cursus but relates to early Iron Age activity.

Rollright series

Samples from stone round cairn and ploughed-out round barrow near King Stone, single outlying monolith assoc with Rollright Stones megalithic complex, Great Rollright, 5 km N of Chipping Norton, Oxfordshire (52° 00′ N, 1° 30′ W, Natl Grid Ref SP 296309). Coll 1982 and 1984 and subm by G Lambrick, Oxford Archaeol Unit.

BM-2427. Rollright **3370 ± 40**
$\delta^{13}C = -21.8‰$

Charcoal, ref RR VII 15/4, (mixed *Quercus* and *Corylus* spp) id. by Vanessa Straker, Univ Bristol, from cremation deposit secondary to construction of round cairn, next to King Stone, overlying first trace of collapsed cairn material and sealed by further collapse and rubble.

BM-2428. Rollright **3480 ± 50**
$\delta^{13}C = -23.1‰$

Charcoal, ref RR VIII 17/4, (*Corylus* sp) id. by M Robinson, Univ Mus, Oxford, from cremation deposit at base of post hole in round barrow ca 40m NW of King Stone.

3320 ± 90

BM-2429. Rollright $\delta^{13}C = -24.3‰$

Charcoal, ref RR VIII 14, (*Corylus* sp) id. by M Robinson, from cremation deposit in pit in round barrow assoc with Collared Urn. Deposit was adjacent to that dated by BM-2428, above.

3490 ± 70

BM-2430. Rollright $\delta^{13}C = -23.0‰$

Charcoal, ref RR VII 24, (*Corylus* sp) id. by V Straker, from scattered deposit, assoc with burned stones and burned human tooth from possible cremation, beside round cairn, sealed by rubble spill from collapse of cairn.

General Comment (GL): BM-2427 and -2430 relate to secondary cremation assoc with round cairn recently discovered immediately adjacent to King Stone monolith. On strat grounds both deposits largely antedate accumulation of stone flakes and rubble from weathering of cairn. Very few dates previously existed for round cairns in Cotswolds and even though these determinations do not date primary construction of cairn, they are valuable in providing good agreement for *terminus ante quem.* Since they underlie most of rubble accumulation they may suggest Beaker or Early Bronze Age date for cairn rather than earlier date. BM-2428 and -2429 are from outlying cremations within area of small unditched earthen round barrow ca 30m from cairn. Strat relationships to barrow mound were destroyed by ploughing. BM-2429 is within later end of range expected for Collared Urns. BM-2428, from post-marked cremation is of interest in view of possible function of King Stone as cemetery marker. Separation of dates is slightly surprising because two deposits were immediately next to each other. Their proximity could be coincidental but may indicate longevity of marker dated by BM-2428.

4490 ± 60

BM-2438. Dorset Cursus $\delta^{13}C = -21.1‰$

Collagen from antler, ref 3820/4, (red deer) id. by A Legge, from partially stabilized surface on top of primary ditch silts and sealed by secondary silts containing Mortlake and Fengate Ware in ditch of Dorset Cursus (Barrett, Bradley & Green, The prehistory of Cranborne Chase, ms in preparation) at Down Farm, Woodcutts, Dorset (50° 55′ N, 2° 00′ W, Natl Grid Ref SU 007149). Coll 1984 and subm by R Bradley. *Comment* (RB): result is consistent with OxA-624 to -626 (Gowlett *et al,* 1986, p 122) indicating date towards end of early 5th millennium BP for monument. Date also compares well with dates from long barrow at Wor Barrow (BM-2283, -2284; R, 1987, v 29, no. 1, p 64). Being large antler pick, there is little chance that it had been moved around in soil profile during later activity and date can be regarded as more secure in context than samples subm to Oxford, which were much smaller.

Ireland

BM-2432. Toome **1030 ± 50**
$\delta^{13}C = -23.5‰$

Cellulose from wood (*Quercus* sp) from Toome, near Lough Neagh, Antrim, N Ireland (54° 45′ N, 6° 30′ W) dendrochronologically dated to decade centered on AD 1015. Supplied by M Baillie, Queen's Univ, Belfast. *Comment* (JA & SB): date, when calibrated with high-precision curve (Stuiver & Pearson, 1986) gives date range of AD 965-1030, in good agreement with known age.

Scotland

BM-2353. Synton Moss **5360 ± 50**
$\delta^{13}C = -22.1‰$

Collagen from left maxilla of *Bos primigenius*, from skeleton now in Roxburgh Mus, Hawick (accession nos. 1672–1676) found during excavation of drainage ditch, ca 0.9m below present ground surface at junction of peat and shelly marl, at Synton Moss, Ashkirk Parish, Selkirkshire (55° 30′ N, 2° 50′ W, Natl Grid ref NT 485205). Coll 1980 by A Keddie and subm 1984 by J Rackham, Dept Archaeol, Univ Durham, to date apparently strat early *Bos primigenius* remains. *Comment* (JR): no archaeol assoc, but date and previous finds from Synton Moss indicate that fuller study of site is needed. Well-preserved adult female skeleton offers useful metric inf for sp.

Cameroon

Mbi Crater series

Samples from rock-shelter at Mbi Crater, near Bafanji (6° 05′ N, 10° 20′ E). Coll 1982 and subm by R N Asombang, Inst Archaeol, Univ London.

BM-2425. Mbi Crater **4180 ± 160**
$\delta^{13}C = -24.9‰$

Bulked charcoal, ref 12, from upper deposits of Sq 7C QM4, depth 45 to 50cm from surface, assoc with lower levels of upper concentration of lithic material on site.

BM-2426. Mbi Crater **2770 ± 120**
$\delta^{13}C = -26.1‰$

Bulked charcoal, ref 9, from upper deposits in Sq 7C QM 1 + 3, depth 15 to 20cm from surface, assoc with lower levels of pottery on site.

General Comment (RNA): BM-2425 dates final late Stone Age leading to start of food production. BM-2426 indicates that food production was well established by beginning of 3rd millennium BP. Two dates are in correct stratigraphic order and compare well with other dates from region. Bone sample from lower levels of site is being dated by Oxford lab.

Hungary

E Hungarian Neolithic series

Samples dated to supplement series from Ko Békés and Ko Hajdú-Bihar, E Hungary (R, 1983, v 25, p 48–50). Coll by froth flotation as part of Hungarian Acad Sci Topographic Prog and subm by J Chapman, Univ Newcastle upon Tyne.

6020 ± 170
BM-2321. Tiszapolgár-Csöszhalom $\delta^{13}C = -24.4‰$

Charcoal from late Neolithic layer, 80 to 110cm deep, in tell at Tiszapolgár-Csöszhalom, Ko Hajdú-Bihar (47° 50′ N, 21° 20′ E). Coll 1982. *Comment* (JC): result agrees reasonably well with previous dates for site (Bln-509 to -513; R, 1970, v 12, p 412, and GrN-1993; R, 1963, v 5, p 184) obtained from excavation in 1959 to 1960 by I Bognár-Kutzian. Result is also consistent with two dates for late Neolithic Tisza culture from Kisköre (Bln-179, -515; R, 1970, v 12, p 409–410).

Szegvár-Tűzkövés series

Samples from late Neolithic Tisza deposits overlying middle Neolithic Szakalhát material in tell Szegvár-Tűzkövés, 4m high, Ko Békés (46° 40′ N, 20° 10′ E). Coll 1980.

6250 ± 190
BM-2322. Szegvár-Tűzkövés $\delta^{13}C = -24.3‰$

6120 ± 40
BM-2323. Szegvár-Tűzkövés $\delta^{13}C = -24.7‰$

Charcoal from Pit 5, Tr 23.

General Comment (JC): samples came from pit of late Neolithic Tisza culture and are rather earlier than expected by comparison with dates from Kisköre (Bln-179, -515; R, 1970, v 12, p 409–410). This may be due to contamination from Szakalhát layers or use of old timbers, which would be unrecognizable from size of charcoal pieces.

India

Zawar series

Samples assoc with zinc mining over wide area at Zawar (Craddock *et al*, 1986), Udaipur Dist, Rajasthan (23° 20′ N, 75° 50′ E). Coll 1983 and subm by P T Craddock, Research Lab, British Mus.

170 ± 50

BM-2338. Zawar $\delta^{13}C = -26.6‰$

Wood from outer 5 rings of *in situ* support timber (*Terminalia* sp), id. by Paula Rudall, Royal Botanic Gardens, Kew, from W stope, first level in Balaria mine.

2360 ± 50

BM-2381. Zawar $\delta^{13}C = -28.2‰$

Wood from outer 5 rings and bark of small branch (*Terminalia* sp), id. by P Rudall, from gallery in Mochia mine.

General Comment (PTC): BM-2338 is first date for material from inside mine to agree with dates previously obtained for zinc distillation installation on surface (BM-2222 to -2224; R, 1985, v 27, p 518–519). It is also significant that mine contains iron pyrites which is believed to have been used as flux for lead smelting at Zawar in recent times. BM-2381 shows that Mochia mine was in use during same period as mine at Zawar Mala (BM-2148, -2149; R, 1986, v 26, p 67–68).

2240 ± 60

BM-2356. Agucha $\delta^{13}C = -24.4‰$

Wood (*Terminalia* sp) id. by P Rudall, from mine prop, 30m below ground, recovered in drill core from Agucha mine, Rajasthan (25° 50′ N, 74° 30′ E). Coll 1983 and subm by P T Craddock. *Comment* (PTC): site is close to remains of 3rd century BC Mauryean settlement and is first major source of silver excavated in India. Date fits well with introduction of silver coinage to subcontinent.

1810 ± 35

BM-2364. Ingaldahl $\delta^{13}C = -24.8‰$

Wood from small branch found above 5th level in Zone N11–N13, ca 40m below surface in ancient copper mining workings at Ingaldhal mine, near Chitradurga, Karnataka (14° 15′ N, 76° 25′ E). Coll 1983 and subm by R F Tylecote for Chitradurga Copper Co as part of research into ancient mining in India. *Comment* (JA): date confirms early mining at site. For previous date from site, see PRL-252, 1680 ± 100 BP; R, 1978, v 20, p 236.

Israel

3220 ± 50

BM-2382. Timna $\delta^{13}C = -22.0‰$

Charcoal, ref 103, from Site 2, Layer II, 50cm inside slag heap at early smelting site in Timna Valley (Rothenberg, 1972; 1985), Wadi Arabah, Gulf of Aqaba (34° 55′ N, 29° 45′ E), assoc with circular tap slag. Coll 1982 and subm by B Rothenberg, Inst Archaeol-Metallurgical Studies, London. *Comment* (BR): date completes additional studies in dating copper smelting furnaces of Site 2 at Timna. It is now evident that there was secondary occupation of this late Bronze Age copper smelting site in early Islamic period (see BM-2242; R, 1985, v 27, p 519). For other dates for Timna, see BM-1115 to -1117, -1162, -1163; R, 1979, v 21, p 349–350: BM-1368, -1598; R, 1982, v 24, p 165.

Jordan

8190 ± 60

BM-2349. Dhuweila $\delta^{13}C = -12.1‰$

Charcoal, ref BDS 2202311, from layer of gray ash ca 1m below surface, underlying structure and overlying bedrock in aceramic Neolithic hunting camp at Dhuweila (Betts, 1985, p 33–34), E Jordan (32° 5′ N, 37° 15′ E) assoc with diagnostic flint implements. Coll 1983 and subm by Alison Betts, British Inst at Amman for Archaeol and Hist. *Comment* (AB): date fits well with sequence for area where PPNB seems to continue longer than in other places (Betts, 1986). Material from occupation layers at Wadi Jilat has produced dates of 8810 ± 110 BP, OxA-526, and 8520 ± 110 BP, OxA-527 (Garrard, Byrd & Betts, 1986) for strata with earlier tool kit than Dhuweila.

Pakistan

4170 ± 50

BM-2402. Lak Largai $\delta^{13}C = -23.6‰$

Charcoal sample, ref LKL1, from bottom of rubbish pit (96 to 108cm below surface) in excavation near N edge of site at Lak Largai 1, Bannu Dist, NW Frontier Prov (32° 50′ N, 70° 30′ E) assoc with 3rd millennium BP pottery. Coll 1985 and subm by K D Thomas, Inst Archaeol, Univ London. Measured to date earlier Kot Dijian settlement in Bannu Dist and for comparison with dates from Rehman Dheri (BM-2062, -2063; R, 1983, v 25, p 52). *Comment* (KDT): date is, as expected, rather earlier than date for Islam Chawki (BM-2403, below) and compares well with early dates from Rehman Dheri (PRL-674 to -676; R, 1985, v 27, p 101), where similar (?) pre- and early Kot Dijian pottery was found.

3840 ± 110

BM-2403. Islam Chawki $\delta^{13}C = -24.1‰$

Charcoal, ref ISC1, from ashy material lying on floor deposit, 14cm below surface, in small excavation on W edge of mound at Islam Chawki (Chauki), Bannu Dist, N W Frontier Prov (33° 00′ N, 70° 30′ E). Coll 1985 and subm by K D Thomas. Measured to date important Kot Dijian mound and Late Kot Dijian of region, and to compare with other date for site (BM-1941; R, 1983, v 25, p 51, pub under alternative transliteration of site name, Islam Chauki). *Comment* (KDT): date is rather earlier than other date for site (BM-1941) but is in line with expected dates for Kot Dijian and with dates for nearby site of Tarakai Qila (BM-1690 to -1695; R, 1982, v 24, p 281).

Poland

Wierzbica series

Charcoal from prehistoric flint mine at Zele, Wierzbica, Radom (51° 15′ N, 2° 0′ E). Coll 1982 and 1983 by H Młynarczyk and J Lech and subm by J Lech, Inst Hist Material Culture, Polish Acad Sci, Warsaw.

3150 ± 80
BM-2383. Wierzbica, Zele $\delta^{13}C = -27.0‰$

Charcoal, ref combined samples 88 and 89/82, from scattered fragments (340cm depth) in Cutting II/82 in fill of Shaft 20.

2550 ± 280
BM-2384. Wierzbica, Zele *Est* $\delta^{13}C = -25.0‰$

Charcoal, ref sample 110/82, from scattered fragments (420cm depth) in Cutting II/82 in fill of Shaft 20.

2750 ± 70
BM-2385. Wierzbica, Zele $\delta^{13}C = -25.8‰$

Charcoal, ref 183/83, from scattered fragments (330 to 350cm depth) in Cutting III/83 in fill of Shaft 28.

2780 ± 80
BM-2385A. Wierzbica, Zele $\delta^{13}C = -25.8‰$

Recount of BM-2385, above.

2890 ± 110
BM-2386. Wierzbica, Zele $\delta^{13}C = -24.3‰$

Charcoal, ref 223/83, from scatter of fragments in heap of large limestone blocks, assoc with traces of fire on limestone wall, near base of Shaft 28.

2800 ± 100
BM-2386A. Wierzbica, Zele $\delta^{13}C = -24.3‰$

Recount of BM-2386, above.

General Comment (JL): for other dates from site, see BM XVII; R, 1984, v 26, p 70, and Lech, 1984, p 194. Dates agree well with expected age for flint mining in this part of Zele (Lech, 1984). BM-2386 and -2386A are evidently contemporary with flint exploitation from Shaft 28 and late Bronze Age in Vistule basin. There are no dates for Neolithic and possible late Paleolithic mining on site for which there is independent archaeol evidence (Lech, 1983; 1984). BM-2386, -2386A are among latest dates for flint mining in central Europe (Lech, 1981).

Spain

Early Metallurgy in S E Spain

Samples from Copper and Bronze Age sites in S E Spain, assoc with development of metal-working, subm by A Arribas, Univ Palma and F Molina, Univ Granada.

Los Millares series

Samples from early Copper Age, "Los Millares" culture, occupation site containing evidence of metal-working at Los Millares, Santa Fe, Almeria (37° 00′ N, 2° 30′ W). Coll 1983 by A Arribas and F Molina.

4150 ± 40
BM-2343. Los Millares $\delta^{13}C = -26.3‰$

Charcoal, ref LM-6015, from remains of wooden beam, embedded in one of reinforcements of Wall 2.

4110 ± 110
BM-2344. Los Millares $\delta^{13}C = -21.3‰$

Charcoal, ref LM-17042, from hut level contemporary with construction of barbican defending principal gate of Wall 1.

3820 ± 40
BM-2345. Los Millares $\delta^{13}C = -25.3‰$

Charcoal, ref LM-62035, from central wooden beam supporting ceiling of bastion on outside of Fort 1.

General Comments (AA): BM-2343 comes from Copper Age/Pre-Beaker phase and is as expected. BM-2344 belongs to phase immediately preceding appearance of Beaker material and is as expected. BM-2345 is from phase believed to be immediately pre-Beaker and is later than expected.

El Malagon series

Samples from early Copper Age, "Los Millares" culture, occupation site containing evidence of metal-working at El Malagon, Cúllar Baza, Granada (37° 30′ N, 2° 25′ W). Coll 1983 by F Molina.

4020 ± 60
BM-2347. El Malagon $\delta^{13}C = -23.0‰$

Charcoal, ref CB-5130, from pit outside group of huts.

3870 ± 60
BM-2348. El Malagon $\delta^{13}C = -24.7‰$

Charcoal, ref CB-10213, from deposit outside hut.

General Comment (AA): dates are slightly later than expected.

3440 ± 50
BM-2354. Terrera del Reloj $\delta^{13}C = -23.3‰$

Charcoal, ref DG.6094, from floor of hut in habitation layer of Bronze Age, "Argar Pleno" culture, site at Terrera del Reloj, Dehesas de Guadix, Granada (37° 35′ N, 3° 00′ W). Coll 1983 by F Molina. *Comment* (AA): date is acceptable.

Abrigo de la Peña series

Samples from Abrigo de la Peña (Beguiristain & Cava, 1984), rock shelter in gorge of R Ega, Marañón, Navarra (42° 40′ N, 2° 30′ W). Coll 1983 and subm by I Barandiaran and A Cava, Univ Basque Country, Vitoria, and R J Harrison, Univ Bristol.

2840 ± 70
BM-2357. Abrigo de la Peña $\delta^{13}C = -23.0‰$

Charcoal, ref 1, from early Iron Age phase, Level b.

3610 ± 60
BM-2358. Abrigo de la Peña $\delta^{13}C = -24.9‰$

Charcoal, ref 2, from Bronze Age phase, Level b.

3710 ± 60
BM-2359. Abrigo de la Peña $\delta^{13}C = -24.3‰$

Charcoal, ref 3, from similar context to BM-2358, above.

4350 ± 80
BM-2360. Abrigo de la Peña $\delta^{13}C = -25.1‰$

Charcoal, ref 4, from early Eneolithic phase, Level b.

7890 ± 120
BM-2363. Abrigo de la Peña $\delta^{13}C = -20.1‰$

Collagen from bone (large herbivore, possibly *Cervus*) id. by I Barandiaran, ref 11, Level d, phase assoc with many flints, mostly small geometrics, of Epipaleolithic affinity.

General Comment (IB & RJH): site was used for habitation and burial. Level b is thick stony accumulation up to 185cm deep with many strat subdivisions within it. All dates are in correct strat order and coincide exactly with archaeol and ceramic materials assoc with them. This is best sequence for Basque region so far found.

La Atalayuela series

Collagen from human bone from mass grave of at least 70 individuals at La Atalayuela (Barandiaran & Basabe, 1978), Agoncillo, La Rioja (42° 25′ N, 1° 20′ E), assoc with Eneolithic grave goods, including at least 6 Bell Beakers of various styles, some very early. Beakers include pieces of CZM Beaker and sherds of Maritime transitional types with comb decoration. Coll 1970 by I Barandiaran, and subm 1983 by I Barandiaran and R J Harrison.

4060 ± 60
BM-2365. La Atalayuela $\delta^{13}C = -18.7‰$

Collagen from human long bone, ref E2, from upper level of grave.

4120 ± 70
BM-2366. La Atalayuela *$\delta^{13}C = -18.3‰$*

Collagen from human long bone, ref E42, from middle level of grave.

4110 ± 60
BM-2367. La Atalayuela *$\delta^{13}C = -18.0‰$*

Collagen from human long bone, ref E17, from middle or lower level of grave.

General Comment (IB & RJH): grave was assumed to have been filled simultaneously since all skeletons were intact, flexed burials, and could be excavated individually. BM-2365, -2366, and -2367 date bones from top, middle, and base of deposit, and are indistinguishable, showing tomb to be simultaneous burial. Dates for Bell Beakers are among oldest in W Europe and agree with other dates from Iberia.

Berroberria series

Collagen from bone samples from rock shelter used during Upper Paleolithic (Barandiaran, 1979), 100 to 120m asl at Berroberria, Urdax, N frontier of Navarra (43° 15′ N, 2° 10′ E). Coll 1979 by I Barandiaran and subm 1983 by I Barandiaran and R J Harrison.

11,750 ± 300
BM-2370. Berroberria *$\delta^{13}C = -21.6‰$*

Collagen from bone, ref 1, from Level D, Sq 2G, depth 235 to 250cm, assoc with final Magdalenian or Azilian flint industry, and fragment of "Azilian" harpoon.

10,160 ± 410
BM-2371. Berroberria *$\delta^{13}C = -21.0‰$*

Collagen from bone, ref 2, from Level D, Sq 1G, depth 240 to 245cm, similar context to BM-2370, above.

13,270 ± 220
BM-2373. Berroberria *$\delta^{13}C = -20.5‰$*

Collagen from bone fragments, ref 4, from Level E, Sq 2G, depth 270 to 284cm, assoc with Upper Magdalenian flint industry.

14,430 ± 290
BM-2375. Berroberria *$\delta^{13}C = -20.9‰$*

Collagen from bone fragments, ref 6, from Level G, Sq 1G, depth 308 to 318cm, assoc with Middle Magdalenian flint industry.

General Comment (IB & RJH): dates are in correct strat order and agree well with archaeol material assoc with them.

Sri Lanka

Mantai series

Samples from occupation at Mantai, on NW coast, 6.1km SE of Mannar and 200m from modern coast (9° 00′ N, 80° 00′ E). Coll 1982 and subm by M E Prickett, Peabody Mus, Harvard Univ.

3520 ± 45
BM-2340. Mantai $\delta^{13}C = -25.8‰$

Charcoal, ref sample 1, from upper 40cm of clay stratum.

3550 ± 70
BM-2341. Mantai $\delta^{13}C = -24.0‰$

Charcoal, ref sample 2, from middle 15cm of clay stratum.

3790 ± 70
BM-2342. Mantai $\delta^{13}C = -24.3‰$

Charcoal, ref sample 3, from lowest 20cm of clay stratum.

General Comment (MP): samples underlie Mesolithic midden deposit from hunter/gatherer camp on lagoon edge and date higher relative sea level ca 1m above modern. Dates correspond well with other evidence in Sri Lanka for late continuation of Stone Age occupation and for higher sea levels.

United Arab Emirates

Ghanadha series

Samples from multi-period site at Ghanadha Island (al-Tikriti, 1985), Abu Dhabi (25° 00′ N, 54° 40′ E). Coll 1982 and subm by Walid al-Tikriti, Dept Antiquities, Abu Dhabi.

2470 ± 100
BM-2261. Ghanadha 2 $\delta^{13}C = -23.5‰$

Charcoal, ref sample 3, from fireplace no.1, 40cm below surface of Site 2, S of Umm an-Nar Site 1.

3010 ± 220
BM-2263. Ghanadha 3 $\delta^{13}C = -21.2‰$

Charcoal, ref sample 1, from inside Structure 1, 10cm below surface, assoc with Iron Age pottery.

General Comment (Wa-T): BM-2261 is later than date originally suggested for site, but lack of assoc material together with nature of Iron sites in UAE makes estimation difficult. BM-2261 indicates that fireplace belongs to final stages of occupation of site, which is believed to end in mid-1st century BC. BM-2263 is slightly earlier than expected but problem of dating Iron Age in Gulf will not be solved until there is series of reliable dates for several sites in area. Both dates are acceptable within present state of knowledge.

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[RADIOCARBON, VOL. 29, NO. 2, 1987, P 197–208]

INSTITUT ROYAL DU PATRIMOINE ARTISTIQUE RADIOCARBON DATES XII

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This list contains the results of ^{14}C determinations obtained at the laboratory in 1985. *$\delta^{13}C$ values are estimated (Stuiver & Polach, 1977).

GEOLOGIC SAMPLES

Belgium

Western coastal plain of Belgium series

The following results complete previously pub series (R, 1986, v 28, no. 1, p 71–73) of peat and wood from W Vlaanderen. Coll and subm 1984 by C Baeteman, Geol Service Belgium.

5810 ± 70

IRPA-612. Pervijse orthodoxe kerk *$\delta^{13}C = -24‰$*

Peat from top of second peat layer, 6.57 to 6.63m below surface at Lampernisse (51° 03′ 20″ N, 2° 47′ 32″ E).

5550 ± 70

IRPA-613. Dijk *$\delta^{13}C = -24‰$*

Peat from top of second peat layer, 5.80 to 5.85m below surface at Oudekapelle (51° 01′ 11″ N, 2° 48′ 10″ E).

General Comment (CB): second regional peat layer occurring at depth −2.5m (absolute level) was dated. The age is identical to all other dates of second peat layer.

7610 ± 70

IRPA-614. Westende 4 *$\delta^{13}C = -24‰$*

Peat from top of base peat, 9.45 to 9.50m below surface at Westende (51° 09′ 53″ N, 2° 46′ 47″ E).

6780 ± 80

IRPA-615. Westende 4 *$\delta^{13}C = -24‰$*

Peat from base of base peat, 9.56 to 9.61m below surface at Westende (51° 09′ 53″ N, 2° 46′ 47″ E).

8120 ± 100

IRPA-616. Woestyne *$\delta^{13}C = -24‰$*

Peat from top of base peat, 17.67 to 17.75m below surface at Adinkerke (51° 03′ 40″ N, 2° 34′ 50″ E).

5710 ± 70
IRPA-617. Jacobs 1 $*\delta^{13}C = -24‰$

Peat from top of base peat, 5.96 to 6.00m below surface at Oudekapelle (51° 01′ 30″ N, 2° 49′ 45″ E).

5720 ± 70
IRPA-618. Jacobs 2 $*\delta^{13}C = -24‰$

Wood from top of base peat, 5.88 to 5.93m below surface at Oudekapelle (51° 01′ 30″ N, 2° 49′ 45″ E).

9190 ± 190
IRPA-677. Gasthuis $*\delta^{13}C = -27‰$

Humic acids from base peat, 18.13 to 18.20m below surface at Adinkerke (51° 05′ N, 2° 36′ 25″ E).

7620 ± 90
IRPA-678. Gasthuis $*\delta^{13}C = -27‰$

Peat from base peat, 17.81 to 17.83m below surface at Adinkerke (51° 05′ N, 2° 36′ 25″ E).

9940 ± 110
IRPA-680. Schoudervliet $*\delta^{13}C = -27‰$

Peat from base of base peat, 20.16 to 20.21m below surface at Wulpen (51° 05′ 30″ N, 2° 42′ 15″ E).

8440 ± 130
IRPA-681. Schoudervliet $*\delta^{13}C = -27‰$

Peat from top of base peat, 19.83 to 19.88m below surface at Wulpen (51° 05′ 30″ N, 2° 42′ 15″ E). Diluted; 84.7% sample.

8170 ± 90
IRPA-734. Oostkerke $*\delta^{13}C = -27‰$

Peat from base of base peat, 20.50 to 20.54m below surface at Oostkerke (51° 02′ 40″ N, 2° 43′ 30″ E).

General Comment (CB): basal peat of Holocene sequence was dated and ages correspond with trend of transgression sea-level in that area, except in IRPA-734, where basal peat started to grow in pre-existing Pleistocene depression, independent of sea-level rise.

4540 ± 60
IRPA-682. Schoudervliet $*\delta^{13}C = -27‰$

Peat from base of upper peat layer, 3.19 to 3.24m below surface at Wulpen (51° 05′ 30″ N, 2° 42′ 15″ E).

4790 ± 90
IRPA-721. B753 $*\delta^{13}C = -27‰$

Peat from base of upper peat layer, 3.52 to 3.60m below surface at Ramskapelle (51° 05′ 15″ N, 2° 47′ 25″ E).

General Comment (CB): ages of base of first regional peat layer or surface peat agree, indicating that Subboreal peat growth started between 4800–4500 BP.

5490 ± 100
IRPA-722. B746 $*\delta^{13}C = -27‰$

Peat from base of base peat, 4.30 to 4.40m below surface at Schoorbakke (51° 05′ 58″ N, 2° 50′ 45″ E). Diluted; 61.83% sample.

4990 ± 70
IRPA-723. B747 $*\delta^{13}C = -27‰$

Peat from base of base peat, 2.55 to 2.65m below surface at Leke (51° 05′ 40″ N, 2° 51′ E).

6380 ± 110
IRPA-724. B755 $*\delta^{13}C = -27‰$

Peat from base of second peat layer, 5.85 to 5.90m below surface at Booitshoeke (51° 05′ 30″ N, 2° 44′ 35″ E). Diluted; 55.5% sample.

5970 ± 120
IRPA-725. B742 $*\delta^{13}C = -27‰$

Peat from base of base peat, 5.05 to 5.20m below surface at Schore (51° 06′ 30″ N, 2° 50′ 35″ E). Diluted; 51.35% sample.

4880 ± 70
IRPA-679. Langeleed $*\delta^{13}C = -27‰$

Peat from erosion layer, 10.60 to 10.65m below surface at Oostduinkerke (51° 06′ 20″ N, 2° 41′ 30″ E).

4220 ± 60
IRPA-726. Nieuwpoort 2 $*\delta^{13}C = -27‰$

Peat from base peat, 5.65 to 5.72m below surface at Nieuwpoort (51° 07′ 38″ N, 2° 53′ 20″ E).

3580 ± 60
IRPA-727. Nieuwpoort 2 $*\delta^{13}C = -27‰$

Peat from top peat, 5.23 to 5.27m below surface at Nieuwpoort (51° 07′ 38″ N, 2° 53′ 20″ E).

1640 ± 50
IRPA-728. De Panne $*\delta^{13}C = -27‰$

Peat from 1.75 to 1.85m below surface at De Panne (51° 05′ 38″ N, 2° 34′ 13″ E).

5770 ± 100
IRPA-729. Noordhoek $*\delta^{13}C = -27‰$

Peat from base of base peat, 6.13 to 6.20m below surface at Leffinge (51° 11′ 05′ N, 2° 53′ 20″ E). Diluted; 63.17% sample.

IRPA-730. Noordhoek **2220 ± 50**
$*\delta^{13}C = -27‰$

Peat from top of base peat, 3.62 to 3.66m below surface at Leffinge (51° 11′ 05″ N, 2° 53′ 20″ E).

IRPA-731. Antoine **5680 ± 70**
$*\delta^{13}C = -25‰$

Shells (*Cardium*) from storm level, 0.50 to 0.57m below surface at Adinkerke (51° 03′ 05″ N, 2° 34′ 10″ E).

IRPA-722. Antoine **2690 ± 60**
$*\delta^{13}C = -27‰$

Peat from 0.31 to 0.35m below surface at Adinkerke (51° 04′ 05″ N, 2° 34′ 10″ E). *Comment* (CB): age of vegetation layer, covered with dunes, agrees with dates of similar situations in area.

IRPA-742. Middelkerke **1240 ± 50**
$*\delta^{13}C = -25‰$

Shells (*Cardium*) from storm deposition at Middelkerke (51° 12′ N, 2° 50′ 45″ E). *Comment* (CB): result, expected to belong to Dunkerke II transgression, was younger.

Zonien Forest series

Charcoal fragments from alluvial deposits in Zonien Forest, Brussels. Coll Sept 1984 and subm Dec 1984 by J Sanders, Univ Gent, Belgium.

IRPA-654. Auderghem **1570 ± 80**
$*\delta^{13}C = -25‰$

Charcoal fragments at 100cm below surface (50° 48′ 08″ N, 4° 26′ 50″ E).

IRPA-655. La Hulpe **2900 ± 90**
$*\delta^{13}C = -25‰$

Charcoal fragments at 110cm below surface (50° 44′ 15″ N, 4° 26′ 30″ E). Diluted; 19.47% sample.

IRPA-656. Hoeilaart **1750 ± 90**
$*\delta^{13}C = -25‰$

Charcoal fragments at 130cm below surface (50° 44′ 45″ N, 4° 25′ 30″ E).

IRPA-657. Tervuren **2170 ± 50**
$*\delta^{13}C = -25‰$

Charcoal fragments at 130cm below surface (50° 48′ 19″ N, 4° 28′ 13″ E).

1580 ± 50

IRPA-658. Watermael-Boisfort *$*\delta^{13}C = -25‰$*

Charcoal fragments at 70cm below surface (50° 47′ 51″ N, 4° 27′ 05″ E).

General Comment (JS): IRPA-654, -656, -657 and -658, sampled from same stratigraphic unit, reflect alluvial activity which was at least active during period of charcoal deposition. Charcoal is probably anthropogenic in origin.

Shell coastal series

Samples from coastal plain dated to obtain standard for ^{14}C dating of sea shells. Subm March 1985 by R De Ceunynck, Univ Gent.

5360 ± 70

IRPA-706. Koksijde KKW/M1 *$*\delta^{13}C = -25‰$*

Shells (*Cerastoderma edule,* simple valves) at 2.7m below surface (51° 07′ 51″ N, 2° 42′ 40″ E).

480 ± 50

IRPA-707. Nieuwpoort-haven *$*\delta^{13}C = -25‰$*

Shells (*Cerastoderma edule,* valves) coll 1901 from Nieuwpoort harbor, supposedly taken when they were still living. No coordinates available.

2070 ± 50

IRPA-708. Bredene *$*\delta^{13}C = -25‰$*

Shells (*Cerastoderma edule,* double valves) from archaeol layer at Roman site in Bredene (51° 14′ 24″ N, 2° 57′ 33″ E). Coll 1985 by H Thoen, Univ Gent.

Modern

IRPA-709. Koksijde *$*\delta^{13}C = -25‰$*

Shells (*Mytilis edulis,* double valves) from beach of Koksijde; no coordinates. Coll June 1922 by P Dupuis.

General Comment (RDeC): results are rather disappointing; both IRPA-707 and -709 were expected to give result close to their real age; only IRPA-709 yielded acceptable age; for IRPA-707, uncertain sampling conditions may be blamed. IRPA-708 was subm as test sample; its archaeol age is estimated at AD 50–100, which agrees well with obtained ^{14}C date. IRPA-706 was subm as "unknown age sample"; its age was estimated to be not older than 3000 BP. Result is much older; it may have been reworked older material. In general, results are rather inconsistent.

Oosterweel series

Samples from Oosterweel, Antwerpen (51° 14′ 35″ N, 4° 23′ 10″ E). Coll and subm 1985 by P Kiden, Univ Gent, and K Leenders, Rotterdam.

IRPA-652. Oosterweel 3 **1630 ± 50**
$*\delta^{13}C = -27‰$

Top of peat under Oosterweel's church.

IRPA-713. Oosterweel 1 **3890 ± 60**
$*\delta^{13}C = -27‰$

Base of peat.

IRPA-714A. Oosterweel 2A **1840 ± 60**
$*\delta^{13}C = -27‰$

Wood from top of peat.

IRPA-714B. Oosterweel 2B **1300 ± 50**
$*\delta^{13}C = -27‰$

Top of peat.

General Comment (PK): date of IRPA-713 is as expected with respect to absolute height of sample. Wood sample IRPA-714A, from top, seems to be too old compared to peat samples IRPA-714B and -652 from ca 30cm below top of peat.

Wintham series

Samples from Scheldt R alluvial deposit at Wintham, O Vlaanderen (51° 07′ 08″ N, 4° 18′ 15″ E). Coll and subm 1985 by P Kiden.

IRPA-712. Zeesluis 1 **4220 ± 60**
$*\delta^{13}C = -27‰$

Peat at 1.10m depth.

IRPA-741. Zeesluis 2 **5110 ± 70**
$*\delta^{13}C = -27‰$

Peat at 2.0m depth.

IRPA-740. Zeesluis 3 **5550 ± 80**
$*\delta^{13}C = -27‰$

Peat at 2.85m depth.

General Comment (PK): dates agree with absolute height with respect to contemporaneous sea level and possible flood basin and river gradient effects (Van De Plassche, 1982), and show gradual rise of local water level in Scheldt alluvial plain under influence of rising sea level.

IRPA-665. Bred top V1 **4380 ± 60**
$*\delta^{13}C = -27‰$

Peat from Bredene, W Vlaanderen (51° 14′ 28″ N, 2° 58′ 42″ E) at 0.15m depth. Coll Nov 1984 by F Mostaert and subm Feb 1985 by C Verbruggen, Univ Gent. *Comment* (CV): lagoonal clay intercalated between two peat layers. Sample from base of upper peat. Date confirms expectations based on position in stratigraphic context.

The Netherlands

2640 ± 60

IRPA-649. Brouwersmoer *$*\delta^{13}C = -27‰$*

Peat from Zundert (51° 29′ 08″ N, 4° 36′ 08″ E). Coll and subm Oct 1985 by C Verbruggen. *Comment* (CV): thin but complete remnant layer of peat bog excavated in 17th century. Sample from lower part of sequence. Date is in perfect agreement with pollen analysis.

Africa

Zaïre series

Calcareous crust and organic material from Natl Park of Virunga, Zaïre (0° 30′ S, 29° 10′ E). Coll 1979 and subm Dec 1984 by M Vanoverstraeten, Fac Agronom Gembloux, Belgium. Dates are part of morphol and pedol study in Western African Rift where soils and calcareous crusts are assoc.

11,990 ± 130

IRPA-646. 2450 *$*\delta^{13}C = -25‰$*

Calcareous crust. Pretreated with 37% HCl until 50% weight loss.

11,400 ± 130

IRPA-647. 0508 *$*\delta^{13}C = -25‰$*

Calcareous crust. Same pretreatment as above.

9280 ± 100

IRPA-648. 6404 II *$*\delta^{13}C = -25‰$*

Calcareous crust. Same pretreatment as above.

Modern

IRPA-668. *$*\delta^{13}C = -25‰$*

Organic material. Humic acids extraction; diluted; 55.9% sample.

460 ± 50

IRPA-669. *$*\delta^{13}C = -25‰$*

Organic material. Humic acids extraction.

Modern

IRPA-670. *$*\delta^{13}C = -25‰$*

Organic material. Humic acids extraction.

Modern

IRPA-671. *$*\delta^{13}C = -25‰$*

Organic material. Humic acids extraction.

Modern

IRPA-672. *$*\delta^{13}C = -25‰$*

Organic material. Humic acids extraction.

IRPA-623. Malha Lake **8290 ± 150**
*$\delta^{13}C = -25‰$

Organic material from Darfur, Sudan, no coordinates. Coll and subm Nov 1985 by H Dumont, Univ Gent. Humic acids extraction; diluted; 50.46% sample.

Asia

Bangladesh series

Samples from Bangladesh. Coll April 1984 and subm Jan 1985 by H Mohammad, Geol Inst, Free Univ. Brussels.

IRPA-659. S1 **3670 ± 60**
*$\delta^{13}C = -27‰$

Peat at 170cm depth from Kachpur (23° 41′ 05″ N, 90° 30′ E).

IRPA-660. S2 **6060 ± 70**
*$\delta^{13}C = -27‰$

Peat at 260cm depth from Kachpur (23° 41′ 05″ N, 90° 30′ E).

IRPA-661. S4 **6460 ± 80**
*$\delta^{13}C = -27‰$

Peat at 280cm depth from Kachpur (23° 41′ 05″ N, 90° 30′ E).

IRPA-662. S3 **5580 ± 70**
*$\delta^{13}C = -27‰$

Peat at 150cm depth from Karampur (23° 52′ N, 91° 13′ E).

IRPA-663. S4 **5620 ± 80**
*$\delta^{13}C = -27‰$

Peat at 210cm depth from Karampur (23° 52′ N, 91° 13′ E).

IRPA-664. **6390 ± 80**
*$\delta^{13}C = -27‰$

Peat from 600cm depth from W Bank Lakla (23° 41′ 05″ N, 90° 30′ E).

General Comment (HM): dates seem to be accurate and they are satisfactory. They have added points to evolutionary history of area.

ARCHAEOLOGIC SAMPLES

Belgium

Wenduine series

Samples from Wenduine, W Vlaanderen (51° 17′ 50″ N, 3° 04′ 02″ E). Coll May 1984 and subm July 1985 by H Thoen, Univ Gent, Belgium.

IRPA-716. WEN 84/1 **1930 ± 50**
*$\delta^{13}C = -24‰$

Wood (*Alnus*).

1860 ± 50

IRPA-717. WEN 84/2 *$\delta^{13}C$ = −24‰

Wood (*Alnus*).

4940 ± 70

IRPA-718. WEN 85/7 *$\delta^{13}C$ = −24‰

Wood (*Quercus*).

3670 ± 60

IRPA-719. WEN 85/9 *$\delta^{13}C$ = −24‰

General Comment (HT): IRPA-716 and -717 agree with archaeol date: Roman period. IRPA-718 and -719 point to re-use of exceptionally well-preserved wood recovered from coastal plain peat fm in Roman times; indeed, IRPA-718 concurs with base of peat and IRPA-719 with middle part of it.

2480 ± 60

IRPA-645. Lele 84/1C′ *$\delta^{13}C$ = −24‰

Wood from well in Lede, O Vlaanderen (50° 58′ N, 4° 0′ E). Coll July 1984 by W de Swaef and subm Nov 1985 by J Nenquin, Univ Gent. La Tène date is expected.

990 ± 50

IRPA-666. Kouter *$\delta^{13}C$ = −24‰

Wood from medieval ditch along best known arable land. Complex (Kouter) in Gent, O Vlaanderen (51° 03′ N, 3° 43′ 40″ E). Subm Feb 1984 by C Verbruggen, Univ Gent. *Comment* (CV): scarce archaeol findings point to date between 11th and 13th century AD. Pollen analysis shows *Secale* and *Centaurea cyanus.*

1450 ± 80

IRPA-653. DO18-20/4 DO19-20/4 *$\delta^{13}C$ = −25‰

Charcoal from eolian sand layer (leaching A2-horizon) in Donk, Limburg (50° 56′ 57″ N, 5° 07′ 35″ E) at 70cm depth. Coll and subm Dec by PM Vermeersch, Univ Leuven, Belgium. Diluted; 55% sample. No agreement with archaeol date.

Donk series

The following results complete pub list (R, 1984, v 26, no. 3, p 390) of samples from multicomponent site in Donk, Limburg (50° 56′ N, 5° 07′ 30″ E). Subm 1985 by L Van Impe, Natl Service Excavations, Belgium.

2410 ± 70

IRPA-688. 84DO820 *$\delta^{13}C$ = −24‰

Charcoal from pit. Groove LXVIII. Diluted; 66.38% sample. No NaOH pretreatment. Iron Age period expected.

2350 ± 50
IRPA-689. 84DO839 *$\delta^{13}C = -24‰$

Charcoal from pit. Groove LXVII. No NaOH pretreatment. Iron Age period expected.

2320 ± 60
IRPA-690. 84DO880 A *$\delta^{13}C = -24‰$

Charcoal from pit. Groove LXIX; Iron Age period expected.

2490 ± 60
IRPA-691. 84DO880 C *$\delta^{13}C = -24‰$

Charcoal from pit. Groove LXIX. Iron Age period expected.

3400 ± 90
IRPA-692. 84DO883 *$\delta^{13}C = -24‰$

Charcoal from pit. Groove LXIX. Diluted; 54.15% sample. Iron Age period expected.

2480 ± 60
IRPA-693. 84DO895 *$\delta^{13}C = -24‰$

Charcoal from pit. Groove LXIX. Iron Age period expected.

2590 ± 60
IRPA-694. 84DO999 *$\delta^{13}C = -24‰$

Charcoal from pit. Groove LXXV. Iron Age period expected.

1740 ± 50
IRPA-696. 80DO410 *$\delta^{13}C = -24‰$

Wood from Roman well. Groove XXXI.

1800 ± 50
IRPA-697. 80DO411 *$\delta^{13}C = -24‰$

Wood from Roman well. Groove XXXI.

1840 ± 60
IRPA-698. 80DO415 *$\delta^{13}C = -24‰$

Wood from Roman well. Groove XXXI.

1980 ± 50
IRPA-699. 83DO677 *$\delta^{13}C = -24‰$

Wood from Roman well. Groove LVII.

1550 ± 50
IRPA-700. 83DO745 *$\delta^{13}C = -24‰$

Wood from Roman well. Groove LX.

1110 ± 50
IRPA-701. 83DO746 *$\delta^{13}C = -24‰$

Wood from well. Groove LIX-A. Middle Ages date expected.

3670 ± 80
IRPA-702. 84DO773 *$*\delta^{13}C = -24‰$*

Charcoal from grave. Groove LXVII. Diluted; 74.23% sample. No NaOH pretreatment. Roman period expected.

1830 ± 90
IRPA-703. 84DO919 *$*\delta^{13}C = -24‰$*

Charcoal from grave. Groove LXXVI. Diluted; 44.33% sample. No NaOH pretreatment. Roman period expected.

General Comment (L VI): most dates agree with expected archaeol ages. IRPA-688 to -694 coincide with other Iron Age dates and will help establish more reliable chronology of Iron Age ceramics in Campine region. IRPA-696 to -700 were coll from wooden wells (without datable finds) and dates will help relate them to succeeding settlements in Roman period. Dates agree in general with expected ages. IRPA-700, however, seems a bit too young, IRPA-701, coll from a wooden well, belongs to medieval priory. IRPA-703, charcoal coll from burial grave, can be assoc with IRPA-509: 1740 ± 80 BP coll in Germanic Grulenhaus. IRPA-692 (expected Iron Age) and IRPA-702 (same expected age as IRPA-703) are too old. However, results will not be rejected without further archaeol analysis of finds.

Sugny series

Samples from same site as IRPA-584 in Sugny, Namur (49° 50′ N, 4° 54′ E) are remnants of fire-destroyed upper parts of stone keep. Coll July 1982 and subm Feb 1985 by A Matthijs, Natl Service Excavations, Belgium.

1110 ± 50
IRPA-683. 82SU14 *$*\delta^{13}C = -24‰$*

Charcoal.

1140 ± 50
IRPA-684. 82SU6 *$*\delta^{13}C = -24‰$*

Charcoal.

General Comment (AM): IRPA-584 is stratigraphically previous to IRPA-683 and -684. These two samples must be contemporaneous, which is confirmed by ^{14}C analyses. Nevertheless, dates do not match traditional archaeol dating of structures (AD 10th–11th centuries) and are much older. Analyzed remnants come from full-grown construction logs, which give average date much before cutting date of trees.

1690 ± 60
IRPA-715. 82WE82 *$*\delta^{13}C = -24‰$*

Charcoal from pit in Wellin, Luxembourg (50° 05′ N, 5° 07′ E) at 2m depth. Coll Aug 1982 by M Evrard and subm June 1985 by A Matthys.

Italy

Artena series

The following results complete pub list (R, 1981, v 3, p 350) of samples from occupation layer at Artena, Prov Rome (41° 43′ N, 12° 57′ E). Coll Sept 1984 and 1985 and subm 1985 by R Lambrechts, Univ Louvain, Belgium.

IRPA-705. 84-AR-B-V — **1380 ± 50**, $*\delta^{13}C = -24‰$

Charcoal with rootlets. Date is too young.

IRPA-735. 85-AR-B-XIA — **2390 ± 50**, $*\delta^{13}C = -24‰$

Charcoal from fill of cistern.

IRPA-736. 85-AR-B-XIB — **2280 ± 60**, $*\delta^{13}C = -24‰$

Charcoal from fill of cistern.

IRPA-737. 85-AR-B-XIC — **2090 ± 70**, $*\delta^{13}C = -24‰$

Charcoal from fill of cistern. Diluted; 73.34% sample.

IRPA-738. 85-AR-B-XID — **2350 ± 50**, $*\delta^{13}C = -24‰$

Charcoal from fill of cistern.

IRPA-739. 85-AR-B-XIE — **2230 ± 80**, $*\delta^{13}C = -24‰$

Charcoal from fill of cistern. Diluted; 57.19% sample.

ART SAMPLES

IRPA-685. Bodhisattva Maitreya — **130 ± 50**, $*\delta^{13}C = -25‰$

Wood from Chinese statue, Wei period. Subm 1985 by J Tirtiaux, antiquarian, Brussels. No NaOH pretreatment.

IRPA-711. AAM65-13-1 — **1330 ± 50**, $*\delta^{13}C = -24‰$

Wood (bamboo) from Peru's boom, Chancay period. Expected age: AD 1100–1450. Date is same as L-384a: AD 570 ± 160.

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[RADIOCARBON, VOL. 29, NO. 2, 1987, P 209–238]

SOUTHERN METHODIST UNIVERSITY RADIOCARBON DATE LIST III

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INTRODUCTION

The dates presented in this list were determined between June 1974 and October 1983. They relate to projects in North America and in Algeria. Dates with numbers prior to SMU-500 have generally no correction for fractionation. Following this initial series of dates an increasing number of $\delta^{13}C/^{12}C$ measurements were made by an outside laboratory, especially if the submitter requested a fractionation correction or if the sample was of carbonate or bone.

Our dating method is based on benzene synthesis and liquid scintillation counting. Equipment and procedures were previously described (Haynes & Haas, 1974; Haas & Haynes, 1975; Haas, 1979; Meeks, 1979; Devine & Haas, 1987).

The modern standards used in our laboratory are NBS Oxalic Acid I and II. These are converted to CO_2 with low temperature combustion in an oxygen atmosphere. The CO_2 yield is mostly between 99 and 100% of the theoretical carbon content. If an occasional lower yield falls below 97% the standard is discarded. An additional test is made on the pH of the water of combustion, which should be 3 or higher for a complete combustion. A pH of 1.5 or lower is an indication of an insufficient combustion yield which may be caused by the lack of an efficient platinum catalyst at the end of the combustion tube.

A fresh modern standard is made about every six weeks. This is necessary because of transfer losses between the different counting vials. Every vial used for sample counting is calibrated individually about every four weeks for counting efficiency and for background. The background standard is benzene synthesized in our system from anthracite of Pennsylvanian age. These background standards are made about every month. This also serves as a check on the cleanliness and reliability of our benzene synthesis system.

During the counter calibration several different modern and background standards are rotated in their use in order to detect any slight anomaly in a particular standard and to lower the risk that a very small and statistically hard-to-detect deviation by one of the standards might cause a bias on the counter calibration.

Reporting dates or ^{14}C results to the submitter of samples is done in two steps at our laboratory. Directly after counting, the results are calculated with recent calibration data of the counters. These calculations are reported as "temporary data." At about six month intervals calibration data of each vial used in the same counter are examined for trends observed on individual vials and for counter instability. Single or multiple linear regressions are used to determine the most probable background and efficiency values for each day during which samples were counted. These new calibration values are then used to recalculate sample ages. The resulting second report is then sent to the submitter as the finalized date.

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Contributions to the content of this list were made by David Lubell (Algerian dates), Marvin Kay (Phillips Spring and Rodgers Shelter) and C V Haynes (Pomme de Terre River Valley, Missouri).

United States

Missouri

Phillips Spring series

Phillips Spring, an active artesian spring in the lower Pomme de Terre River Valley, Hickory Co (38° 3′ 45″ N, 93° 18′ 33″ W), was the subject of intensive archaeologic, geomorphologic, and palynologic investigations in the 1970s. Extensive excavations were conducted in 1977 and 1978 and were preceded in 1973, 1974, and 1976 by stratigraphic probes of the mainly Holocene (Rodgers) terrace deposits. The prime results of these efforts were: 1) ^{14}C dates of probable domesticated plants to the mid-Holocene (Table 1) with specific reference to Unit K2, the Squash and Gourd Zone; 2) delineation of the major Holocene alluvial cut-and-fill deposits and ^{14}C dates in the lower Pomme de Terre (Tables 1 & 2); and 3) the recovery of pollen from dated late Pleistocene and Holocene contexts (Tables 1 & 2). Synopses of these analyses are found in Chomko (1978), Chomko and Crawford (1978), Haynes (1985), Kay (1983), Kay (1986), Kay, King and Robinson (1980) and King (1980). Tables 1 & 2 provide, in sequence of depositional units, a chronologic overview of the project. The tables are followed by a listing of all dates with complete information on each sample. Transit datum depths (cm) throughout this date list are below a horizontal plane ca 60cm above the highest point on the excavation ground surface. A few early dates, derived from samples collected in 1974, are based on a different reference system, in which depths are given in cm below surface and the use of a different grid system is indicated by parentheses.

SMU-193. Phillips Spring **7480 ± 80**

Moss (160°N, 108° E), depth 170 to 180cm below surface, possibly from Unit C2. Coll July 1974.

TABLE 1
Radiocarbon assays for Phillips Spring (23HI216) archaeologic units

SMU Lab no.	Age BP ($t_{1/2}$ = 5568 yr)	Provenience	Datum depth (m)*	Depositional unit	Archaeologic component	Material	Comments
SMU-1213	5070 ± 150	512.5SE508.5	3.5–3.6	K2	Squash & gourd zone	Charcoal	Acceptable as date for cucurbits in 50 cm unit 512.5SE509.5 at same depth
-811	4970 ± 70	514SE506	3.25	K2	Squash & gourd zone	Uncarbonized twigs	Acceptable, from profile wall, Tr 7
-1214	4500 ± 100	512SE508.5	3.34–3.40	K2	Squash & gourd zone	Charcoal	Acceptable, assoc with cucurbits
-98	4310 ± 70			K2	Squash & gourd zone	Charcoal	Acceptable, from hearth in 1973 backhoe trench**
-102	4240 ± 80			K2	Squash & gourd zone	Charcoal	Acceptable, see SMU-98**
-483	4220 ± 60	510SE508	3.35	K2	Squash & gourd zone	Charcoal	Acceptable, assoc with cucurbits
-1167	4100 ± 250	512SE508	3.0–3.1	E	Sedalia #1	Charcoal	Acceptable
-1165	4100 ± 420	504SE508	3.2	E	Sedalia #1	Charcoal	Acceptable, feature has cucurbits
-423	4000 ± 100	502SE510	3.4	E	Sedalia #1	Charcoal	Acceptable
-1195	3760 ± 100	504SE510	3.2–3.3	E	Sedalia #1	Charcoal & uncharred wood	Reject, sample contaminated by aquatic moss
-1172	3240 ± 450	506SE510	3.2–3.3	E	Sedalia #1	Charcoal	Reject, lab problem with benzene
-556	3960 ± 70	511SE508.5	3.3–3.4	E	Sedalia #1	Charcoal	Acceptable, note Feature 1173 has cucurbits
-419	3940 ± 70	508SE508	3.28	E	Sedalia #1	Charcoal	Acceptable
-558	3920 ± 70	511.5SE508	3.3–3.4	E	Sedalia #1	Charcoal	Acceptable
-319	3930 ± 60	510SE508 ?	3.33	E	Sedalia #1	Charcoal	Acceptable
-1171	4010 ± 90	516SE504	3.5–3.54	E	Sedalia #1	Uncarbonized nut shells	Acceptable, from unit beneath Feature 1969; assoc with cucurbits
-1178	3850 ± 230	516SE504	3.1–3.2	E	Sedalia #3	Charcoal	Acceptable, assoc with cucurbits
-1179	3170 ± 90	516SE504	3.2–3.3	E	Sedalia #3	Charcoal	Reject, inverted stratigraphy
-559	3800 ± 180	500SE508	2.78–2.82	E	Sedalia #3	Charcoal	Acceptable

TABLE 1 (continued)

MU lab no.	Age BP ($t_{1/2}$ = 5568 yr)	Provenience	Datum depth (m)*	Depositional unit	Archaeologic component	Material	Comments
-820	3750 ± 50	506SE514	3.45	E	Sedalia #3	Uncarbonized plant fragments	Acceptable, from unit with pollen
-550	3650 ± 70	514SE508	2.8–2.9	E	Sedalia #4	Charcoal	Acceptable
-1112	3480 ± 50	512SE502	2.9–3.0	E	Sedalia #4	Charcoal	Acceptable
-818	3400 ± 50	508SE514	3.25	E	Sedalia #4	Uncarbonized nut shells	Acceptable, from unit with pollen
-331	3300 ± 50	508SE504	2.94	E	Sedalia #4	Charcoal	Acceptable
-235	3050 ± 60	504SE508	2.66	E	Sedalia #5	Charcoal	Acceptable
-238	2910 ± 50	515SE496	3.38–3.44	E	Sedalia #5	Uncarbonized wood	Acceptable
-1166	2860 ± 250	504SE504	2.8–2.9	E	Sedalia #5	Charcoal	Acceptable, but note age difference for underlying Feature 1858 assay (SMU-235) is insignificant
-1170	2450 ± 220	520SE506	2.6–2.7	E	Middle Woodland?	Charcoal	Acceptable
-236	2340 ± 80	508SE508 ?	2.58	E	Middle Woodland	Uncarbonized wood	Acceptable
-554	2250 ± 100	512SE512	2.8–2.9	E	Middle Woodland	Charcoal	Acceptable, charcoal is mainly oak
-1114	2210 ± 60	514SE510	2.75–2.85	E	Middle Woodland	Charcoal	Acceptable
-1113	2140 ± 60	512SE510	2.8–2.9	E	Middle Woodland	Charcoal	Acceptable
-537	2040 ± 60	514SE508	2.77–2.9	E	Middle Woodland	Charcoal	Acceptable
-234	1990 ± 50	515SE496	2.79	E	Middle Woodland	Charcoal	Acceptable
-538	1900 ± 80	518SE508	2.7–2.8	E	Middle Woodland	Charcoal	Acceptable
-327	1410 ± 50	515SE496	2.6–2.7	G ?	Late Woodland?	Uncarbonized wood	Acceptable
-237	270 ± 50			H	Historic	Charcoal	Acceptable

* As defined in text
Haas & Haynes (1975)

TABLE 2
Non-archaeologic ^{14}C assays for Phillips Spring (23H1216)

Lab no.	Age BP ($t_{1/2}$ = 5568 yr)	Provenience	Datum depth (m)	Depositional unit	Material	Comments
SMU-813	25,050 ± 330	510.9SE511.2	6.5–6.6	A	Humate fraction	Acceptable, Monolith 3266 unit assoc with pollen
-518	8,570 ± 90				Carbonate sediment	Precipitate from spring water
-825	8,090 ± 90	513.4SE511.2	5.1–5.2	C2	Uncarbonized wood	Acceptable, Monolith 3264 unit assoc with pollen
-737	8,050 ± 90	Trench 7	6.25	C1	Uncarbonized wood	Acceptable
-727	7,980 ± 70	513.4SE511.2	4.7–4.8	C2	Uncarbonized wood	Acceptable, Monolith 3264 unit assoc with pollen
-78	7,870 ± 90	Trench 1		C2 ?	Uncarbonized wood	Acceptable, unit assoc with pollen; see Haynes & Haas (1974, p 373)
-735	7,750 ± 90	Trench 7	5.25	C1	Uncarbonized wood	Acceptable
-826	7,650 ± 190	510.9SE511.2	5.5-5.6	C1	Uncarbonized wood & plants	Acceptable, Monolith 3266 unit assoc with pollen
-736	7,620 ± 90	Trench 7	4.7	C1	Uncarbonized wood	Acceptable
-193	7,480 ± 80	515SE496	3.2–3.3	C2 ?	Moss	Acceptable, from pollen profile 74-2; see Haas & Haynes (1975, p 360)
-726	7,300 ± 80	513.4SE511.2	4.2–4.3	C2	Uncharred wood, seeds, & nuts	Acceptable, Monolith 3264 unit assoc with pollen
-812	7,200 ± 100	Trench 7	4.48	C1	Uncarbonized wood & plants	Acceptable
-557	7,090 ± 90	510SE508	3.92	C2	Uncarbonized wood	Acceptable
-819	6,900 ± 80	Trench 7	3.75	C2	Uncarbonized twigs	Acceptable, but lacks ^{13}C correction
-505	6,580 ± 180	510SE508	3.92	C2	Charcoal	Acceptable, see SMU-557 for assay from same sample
-824	6,280 ± 100	513.4SE511.2	3.4–3.5	K1	Mainly uncharred wood	Acceptable, Monolith3264 unit assoc with pollen
-815	5,400 ± 110	Trench 7	3.60	K1	Uncarbonized wood	Acceptable
-539	5,390 ± 90	Pollen profile 74-1		K1 ?	Uncharred moss & wood	Acceptable, unit assoc with pollen
-810	6,430 ± 80	Trench 7	3.40	C3	Uncarbonized wood	Acceptable

SMU-234. Phillips Spring 15-10 **1990 ± 50**

Charcoal (160° N, 108° E), depth 129cm below surface in peat assoc with pottery in Unit E (R 4-5). Coll Dec 1974 by J E King.

SMU-235. Phillips Spring 102-1 **3050 ± 60**

Charcoal (176° N, 116° E), depth 140 to 150cm below surface in Unit E (R 4-5). Light gray clay. Sample was flecks of charcoal scattered across level near top of horizon below rock Unit I. Coll July 1974 by S Chomko and W R Wood.

SMU-236. Phillips Spring 51-1 **2340 ± 80**

Wood (170° N, 116° E) depth 114.5cm below surface in Unit E (R 4-5) organic clay. Coll July 1974 by S Chomko and W R Wood.

SMU-237. Phillips Spring 114-1 **270 ± 50**

Charcoal from trench across spring, in silt Unit H, Feature 14. Flotation recovery from pit fill; may be recent pit assoc with disturbed horizon, S of spring. Coll 1974 by S Chomko and W R Wood.

SMU-238. Phillips Spring 22-1 **2910 ± 50**

Wood (160° N, 108° E) depth 188 to 194 cm below surface in Unit E (R 4-5). In peat, non-ceramic horizon; rests on peat clay contact. Coll July 1974 by S Chomko and W R Wood.

SMU-319. Phillips Spring 108-6 **3930 ± 60**

Charcoal from Feature 1173, Unit E, assoc with squash seeds. Coll by S Chomko and W R Wood.

SMU-327. Phillips Spring 13-10 **1410 ± 50**

Wood (160° N, 108° E) SE quad, 110 to 120cm below surface possibly Unit G (R 6) base of Unit 6, S of spring. Coll by S Chomko and W R Wood.

SMU-331. Phillips Spring 37-2 **3300 ± 50**

Charcoal (180° N, 114° E) from Feature 3 in Unit E (R 4-5); flotation sample. Coll by S Chomko and W R Wood.

SMU-419. Phillips Spring 175 **3940 ± 70**

Charcoal depth 170 to 190cm below surface in Unit E (R 4-5), Feature 1173. From trench excavated in 1976, hearth in occupational horizon. Coll July 1976 by M Kay and J King.

SMU-423. Phillips Spring 202 **4000 ± 100**

Charcoal from Trench 2, excavated in 1976, depth 3.40m. Lower end of hearth buried in occupational horizon Unit E, Feature 201. Coll July 1976 by M Kay.

SMU-483. Phillips Spring 1502 **4220 ± 60**

Charcoal from Sq 510 SE 508 (S half). Sample is well-defined cultural zone below rock-lined pit with Sedalia complex artifacts at depth 3.35m, Unit K2. Sample processed through field flotation. Coll July 1977 by M Kay and J Phillippe.

SMU-505. Phillips Spring 1640, 1st sample **6580 ± 180**

Charcoal from Sq 510 SE 508. Upper portion of rock-lined stream channel defined in field; Unit C2; depth 3.92m. Sample processed through field flotation; trisodium phosphate added to disperse clays. Coll July 1977 by J Phillippe. Second sample fraction of uncharred wood was dated as SMU-557.

SMU-518. Phillips Spring water **8570 ± 90**
$\delta^{13}C = -11.5‰$

Carbonate sediment. Precipitation procedure: water was allowed to rise to near surface by stopping pumps for 10 min, then pumping resumed and water was collected in three 25L and one 20L carboys. KOH (in pellet form), $SrCl_2$, and $FeSO_4$ were added to filled carboy. Dissolved CO_2 and HCO_3^- in water reacts to $SrCO_3$, which flocculates readily in presence of $FeSO_4$ and settles rapidly in neck of inverted carboy. Faucet attached to cap allowed draining of sediment into 0.5L bottles. In laboratory, sediment was transferred into hydrolysis system where it was acidified under vacuum. Released CO_2 was processed to benzene. Coll 1977 by H Haas.

SMU-537. Phillips Spring 393 **2040 ± 60**

Charcoal from Sq S514 SE 508, to 512 SE 508. Sample from 2nd level of pit, Feature 392 in Unit E (R 4-5). Sample was processed through field flotation and was presoaked with trisodium phosphate. Coll July 1977 by R Hake.

SMU-538. Phillips Spring 713 **1900 ± 80**

Charcoal from Sq 518 SE 508, 2nd level of pit Feature 408 in Unit E (R 4-5); depth 2.7 to 2.8m. Sample was processed through field flotation and was presoaked with trisodium phosphate. Coll July 1977 by J Phillippe.

SMU-539. Phillips Spring pollen profile **5390 ± 90**

Uncharred moss and wood fragments, 18.2g. Profile 1974-1, depth 65 to 75cm below surface in peat layer, ca 40cm thick, (probably Unit K1) above what are believed to be artifacts from Upper Sedalia components. Top of peat is below Woodland artifacts. Coll July 1974 by J King.

SMU-550. Phillips Spring 823 **3650 ± 70**

Charcoal from Sq 514 SE 508, first level of pit Feature 424 in Unit E (R 4-5), depth 2.8 to 2.9m on E end of pit above sand-lined floor. Sample was processed through field flotation and was presoaked with trisodium phosphate. Coll July 1977 by J Behm.

SMU-554. Phillips Spring 789 **2250 ± 100**

Charcoal (predominantly oak) from Sq 512 SE 512. Samples are respectively from 3rd and 4th 10cm levels of Pit 415 in Unit E (R 4-5). Sample was processed through field flotation and was presoaked with trisodium phosphate. Coll July 1977 by J Nylander.

SMU-556. Phillips Spring 1278 **3960 ± 70**

Charcoal Sq 511 SE 508.5, from 50sq cm block in Feature 1173, Unit E (R 4-5). Upper portion of rock-lined basin above "Squash Horizon" defined in field, depth 3.3 to 3.4m. Sample was field processed through flotation; trisodium phosphate added to disperse clays. Coll July 1977 by J Phillippe.

SMU-557. Phillips Spring 1640, 2nd sample **7090 ± 90**

Uncharred wood from Sq 510 SE 508; for first sample, see SMU-505. From top of stream channel fill in Unit C2 (R 2).

SMU-558. Phillips Spring 1453 **3920 ± 70**

Charcoal from Sq 511.5 SE 508, from 50cm block in Feature 117, Unit E (R 4-5). Sample is from rock-lined basin above "Squash Horizon" defined in field, depth 3.3 to 3.4m. Sample field processed through flotation; trisodium phosphate added to disperse clays. Coll July 1977 by J Phillippe.

SMU-559. Phillips Spring 1124 **3800 ± 180**

Charcoal from grid Sq 500 SE 508, 4m, Upper Sedalia complex component-sealed floor. Sample is lumped from several $50cm^2$ units and comprises all charcoal from Feature 1124, Unit E (R 4-5). Coll July 1977 by Field Crew.

SMU-726. Phillips Spring 3464 **7300 ± 80**

Uncharred wood and seeds of nut hulls, 61.5g from 513.4 SE 511.2, depth 4.2 to 4.3m, top of Unit C2 (R 2), channel fill, top of Holocene pollen profile; wood fragments include bark, bur oak acorns, twigs. Coll July 1978 by M Kay.

SMU-727. Phillips Spring 3469 **7980 ± 70**

Uncharred wood, 55.5g, piece of grape vine, piece of charred elm from 513.4 SE 511.2, depth 4.7 to 4.8m. Sample was near center of Unit C2 (R 2) channel fill. Base of Holocene pollen profile. Coll July 1979 by M Kay.

SMU-735. Phillips Spring 40MO78 **7750 ± 90**

Wood from Tr 7 (38° 03′ 45″ N, 93° 18′ 33″ W), depth 5.25m, Unit C1. Coll July 1978 by C V Haynes.

SMU-736. Phillips Spring 41MO78 **7620 ± 90**
$\delta^{13}C = -27.4‰$

Wood from Tr 7, depth 4.7m, Unit C1. Coll July 1978 by C V Haynes.

SMU-737. Phillips Spring 43MO78 **8050 ± 90**
$\delta^{13}C = -30.0‰$

Wood from Tr 7, depth 6.25m, Unit C1. Coll July 1978 by C V Haynes.

SMU-810. Phillips Spring 29MO78 **6430 ± 80**
$\delta^{13}C = -26.7‰$

Sticks, twigs from Tr 7, depth 3.4m, Unit C3, 3.6g coarse, 4.3g fine wood fragments after pretreatment. Coll July 1978 by C V Haynes.

SMU-811. Phillips Spring 31MO78 **4970 ± 70**
$\delta^{13}C = -27.2‰$

Twigs from Tr 7, depth 3.25m, Unit K2, 2.8g coarse, 2.6g fine wood fragments after pretreatment. Coll July 1978 by C V Haynes.

SMU-812. Phillips Springs 39MO78 **7200 ± 100**
$\delta^{13}C = -27.4‰$

Wood, plant fragments from Tr 7, depth 4.48m, Unit C1, 15.8g after pretreatment. Coll July 1978 by C V Haynes.

SMU-813. Phillips Spring 3484 **25,050 ± 330**

Humate fraction from 510.9 SE 511.2, depth 6.5 to 6.6m at top of recovered sec from Unit A; sample was sectioned for pollen, primary spectra was pine. Coll July 1978 by M Kay.

SMU-815. Phillips Spring 30MO78 **5400 ± 110**
$\delta^{13}C = -26.8‰$

Small pieces of wood from Tr 7, depth 3.6m, Unit K1, pretreated by C V Haynes.

SMU-818. Phillips Spring 36MO78 **3400 ± 50**
$\delta^{13}C = -29.2‰$

Walnut shells from Tr 7, from Feature 3492, Unit E, depth 3.25M. Coll July 1978 by C V Haynes.

SMU-819. Phillips Spring 28MO78 **6900 ± 80**

Sticks, twigs from Tr 7, Unit C2, depth 3.75m. Coll July 1978 by C V Haynes.

SMU-820. Phillips Spring 37MO78 **3750 ± 50**
$\delta^{13}C = -26.6‰$

Plant fragments in clay from Tr 7, Feature 3493, Unit E, depth 3.45m. Coll July 1978 by C V Haynes.

SMU-824. Phillips Spring 3455/56 **6280 ± 100**
$\delta^{13}C = -27.8‰$

Wood and plant fragments, mostly uncharred, 27.2g, from 513.4 SE 511.2, depth 3.4 to 3.5m, Unit K1 channel fill deposit. Matrix reduced with trisodium phosphate and sample coll through flotation. Coll 1978 by M Kay.

SMU-825. Phillips Spring 3473/74 **8090 ± 90**
$\delta^{13}C = -23.9‰$

Wood and plant fragments, 20.85g, from 513.4 SE 511.2, depth 5.1 to 5.2m, base of Unit C2 channel fill. Coll 1978 by M Kay.

•SMU-826. Phillips Spring 3266 **7650 ± 190**

Uncharred wood and plant fragments, 6.15g, from 510.9 SE 511.2, depth 5.5 to 5.6m, base of Unit C1 overlying Unit A3 gravel. Matrix reduced with trisodium phosphate and sample coll through flotation. Coll July 1978 by M Kay.

SMU-1112. Phillips Spring 3428 **3480 ± 50**

Charcoal, 12.7g, from 512 SE 502, depth 2.9 to 3.0m from Feature 3428, Unit E; possible Sedalia Component 4. Coll summer 1978 by M Kay.

SMU-1113. Phillips Spring 416 **2140 ± 60**
$\delta^{13}C = -26.3‰$

Charcoal, 15.9g, from 512 SE 510, depth 2.8 to 2.9m from Feature 414, Unit E. Coll Dec 1977 by M Kay.

SMU-1114. Phillips Spring 936 **2210 ± 60**
$\delta^{13}C = -25.3‰$

Charcoal, 14.8g from 514 SE 510, depth 2.75 to 2.85m from Feature 935, Unit E. Coll Dec 1977 by M Kay.

SMU-1165. Phillips Spring 3309 **4100 ± 420**

Charcoal, 0.8g, from 504 SE 508, depth 3.2m, Unit E of Sedalia Component 1 in Feature 201. Coll summer 1978 by M Kay.

SMU-1166. Phillips Spring 2027 **2860 ± 250**

Charcoal, 2.5g, from 504 SE 504, depth 2.8 to 2.9m, from pit Feature 1931 Sedalia Component 4, Unit E. Coll 1978 by M Kay.

SMU-1167. Phillips Spring 2074 **4100 ± 250**

Charcoal, 2.5g, from 512 SE 508, depth 3.0 to 3.1m, from Feature 2074, Unit E Sedalia Component 3; prospective Component 3 small pit. Coll summer 1978 by M Kay.

SMU-1170. Phillips Spring 3047 **2450 ± 220**

Charcoal, 1.8g, from 520 SE 506, depth 2.6 to 2.7m, Unit E in Feature 3011 Woodland period. Coll summer 1978 by M Kay.

SMU-1171. Phillips Spring 3008 **4010 ± 90**

Uncarbonized nut shells, including hickory and walnut, from 516 SE 504, depth 3.5 to 3.54 from complex peat and sand levels beneath Feature 1969; sample from peat. Coll summer 1978 by M Kay.

SMU-1172. Phillips Spring 3366 **3240 ± 450** $\delta^{13}C = -26.4‰$

Charcoal, 15.8g, from 506 SE 510, depth 3.2 to 3.3m, Unit E Sedalia Component 1 Feature 201. Coll summer 1978 by M Kay. *Comment:* lab problem with benzene; assay is rejected-inconsistent with SMU-423 and -1165.

SMU-1178. Phillips Spring 2095 **3850 ± 230** $\delta^{13}C = -26.6‰$

Charcoal, 1.7g, from 516 SE 504, depth 3.1 to 3.2m, Feature 1969, Unit E Sedalia Component 3. Coll summer 1978 by M Kay.

SMU-1179. Phillips Spring 3001 **3170 ± 90** $\delta^{13}C = -27.0‰$

Charcoal, 3.0g, from 516 SE 504, depth 3.2 to 3.3m, Feature 1969, Unit E Sedalia Component 3; sample in Archaic rock concentration. Coll summer 1978 by M Kay.

SMU-1195. Phillips Spring 3410 and 3411 **3760 ± 100** $\delta^{13}C = -26.6‰$

Charcoal and some uncarbonized wood, 5.0g, from 504 SE 510, depth 3.2 to 3.3m, Unit E Sedalia Component 1 Feature 201. Coll summer 1978 by M Kay. *Comment:* aquatic moss infiltrated feature after its abandonment. Sample is contaminated and assay is unacceptable.

SMU-1213. Phillips Spring 3190 **5070 ± 150** $\delta^{13}C = -25.8‰$

Charcoal, 2.3g, from 512.5 SE 508.5, depth 3.5 to 3.6m, lower Unit K2. Coll summer 1978 by M Kay.

SMU-1214. Phillips Spring 3173 **4500 ± 100** $\delta^{13}C = -26.2‰$

Charcoal, 7g, from 512 SE 508.5, depth 3.34 to 3.40, upper Unit K2. Coll summer 1978 by M Kay.

General Comment: significance of individual dates and of entire series from Phillips Spring is indicated in Tables 1 and 2 and is more fully discussed in references. Assays are generally from stratigraphically well-controlled natural depositional units and/or archaeologic features within and below Holocene-age Rodgers alluvium. These and accompanying Rodgers Shelter date list represent most comprehensive alluvial dating program of individual archaeologic sites and Holocene deposits in lower Pomme de Terre River valley.

Rodgers Shelter series

Rodgers Shelter, a multilayered site of four main strata in Benton Co, Missouri (38° 5′ 30″ N, 93° 20′ 40″ W) is the premiere archaeologic site in the lower Pomme de Terre River valley. Thirty-two ^{14}C assays (Table 3) are available for charcoal samples from its depositional units, including 21 newly reported SMU assays; an additional 4 SMU assays are on non-human bone from the site.

The primary concern of the 1960s ^{14}C dating program was to bracket the ages of natural strata noted within the 9m deposit (Ahler, 1976, p 124, Fig 8.2). This, however, was only partly successful, as charcoal samples were of insufficient size to date the uppermost Statum 4. Excavations were renewed in 1974 and completed in 1976 (Kay, 1980). All four strata are now securely dated (Table 3). Excavations were in three areas of the site, the

TABLE 3
Rodgers Shelter radiocarbon dates on charcoal

Lab no.*	5568 BP half-life	Provenience	Datum depth (m)	Stratum
ISGS-48	10,530 ± 650	225NW95	8.53	1
M-2333	10,200 ± 330	225NW95	8.98	1
A-868A	8,100 ± 300	240NW110	3.81	1
GAK-1170	8,100 ± 140	250NW110	3.05	1
M-1900	8,030 ± 300	240NW105	4.52	1
SMU-461	7,960 ± 130	220NW405	4.57	1WT
GAK-1172	7,490 ± 170	245NW110	3.44	2
SMU-507	7,260 ± 290	265NW115	2.06	2
SMU-502	7,170 ± 160	265NW115	1.90	2
GAK-1171	7,010 ± 160	250NW115	3.20	2
ISGS-35	6,300 ± 590	265NW95	1.77	2
M-2281	5,200 ± 200	260NW70	1.37	3
SMU-459	5,130 ± 160	220NW405	3.66	2WT
M-2332	5,100 ± 400	260NW70	1.37	3
SMU-451	3,530 ± 80	243NW75	1.43	4
SMU-524	3,430 ± 50	265NW115	1.14	4
SMU-510	3,360 ± 70	265NW115	1.14	3
SMU-488	3,150 ± 60	243NW75	1.29	4
SMU-465	2,620 ± 140	220NW405	2.44	4WT
SMU-448	2,520 ± 60	265NW110	0.84	4
SMU-454	2,350 ± 80	243NW75	1.20	4
SMU-478	2,250 ± 70	243NW75	1.28	4
SMU-439	2,070 ± 70	265NW110	0.69	4
SMU-455	1,910 ± 100	220NW405	2.28	4WT
SMU-447	1,580 ± 70	265NW110	0.53	4
SMU-446	1,460 ± 60	265NW110	0.38	4
SMU-438	1,390 ± 70	265NW110	0.53	4
SMU-474	1,060 ± 100	220NW405	2.21	4WT
SMU-466	530 ± 70	243NW75	1.13	4
A-867	430 ± 100			4
SMU-467	200 ± 70	220NW405	1.98	4WT
SMU-456	200 ± 60	220NW405	2.05	4WT

* All SMU dates are from 1974, 1976 excavations; all other dates are from the 1960s excavations, none is $\delta^{13}C$ adjusted.

Shelter, a contiguous Main Excavation, and the West Terrace. All West Terrace assays stem from the 1976 excavations and are from the 22ONW405 provenience unit. Basal Stratum 4 dates for the Shelter and Main Excavation areas are reasonably consistent but differ from the West Terrace assays because of an erosional interval that affected sedimentation on the West Terrace. Table 3 is followed by descriptions of the samples.

SMU-438. Rodgers Shelter 10003 **1390 ± 70**

Charcoal from Sq 265 NW 110, depth 0.53m, St 4. Coll 1974 by K McGrath. Different sample from same depth was dated; see SMU-447.

SMU-439. Rodgers Shelter 10005 & 10006 **2070 ± 70**

Charcoal from Sq 265 NW 110, depth 0.69m, St 4. Coll 1974 by K McGrath.

SMU-446. Rodgers Shelter 10001 & 10002 **1460 ± 60**

Charcoal from Sq 265 NW 110, depth 0.38m St 4. Coll 1974 by K McGrath.

SMU-447. Rodgers Shelter 10004 **1580 ± 70**

Charcoal, nuts from Sq 265 NW 110, depth 0.53m, St 4. Coll 1974 by K McGrath.

SMU-448. Rodgers Shelter 10007 & 10008 **2520 ± 60**

Charcoal from Sq 265 NW 110, depth 0.84m, St 4. Coll 1975 by K McGrath.

SMU-451. Rodgers Shelter 11099 **3530 ± 80**

Charcoal, 2.6g, from Sq 243 NW 75, depth 1.29–1.52m. Sample should provide basal date for St 4 from main excavation area of Rodgers Shelter. Charcoal was hand-picked from flotation residue by F King and subsample was retained for charcoal identification. Coll July 1976 by M Kay.

SMU-454. Rodgers Shelter 11052 **2350 ± 80**

Charcoal, 11.8g, Sq 243 NW 75, depth 1.13 to 1.21m, upper St 4. Sample should date upper portion of St 4. Coll July 1976 by M Kay.

SMU-455. Rodgers Shelter 11047 **1910 ± 100**

Charcoal, 2.9g, Sq 220 NW 405, depth 2.21 to 2.28, base of St 4, W terrace. Coll July by M Kay.

SMU-456. Rodgers Shelter 11033 **200 ± 60**

Charcoal, 6.8g, Sq 220 NW 405, depth 1.98 to 2.06m, upper St 4, W terrace. Sample should provide closely correlated date for upper sediments from W terrace. Coll July 9, 1976 by M Kay.

SMU-459. Rodgers Shelter 11318, 11324, 11358 combined **5130 ± 160**

Charcoal, 2.1g, Sq 220 NW 405, depth 3.46 to 3.73m, base of St 2, W terrace. Sample should provide basal date for St 2, like unit from W terrace. Coll Aug 19, 1976 by M Kay.

SMU-461. Rodgers Shelter 11476 **7960 ± 130**

Charcoal, 6.6g, Sq 220 NW 405, depth 4.42 to 4.57m, burned tree stump truncated by gravels in upper part of St 1. Sample should provide upper date for St 1 on W terrace, possibly correlated with earliest occurrence of Rice Lobed and Graham Cave Notched points. Coll Sept 1976 by M Kay.

SMU-465. Rodgers Shelter 11049, 11053, 11068 combined **2620 ± 140**

Charcoal, 1.5g, Sq 220 NW 405, depth 2.29 to 2.51m, base of St 4 or top of St 3, from W terrace. Sample should provide upper date from St 3. Coll July 1976, by M Kay.

SMU-466. Rodgers Shelter 11046 **530 ± 70**

Charcoal, 7.1g, Sq 243 NW 75, depth 1.03 to 1.13m, top of St 4. Sample should provide upper date for Rodgers Shelter. Coll July 13, 1976 by M Kay.

SMU-467. Rodgers Shelter 11032 **200 ± 70**

Charcoal, 7.4g, Sq 220 NW 405, depth 1.91 to 1.98m, top of St 4 from W terrace. Sample should provide upper date for W terrace, and hopefully will closely correlate with dates from sample 11046. Coll July 9, 1976 by M Kay.

SMU-474. Rodgers Shelter 11039 **1060 ± 100**

Charcoal, Sq 220 NW 405, depth 2.13 to 2.21m, near top of St 4 from W terrace. Coll 1976 by M Kay.

SMU-478. Rodgers Shelter 11054 **2250 ± 70**

Charcoal, 9.7g, Sq 243 NW 75, depth 1.20 to 1.28m, lower portion of St 4. Sample was hand-picked from flotation residues that were pre-soaked with trisodium phosphate. Coll July 1976 by M Kay. *Comment* (HH): sample consisted of organic materials coll over 2.3m^2 area. St 4 has total thickness of ca 50cm at this excavation square. Date is in fair agreement with SMU-454.

SMU-488. Rodgers Shelter 11089 **3150 ± 60**

Charcoal, 9.8g, Sq 243 NW 75, depth 1.28 to 1.29m, lower part of St 4. Sample was hand-picked from flotation residues that were pre-soaked with trisodium phosphate. Coll July 1976 by M Kay.

SMU-502. Rodgers Shelter 10022 **7170 ± 160**

Charcoal, 1.7g, 1974 excavation, Sq 265 NW 115 (Sq C), depth 1.90m, near top of St 2. Coll June 1974 by K McGrath.

SMU-507. Rodgers Shelter 10023 **7260 ± 290**

Charcoal, 1.4g, 1974 excavation Sq 265 NW 115, depth 2.06m, near top of St 2. Coll June 1974 by K McGrath.

SMU-510. Rodgers Shelter 10015 **3360 ± 70**

Charcoal, 6.4g, 1974 excavation Sq 265 NW 115, depth 1.14m, top of St 3, below black soil. Coll by K McGrath.

SMU-524. Rodgers Shelter 10015 **3430 ± 50**

Charcoal, 20.9g, 1974 excavation Sq 265 NW 115, depth 1.14m, base of St 4 beneath overhang. Coll by K McGrath.

Rodgers Shelter bone series

The following four bone samples were coll and subm by C V Haynes to analyze ^{14}C content of secondary carbonate deposited inside bone structure. Samples were hydrolized in 50% acetic acid.

SMU-533. Rodgers Shelter, bone scrap **105.4 ± 2.9% modern**

St 4, Level 4, 0.84m.

SMU-530. Rodgers Shelter, bone scrap **96.6 ± 2.0% modern**

St 2, Levels 11 and 12, 1.9 to 2.06m.

SMU-532. Rodgers Shelter, bone scrap **118.0 ± 2.1% modern**

St 2, Level 16.

SMU-526. Rodgers Shelter, bone scrap **121.2 ± 1.7% modern**

St 1, Level 18.

General Comment: test indicates penetration of nuclear-age carbon to at least 0.6m depth and rise of groundwater level by at least 6m above normal (Haynes, 1985).

Trolinger Spring series

Trolinger Spring dates were discussed in Haynes *et al* (1983). Five samples were coll and pretreated by C V Haynes July and Aug, 1978.

32,270 ± 920

SMU-931. Missouri 5M078 $\delta^{13}C = -28.3‰$

Peat residue, 10.49g, (48°03′59″N, 93°20′42″W), 7″ below well collar DD, above 4MO78. Standard pretreatment with multiple acid-base cycles to reduce humate content.

32,950 ± 1040

SMU-932. Missouri 6MO78 $\delta^{13}C = -28.2‰$

Peat residue, 12.37g, 1″ above well collar DD, above 5MO78.

38,200 ± 1680

SMU-933. Missouri 7MO78 $\delta^{13}C = -28.0‰$

Peat residue, 16.75g, 12″ below well collar DD. Standard pretreatment with multiple acid-base cycles to reduce humate content.

SMU-934. Missouri 8MO78 **38,880 ± 3750**
$\delta^{13}C = -28.3‰$

Peat residue, 5.9g. Standard pretreatment with multiple acid-base cycles to reduce humate content.

SMU-935. Missouri 9MO78 **38,020 ± 2850**
$\delta^{13}C = -28.3‰$

Peat residue, 4.37g. Standard pretreatment with multiple acid-base cycles to reduce humate content.

General Comment: results indicate that Trolinger Spring Fm (Haynes, 1985) is ≧30,000 BP.

Rodgers Shelter Formation series

The following samples were coll 1977 by C V Haynes in Trench 76D, opposite Rodgers Shelter. A full report on these samples, as well as on those from Trench 78, which are also reported here, is given in Haynes (1985).

SMU-429. Pomme de Terre 1MO76 **3560 ± 90**

Charcoal from Tr 76D, Unit R4. Coll April 1977.

SMU-430. Pomme de Terre 5MO76 **1750 ± 90**

Charcoal from Tr 76D, Unit R5. Coll Aug 1976.

SMU-431. Pomme de Terre 2MO76 **230 ± 40**

Wood stick from Tr 76D, Unit P2. Coll April 1977.

SMU-485. Pomme de Terre 3MO76 **330 ± 50**

Leafmat (lower) from Tr 76D, Unit P2. Coll Aug 1976.

SMU-499. Pomme de Terre 3MO76 **140 ± 90**

Leafmat (lower) from Tr 76D, Unit P2. Coll Aug 1976.

SMU-500. Pomme de Terre 4MO76 **190 ± 40**

Leafmat (upper) from Tr 76D, Unit P2. Coll Aug 1976.

SMU-506. Pomme de Terre 6MO76 **2360 ± 70**

Charcoal from Tr 76D, Unit R5. Coll Aug 1976 by C V Haynes.

SMU-508. Pomme de Terre 7MO76 **280 ± 50**

Wood from Tr 76D, Unit P2. Coll Aug 1976 by C V Haynes.

SMU-814. Missouri 57MO78 **8050 ± 100**
$\delta^{13}C = -26.8‰$

Charcoal from Tr 78B.

SMU-816. Missouri 58MO78 **5150 ± 330**
$\delta^{13}C = -26.6‰$

Charcoal from Tr 78B, pretreated by C V Haynes.

SMU-823. Missouri 23MO78 **3630 ± 70**

Charcoal from Tr 78B, Unit R4.

SMU-817. Missouri 59MO78 **520 ± 330**

Charcoal from Tr 78C.

General Comment: results help to confirm and date six-fold subdivision of Rodgers Shelter Fm (Haynes, 1985).

Texas

Cooper Lake series

The Cooper Dam and Lake Project was established to provide flood control and water retention along 25.6km of the South Sulphur River. When built, the lake will cover ca 13,760ha of flood plain and Pleistocene terraces on either side of the Sulphur River. Prior to construction an inventory and extensive evaluation of the cultural resources were made. These dates are part of this study; detailed reports were previously pub (Butler, Hyatt & Mosca, 1974; Doehner & Larson, 1975; Doehner, Peter & Skinner, 1978). Samples were from 33° 18′ N, 95° 40′ W unless otherwise indicated.

SMU-310. **870 ± 50**

Charcoal from Sq 112, 30 to 35cm depth. Coll June 1975 by K Doehner.

SMU-316. **950 ± 60**

Charcoal from Feature 112A. Coll July 1975 by J Saunders. *Comment* (HH): obviously large quantity of silt and soil and separate pieces of charcoal coll with shovel.

SMU-325. **950 ± 50**

Charcoal from Feature 97A, 41cm depth, beneath ash pit.

SMU-328. **850 ± 60**

Charcoal from Feature 112A, 49cm depth. Coll July 1975 by K Doehner.

SMU-335. **1360 ± 140**

Charcoal from Sq 52, 40 to 45cm depth. Coll Oct 1975 by P Stark.

SMU-338. **1070 ± 60**

Charcoal from Sq 109, 42.5cm depth, 24cm S of N wall in W wall. Coll 1975 by J Garber.

SMU-339. **1410 ± 120**

Charcoal from Sq 155, 61cm depth. Coll June 1975 by J Morris.

SMU-341. **860 ± 60**

Charcoal from Sq 127, 35 to 40cm depth, NW corner. Coll June 1975 by B Rader.

SMU-346. **1090 ± 100**

Charcoal (33° 20′ N, 95° 50′ W) from Sq 113, 54 to 56cm depth. Coll by K Doehner.

SMU-349. **1320 ± 190**

Charcoal from 30 to 35cm below surface.

SMU-359. **115.9 ± 0.9% modern**

Charcoal from 5 to 10cm below surface (33° 20′ N, 95° 50′ W).

SMU-363. **270 ± 60**

Charcoal from Sq 46, 10 to 15cm, below surface (33° 20′ N, 95° 40′ W). *Comment* (KD): possible contamination.

SMU-396. **920 ± 40**

Charcoal (33° 17′ 18″ N, 95° 46′ 01″ W) from test pit 21, Feature 21-A. Coll Aug 1976 by N Morris.

SMU-398. **200 ± 80**

Charcoal test pit 14, 45 to 50cm below surface. Coll July 1976 by I McGregor.

SMU-401. **1060 ± 70**

Charcoal (33° 18′ 15″ N, 95° 43′ 49″ W) from test pit 10, 45 to 50cm below surface. Coll July 1976 by I McGregor.

SMU-402. **165 ± 70**

Charcoal (33° 17′ 25″ N, 95° 39′ 01″ W) from test pit 3, 15 to 20cm below surface. Coll July 1976 by I McGregor.

SMU-404. **660 ± 70**

Charcoal (33° 17′ 18″ N, 95° 46′ 01″ W) from test pit 30, 30 to 40cm below surface. Coll Aug 1976 by M Goode.

SMU-417. **160 ± 45**

Charcoal from test pit 31, Feature 31-A.

SMU-471. **280 ± 70**

Charcoal from test pit 19, W wall pedestal, 20 to 30cm below surface. Coll Aug 1976.

SMU-476. **1300 ± 150**

Charcoal from test pit 15 (stained area) 44cm below surface. Coll Aug 1976 by K Doehner.

SMU-477. **1060 ± 120**

Charcoal (33° 18′ 51″ N, 95° 42′ 26″ W) from test pit 7, 20 to 25cm below surface. Coll Aug 1976 by D Kellogg.

Aquilla Reservoir Project series

Aquilla Reservoir is located at Hill Co, Texas (31° 53′ 30″ N, 97° 12′ 15″ W). For progress report, see Skinner *et al* (1978).

SMU-498. X41HI40 Sample 1 **620 ± 80**

Charcoal from Unit 9E, 30 to 40cm depth; large charcoal lumps from clay matrix dispersed throughout unit, not from one hearth. Coll Aug 1977 by K Banks.

SMU-479. X41HI41 Sample 3 **1400 ± 60**

Mussel shell from top of paleosol in cultural layer ca 20cm from present bank face. Coll Aug 18, 1977 by G Rutenberg.

SMU-528. X41HI40 Sample 2 **720 ± 100**

Charcoal from Unit 9E, 40 to 50cm depth; large charcoal lumps from clay matrix dispersed throughout unit. Coll Aug 11, 1977 by K Banks.

SMU-535. X41HI40 Sample 3 **850 ± 60**

Charcoal from Unit 9E, 50 to 60 cm depth; large charcoal lumps from clay matrix dispersed throughout unit. Coll Aug 11, 1977 by K Banks.

SMU-540. X41HI141 Sample 4 **2200 ± 50**

C-horizon soil from cut bank profile 5cm above paleosol. Coll Aug 24, 1977 by K Banks.

SMU-568. X41HI141 Sample 2 **2300 ± 60**

Paleosol from cut bank profile 5cm above base of paleosol cultural layer according to D Pheasant, at base of 3A1 above 2150 datum. Coll Aug 18, 1977 by K Banks.

SMU-633. X41HI141 Sample 1 **1910 ± 45**

Paleosol from cut bank profile 5cm below top of paleosol cultural layer according to D Pheasant, in top of 3A1 below 1790 datum. Coll Aug 1977 by K Banks.

Hog Creek Basin series

Site is at Edward's Plateau (31° 45′ N, 97° 47′ W).

SMU-272. X41BQ19 Charcoal **990 ± 130**

Sample from Five Goat site, 20 to 25cm depth. Coll Oct 1975 by H Mosca.

SMU-280. X41CR1 Charcoal and burned wood **560 ± 45**

Apparently basal layer of cultural deposit. Sample was originally 2 samples coll from same lens of charcoal/ash stain. Coll Oct 1975 by R Larson.

SMU-324. X41CV2-TP1-13 Charcoal **1180 ± 60**

Sample from "Pick A Slab" Rockshelter (31° 38′ 52″ N, 94° 38′ 16″ W)

Hog Creek drainage. From test pit 1, SE quad, 130cm below present ground surface. Coll from ash lens just above disintegrated limestone bedrock of rockshelter. Coll Oct 1975 by R Larson.

Elcor Burial Cave series

Seven human skulls were recovered from small sinkhole cave in west Texas in 1975. These skulls represent secondary burial of undetermined age. ^{14}C dating of two skulls and anthropometric study of entire sample suggest that skulls belong to prehistoric Indians physically similar to those of Trans-Pecos, ca AD 900-1100. Two skulls were subm for dating (Skinner, Haas & Wilson, 1980). Burial cave is in S end of Rustler Hills near E division line of strata change, Gypsum Plain, ca 72km of Van Horn, Culberson Co (31° 41′ N, 140° 15′ W).

880 ± 50
SMU-342. Skull 5 $\delta^{13}C = -7.6‰$

Human skull, apatite fraction. *Comment* (HH): bones seemed relatively thin walled and broke at sutures.

1230 ± 70
SMU-374. Skull 5 $\delta^{13}C = -12.3‰$

Human skull, collagen fraction.

950 ± 50
SMU-387. Skull 1 $\delta^{13}C = -6.6‰$

Human skull, apatite fraction.

960 ± 60
SMU-434. Skull 1 $\delta^{13}C = -13.0‰$

Human skull, collagen fraction.

Rex Rodgers site series

Rex Rodgers site is in Tule Canyon, Brisco Co (34° 32′ 45″ N, 101° 26′ 15″ W), Paleo-Indian bison kill and butchering area (Speer, 1978).

9330 ± 80
SMU-274. Bison bone, scrap bone apatite $\delta^{13}C = -4.2‰$

Lake Lavon series

Enlargement project for this artificial lake in Collin Co. On N end of lake is Sister Grove Creek site (33° 8′ 52″ N, 96° 28′ 47″ W), human burial in round pit, Feature 15. Charcoal from fire in pit, antedating burial, was dated 790 ± 90 (Tx-2040). Sample consisted of ca 450g arm and leg bones. Coll and subm July 1974 by M J Lynott (1975, p 33).

1020 ± 170
SMU-233. Bone apatite $\delta^{13}C = -13.5‰$

Hydrolized with HCL. Discarded initial 2L of CO_2, dated final CO_2, 3.4L.

SMU-239. **880 ± 40**
$\delta^{13}C = -22.5‰$

Collagen fraction, 58.5g yielding 4.9L CO_2.

Oklahoma

Big Hawk Shelter series

Big Hawk Shelter and Cut Finger Cave are two sites in Hominy Creek Valley ca 35km NW of Tulsa, in area of proposed Skiatook Lake.

Big Hawk Shelter (36° 23′ N, 96° 16′ W) was formed by chemical weathering of limestone fm underlying more resistant sandstone fm. Excavation exposed aeolian deposit containing four lithologic layers. Excavation was carried out in 0.25m quadrants in 10cm levels, measured from surface. Artifactual and radiometric evidence indicates prehistoric occupations from AD 200 to 1500, including Plains Woodland and Plains Village. Samples were coll Feb 1976, and subm July 1976 by D O Henry (1978a,b). Depths are reported in cm.

SMU-356. Charcoal, Level 3, 20-30cm **700 ± 60**

SMU-371. Charcoal, Level 4, 30-40cm **880 ± 60**

SMU-344. Charcoal, Level 5, 40-50cm **800 ± 60**

SMU-372. Charcoal, Level 6, 50-60cm **840 ± 60**

SMU-379. Charcoal, Level 8, 70-80cm **660 ± 60**

SMU-380. Charcoal, Level 9, 80-90cm **390 ± 100**

SMU-381. Charcoal, Level 10, 90-100cm **390 ± 60**

Cut Finger Cave series

Cut Finger Cave is ca 25m E of Big Hawk Shelter; cave was formed at contact of limestone and overlying sandstone strata. Excavation revealed 3 stratigraphic layers within cave. Top Layers A and B post-date prehistoric occupation of cave and seal cultural horizon of Layer C. Two dates are from this layer (Henry, 1978b).

SMU-336. Charcoal, Level 2, 30-40cm **740 ± 50**

Sample from hearth (Feature 1).

SMU-382. Charcoal, Level 4, 50-60cm **850 ± 50**

Cedar Creek Shelter series

Cedar Creek Shelter (36° 83′ N, 96° 8′ W) is rock overhang at base of 14m sandstone escarpment along Cedar Creek ca 1km upstream from confluence with Hominy Creek. Excavation revealed three layers (Henry, 1978b).

SMU-495. Charred nuts, Layer B **970 ± 40**

Level 3, 60 to 70cm.

SMU-497. Charcoal and charred nuts, Layer C **1600 ± 40**

Level 5, 80 to 90cm.

SMU-519. Charcoal and charred nuts, Layer C **1540 ± 70**

Level 7, 100 to 110cm. *Comment:* this date and SMU-497 overlap within 1σ and may be viewed as equivalent in age.

SMU-405. Ft Sill Parade Ground site **390 ± 80**

Charcoal from Level 5, 20 to 25cm, Test Sq 3 (34° 40′ 15.7″ N, 98° 23′ 15.1″ W). Charcoal removed from light brown compact clayey silt containing abundant artifactual and organic cultural material. Charcoal lumps coll in field with trowels; excess matrix and some roots removed by hand in lab. Coll Jan 1977 by Mus Great Plains. Subm by R Ferring (Hall, 1978).

New Mexico

Los Esteros series

Los Esteros Archaeol Proj, Guadalupe Co (35° 02′ 13″ N, 104° 40′ 33″ W) was inventory and evaluation for Los Esteros Dam and Reservoir, on Pecos River seven miles upstream from Santa Rosa. Sites evaluated with ^{14}C dates included overhanging cliff shelter (Old Coyote Shelter), small rock shelter (Helter Shelter), 2 Tipi Ring sites (Catfish Falls site, Site 29 GU 236), and hearth site (Spillway site). Regional and local archaeology, artifact analyses, etc are discussed in Levine and Mobley (1976), Unine and Mobley (1976) and Mobley (1978). Subm Nov 1975 by C Mobley.

SMU-294. 29GU20-420 **1890 ± 40**

Charcoal from Old Coyote Feature 2, base Unit C39, Strata III E. Sample was within 1.2m of ground surface under drip line of rock shelter. Coll July 1975 by C Mobley.

SMU-301. 29GU20-162 **820 ± 60**

Charcoal from Old Coyote, Feature 1, Unit A40, Strata III A. Sample was from back of rock shelter within 50cm of ground surface near packrat nest. Coll July 1975 by C Mobley.

SMU-306. 29GU20-348 **850 ± 80**

Charcoal from Old Coyote, Feature 2, top, Unit C39, Strata III A. Sample was within 50cm of ground surface, under drip line of rock shelter. Coll July 1975 by C Mobley.

SMU-312. 29GU229-97 **880 ± 60**

Charcoal from open site, hearth G, Unit 1G, Level 1. Sample was within 0.40m of ground surface. Coll June 1975 by I Russo.

SMU-318. 29GU210-33 **790 ± 60**

Charcoal from Helter Shelter, Unit E, Strata II within rock shelter. Coll June 1975 by F Levine.

SMU-320. 29GU229-338 **810 ± 70**

Charcoal from open site, hearth 3I14, Unit 3I14, Level 1 within 0.40m of ground surface.

SMU-322. 29GU236-122 **5 ± 50**

Charcoal from bulldozed Tipi Ring, Unit 2B1, Strata II. Rather shallow (within 0.40m) but material was coll from under large rock. Expected date within last 700 yr but could be 1890 cowboy campfire. Coll Aug 1975 by C Mobley.

SMU-420. 29GU23-21A-1-254/240 **300 ± 60**

Charcoal from Catfish Falls site, Ring 21, Radius A, Level 1/2. Carbon was composed of two samples from same feature. Coll March 1977 by C Mobley and M Grady.

Last Chance Canyon Packrat Midden series

Site is in Guadalupe Mts, Eddy Co (32° 16′ N, 104° 39′ W).

SMU-406. LC6A **1550 ± 60**

Dung (*Neotoma*) from limestone cave which is separate from LC1 and LC2 but close to LC6A, well-separated unit overlying LC6B. Age estimate of sample was <8000 yr and probably <4000 yr ago, based on plant microfossil content. Coll June 1976 by T R Van Devender.

SMU-409. LC1 **10,010 ± 160**

Twigs and seeds (*Juniperus*) 6.3g, from packrat midden in limestone cave. Age estimate was 8000 yr or older based on earlier midden assemblages with ^{14}C dates. Coll June 1976 by T R Van Devender.

SMU-418. LC2 **90 ± 60**

Leaves (*Dasylirion*) 3.6g, from same small shelter as LC1. Age estimate was probably <2000 yr based on plant macrofossils in midden. Coll June 1976 by T R Van Devender.

SMU-425. LC9A **3940 ± 100**

Dung (*Neotoma*) from limestone cave. Age estimate was <8000 yr, based on earlier midden assemblages with ^{14}C dates. Coll June 1976 by T R Van Devender.

SMU-437. LC6B **850 ± 90**

Leaf fragments (*Agave lechuguilla*) 3.1g, from limestone cave; probably < 4000 yr. Coll June 1976 by T R Van Devender.

SMU-458. LC10 **3870 ± 80**

Dung (*Neotoma*) 13.45g, from limestone cave. Age estimate was <4000 yr. Coll June 1976 by T R Van Devender.

Seven Rivers Quadrant series

SMU-375. Hearth **1950 ± 60**

Charcoal flecks in burned soil at 3200 elev (32° 34′ 15″ N, 104° 23′ 4″ W). Level 9 arbitrary elev 1000.20. Projectile points from occupation area believed assoc with hearth considered to date to Archaic period. Estimated age: pre-AD 900.

Eddy County series

Site is W side of Pecos River (32° 34′ N, 104° 24′ W). Samples subm Sept 1975 by J G Gallagher.

SMU-283. X29ED6-284-10B-1 **750 ± 40**

Charcoal from Sq 284, 45 to 50cm depth, from center of ring midden; expected to date AD 1100. Coll June 1975 by K Vagstad.

SMU-286. X29ED34-2233-15-1 **1310 ± 60**

Charcoal from Sq 2233, 70 to 75cm depth, from burned rock mound; expected to date ca AD 900. Coll July 1975 by J Horoze.

SMU-299. X29ED34-2233-9-1 **1400 ± 80**

Charcoal from Sq 2233, 40 to 45cm depth, from burned rock mound; from same site as SMU-286. Coll June 1975 by J Horoze.

SMU-304. X28ED274-10A-2 **610 ± 40**

Charcoal from Sq 274, 50cm depth, near possible hearth on floor of ring midden. Coll by J Gallagher.

SMU-311. X29ED13-1661-0-1 **1280 ± 100**

Charcoal mixed with sandy soil from Sq 1661, surface material. Another sample from this site coll from trench cut in face of arroyo subm to Univ Texas, Austin ^{14}C lab Aug 1975. Coll July 1975 by P Urban.

SMU-394. X29ED4-0-1-13 **1840 ± 80**

Charcoal from burned rock mound, E face back hoe trench, 25 to 35cm depth within burned rock layer. Sample dry-screened and picked out of heavily stained soil. Coll June 1976 by J Gallagher.

SMU-388. X29ED6-2891-17A **1860 ± 50**

Charcoal from hearth. Coll July 1976 by M Connor.

SMU-449. Rocky Arroyo #3 Packrat Midden **230 ± 80**

Twigs (*Juniperus*) 7.5g, from Rocky Arroyo NW of Carlsbad, Eddy Co. Age estimate of sample was <8000 yr based on plant fossils.

Algeria

Dates in these series result from interdisciplinary research project in Telidjene Basin, S of Cheria, E Algeria. Field research was conducted from 1972 to 1979 under David Lubell, Univ Alberta to investigate man-land relationships during early Holocene to better understand introduction of food-producing economies into NW Africa. Comprehensive refs are given below.

ARCHAEOLOGIC SAMPLES

Kef Zoura series

This northfacing rockshelter (7° 40′ 38″ E, 35° 2′ 26″ N) is listed as Site no. 201 in catalogue compiled by Grebenart (1976, p 80), ca 30m × 5m with at least 2m of deposit. Two industries are represented: Typical Capsian in earlier deposits, exposed primarily in 1m^2 test trench T/20-5, and Upper Capsian in later deposits. Faunal assemblages assoc with these industries are distinct, suggesting that lithic assemblages may represent tool kits designed, in part, for different uses. At this site, as well as Ain Misteheyia, Site 12 and other Capsian sites, there is evidence for technologic change and introduction of primary pressure flaking at ca 8000 BP. For fuller discussion, see Lubell (1984) and Lubell, Sheppard and Jackes (1984). All depths are in cm below datum (see also I-9835 through -9838, unpub).

SMU-704. T/20-5, hearth, 250cm **8580 ± 150**

Charcoal. Typical Capsian.

SMU-712. T/20-5, 270-280cm **9390 ± 130**

Charcoal. Typical Capsian.

7150 ± 200

SMU-1081. E20D, 135cm $\delta^{13}C = -25.4‰$

Charcoal from below SMU-1099 (below), Upper Capsian.

7750 ± 50

SMU-1082. F20B, 82-104cm $\delta^{13}C = -8.6‰$

Helix melanostoma from pit containing almost only shells, within Upper Capsian levels. Date is too old; should be younger than SMU-1081 and -1084, and same age as SMU-1099. Sample suggests land snail shell may not provide accurate dates. For discussion relating to land snail dating, see Evin *et al* (1980) and Goodfriend and Hood (1983).

6620 ± 110

SMU-1084. F20D, 114-118.5cm $\delta^{13}C = -24.1‰$

Charcoal, Upper Capsian.

7590 ± 60

SMU-1095. G20C, 110-122cm $\delta^{13}C = -23.7‰$

Charcoal, Upper Capsian. Probably just above transition from Typical to Upper Capsian. See SMU-1121 (below).

SMU-1096. E20A, 123cm **7210 ± 340** $\delta^{13}C = -22.7‰$

Charcoal, Upper Capsian. Very small sample.

SMU-1098. Humates **6750 ± 70** $\delta^{13}C = -23.7‰$

Humates extracted from charcoal of SMU-1099. Presence of uncarbonized plant materials was considered suspicious but sample appears to be reliable.

SMU-1099. E20D, 120cm **6520 ± 170** $\delta^{13}C = -25.2‰$

Charcoal. Sq E20 contains two distinctive deposits, one apparent stone-lined pit containing loose unbroken shells (*H melanostoma*) (*cf* SMU-1082, above), and one outside it. Sample comes from within rocks forming one edge, and should, therefore, be same age as SMU-1082.

SMU-1108. T/20-5, 260-270cm **9100 ± 130** $\delta^{13}C = -8.3‰$

Terrestrial gastropod shell (mostly *H melanostoma*). Date is for comparison with SMU-704 and -712, over- and underlying sample, respectively. Typical Capsian assoc industry. Although this shell carbonate age does fall between bracketing charcoal dates, it may be several hundred years too old, given usual differences between shell and charcoal dates in this list (*cf* SMU-1082, -1084, -1119, -1141).

SMU-1120. G21A, 85-88cm **7350 ± 50** $\delta^{13}C = -24.5‰$

Charcoal, Upper Capsian.

SMU-1121. G20C, 138cm **8390 ± 170**

Charcoal. Probably Typical Capsian, but assemblage from this level a bit small for accurate designation.

SMU-1154. E20D, 133cm **6770 ± 90** $\delta^{13}C = -25.6‰$

Charcoal, Upper Capsian.

Ain Berriche series

Also known as Site 12, this open-air Capsian site is 10km N of Ain Beida in E Algeria (39° 88′ N, 5° 59′ E). It was excavated in 1930 by Logan Mus Expedition under Alonzo Pond, Beloit Coll, Beloit, Wisconsin. These dates are on samples coll 1930, by P Sheppard and stored at Logan Mus. Trench A was excavated in 60cm levels, I (top) to V (base). Samples date introduction of pressure flaking in lithic manufacture between Levels IV and III, and accord with dates from Ain Misteheyia, Kef Zoura D, and Medjez II.

SMU-1132. Site 12, Tr A, Level III **7330 ± 390**
$\delta^{13}C = -23.8‰$

Charcoal. Shellac contamination.

SMU-1135. Site 12, Tr A, Level IV **7780 ± 250**

Charcoal.

GEOLOGIC AND PALYNOLOGIC SAMPLES

Oum el-Khaled series

This extensive marsh occurs along Wadi Mezeraa (35° 6′ N, 7° 37.5′ E) just upstream from narrow gorge that acts as local base level (perhaps neotectonically active) along stream's course. There is open water at center of marsh throughout dry season. Core was coll Dec 1979 for pollen studies by J C Ritchie and D Lubell. Other deposits of Wadi Mezeraa were dated in terraces ca 6km upstream from this marsh; see SMU-655, -738, -1119, -1141, below, and I-7693, -9833, -9834 (unpub). Full pub of core data is forthcoming (Ritchie, ms).

SMU-1123. 136-146cm **4100 ± 80**

This date falls just prior to boundary between Zones 1 and 2. Zone 1 is dominated by *Pinus* and *Quercus* and most probably represents woodland similar to modern sclerophyl Mediterranean forests of NW Africa. Region today is too dry to support such forests.

SMU-1124. 169.5-179.5cm **5050 ± 100**

Sample marks base of core (not base of sediment in marsh), and base of Zone 1.

Wadi Mezeraa series

A prominent meander of this Wadi (35° 8′ 49″ N, 7° 40′ 34″ E) is bordered by two terrace levels representing two cut-and-fill cycles. Two prehistoric hearths (SMU-655 and -738) occur near base of higher (older) terrace. Despite absence of diagnostic artifacts, hearths probably represent pre-Capsian occupation of region which has yet to be fully investigated or understood. Sites of this age are known somewhat to W around Bou Saada (Amara, 1977; Heddouche, 1977) where they are attributed to Iberomaurusian industry. Snails (SMU-1119) and charcoal (SMU-1141) were dated from single horizon near top of lower (younger) terrace.

SMU-655. Hearth A **11,590 ± 100**

Charcoal. Coll July 1978 by D Lubell, A Miller.

SMU-738. Hearth B **11,870 ± 290**

Charcoal. Coll July 1978 by D Lubell, A Miller.

SMU-1119. Section A, Unit 6 **2260 ± 30**
$\delta^{13}C = -8.6‰$

Helix Melanostoma and *Otala* of Sample AL-80-35C. These appear to be fluvially deposited, not archaeologic. *Comment:* result is average of two counting runs on same sample. Another sample from same horizon (I-9833) was previously dated at 2270 ± 80 BP, not corrected for $^{13}C/^{12}C$. If usual correction is applied, two dates agree very well. See also SMU-1141 for charcoal from same level. Coll July 21, 1980 by W R Farrand.

1450 ± 90

SMU-1141. Section A, Unit 6 $\delta^{13}C = -24.5‰$

Charcoal fragments from same bed, Sample AL-80-35B, as snails dated in SMU-1119. Another part of same sample was dated as Beta-2734 = 1350 ± 70 BP. Coll July 21, 1980 by W R Farrand. *Comment* (WRF): since charcoal and shells were coll from same horizon, dates (SMU, Beta, and Isotopes) indicate discrepancies between charcoal and shell carbonate ages. *Cf* also SMU-1082 and -1084, above, and two dates from Wadi Redif (in this area) where snails were dated 7690 ± 120 BP (I-7692, not corrected for $\delta^{13}C$, and charcoal dated 7340 ± 115 BP (I-7694)).

Wadi Regada series

Wadi Regada in N-central part of Telidjene basin (35° 7′ N, 7° 42.5′ E) cuts through several older alluvial deposits. This charcoal comes from hearth-like feature (without artifacts) within red paleosol exposed in wadi bank. Paleosol and hearth occur ca 270cm above wadi floor and are overlain by ca 240cm of younger alluvium that antedates present wadi incision. Coll June 30, 1980 by W R Farrand.

3160 ± 180

SMU-1142. Field sample AL-80-35A $\delta^{13}C = -22.0‰$

Comment (WRF): age is younger than expected because red soil is believed to occur on surface of "late Pleistocene pediment." Possibly, hearth is intrusive into soil. Another fragment of same sample was dated to 2590 ± 90 (Beta-2733).

Wadi Telidjene series

Snails (mostly *Helicella sitifensis*) were coll from cut bank of Wadi Telidjene (35° 4.6′ N, 7° 42.7′ E) ca 7.75km SW of Telidjene village. Snails occur in layer of gleyed, marshy sediments underlying main "late Pleisotcene Pediment" within Telidjene basin. Coll July 13, 1978 by A Miller, D Lubell, W R Farrand.

9230 ± 80

SMU-711. Snail shells (*Helix melanostoma*) $\delta^{13}C = -9.5‰$

Comment: age is reasonable for late Pleistocene/early Holocene filling of basin. Deposits are probably equivalent to lower part of Wadi Regada sec; see SMU-1142, above.

Wadi Oussif series

Wadi Oussif is major tributary in S-central part of Telidjene basin (35° 4.6′ N, 7° 44.7′ E) cutting through alluvial deposits underlying "late Pleistocene pediment"; see also SMU-711 and -1142. Snails were coll July 1978 by A Miller from very dark gray, organic-rich sediments. Miller compared deposit to Unit II at Ain Misteheyia in E part of basin (Lubell *et al,* 1975).

6950 ± 60

SMU-688. Snails shells (*Helix melanostoma*) $\delta^{13}C = -9.4‰$

Comment (WRF): sample is presumably younger, upper part of same deposit of SMU-711 and is early Holocene.

General Comment: additional refs on this project are: (Heddouche, 1977; Lubell, 1977; Lubell *et al,* 1975; Lubell & Gautier, in press; Lubell *et al,* 1976).

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[RADIOCARBON, VOL 29, NO. 2, 1987, P 239–262]

TBILISI RADIOCARBON DATES IV

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Results presented below were obtained by the Radiocarbon Laboratory of Tbilisi State University from 1976 to 1983. Throughout that period dates were determined not only for archaeologic samples but also for samples of mineral waters, soil humus, and geologic origin. Georgian wines of 1909–1975 were also analyzed but the results obtained are not discussed in this paper as they were published elsewhere (Burchuladze *et al,* 1977, 1979, 1980, 1982).

Dates of the studied samples were obtained by measuring the ^{14}C activity on a 3-channel SL-30 Intertechnique Liquid Scintillation Spectrometer. Working parameters of each channel were determined by manual adjustment of the discrimination threshold. In our procedure the maximally determined age was equal to 45,500 years. The age of individual samples was determined as the mean value of data obtained in three individual channels.

Scintillation solvent was synthesized in the all-purpose physico-chemical unit designed at Tbilisi State University which provides high reaction yields of CO_2—100%, CH_2—98%, and C_6H_6—97% for stoichiometric values (Burchuladze *et al,* 1970, 1974, 1979). The background in individual channels of SL-30 was determined, using CHEMAPOL spectroscopic benzene (Czechoslovakia) for solution volume of 10ml; 5ml of scintillation solution synthesized from the sample were diluted to 10ml by background benzene of the same grade.

As modern ^{14}C standard we used intermediate standard prepared in the Radiocarbon Laboratory of Geology Institute, Academy of Sciences, USSR, the activity of which was corrected by the NBS oxalic acid standard (USA).

In our calculations the value $T = 5730 \pm 40$ years was assumed for the half-life of ^{14}C. It should also be noted that in some instances final data on the ^{14}C activity of the sample were corrected according to ^{13}C.

We present results on the absolute age of archaeologic samples obtained by the radiocarbon method as well as data with corrections made by the conversion table (Damon *et al,* 1972).

ARCHAEOLOGIC SAMPLES

Arakhlo series, Georgian SSR

Institute of History, Archaeology and Ethnography, Acad Sci GSSR, in collaboration with Fine Arts Mus is investigating Arakhlo I, an early Neolithic agric mound. It is a Gora-Tepe type settlement near Arakhlo village, Bolnisi dist, East Georgia. Test trenches were excavated both in the inhabited hill (6m high) and vicinity. In addition to the main settlement, excavations revealed 2 ditches of different periods encircling the hill on 3 sides, a settlement represented by shelters half dug out in the foot of the hill, and synchronous burials. The settlement presently shows 7 building horizons;

the upper 6 consist of structures made of air-dried bricks; the lowest horizon only shows narrow trenches dug into ground.

Archaeol dating of the main layers is 6th to 5th millennium BC. Samples subm by T Chubinishvili (TB-89, -92, -277) and D Gogelia (TB-300, -309, -331).

TB-89. Arakhlo I **2030 ± 40**

Charcoal, depth 0.7m, annex structure no. 4, 1st bldg horizon, from early agric settlement of inhabited hill; site is presently on state farm on Arakhlo village. Est cal age = 2000 ± 49BP.

TB-92. Arakhlo I **6720 ± 60**

Charcoal, depth 0.9m, under 1st floor of structure no. 19, 1st bldg horizon. Est cal age = 7340 ± 73BP.

TB-277. Arakhlo I **6970 ± 60**

Charcoal, depth 1.6m, Tr 1, N sec.

TB-300. Arakhlo I **7350 ± 70**

Charcoal, depth 5.6m, Tr 2, 7th bldg horizon.

TB-309. Arakhlo I **6980 ± 70**

Charcoal, depth 4.85m, Tr 16, structure no. 44.

TB-331. Arakhlo I **6600 ± 140**

Charred organic matter from depth 1.85, 2nd bldg horizon. Est cal age = 7190 ± 73BP.

Gebi series

Samples are from ancient copper and antimony mines and metallurgic slag heaps near Gebi village in Highland Racha, Oni dist, Georgian SSR, except Tvibrasheri sample (TB-304) from ancient copper mine of Highland Abkhazia, upper Kodori R, S slope of Caucasian range. This mine has geol, technol and hist features similar to Gebi mines.

Samples subm by T Mujiri, K Kalandadze, G Gobejishvili, G Imnashvili, B Maisuradze, I G Korinteli, Mining Mechan Eng Inst, Acad Sci GSS, and Archaeol Inv Center, Acad Sci GSSR.

TB-90. Gona **2880 ± 40**

Wood, depth 1m, part of wooden lining (prop) from copper mine, Chkornaliani deposits of settlement Gona, Gebi village, in horizontal underground mine 40m from mine entry; mine was filled with slag and running water. Est cal age = 3010 ± 80BP.

TB-91. Gona **2910 ± 45**

Wood, depth 1m, part of wooden trough; loc, mine, and conditions similar to TB-90. Est cal age = 3050 ± 80BP.

TB-255. Zopkhito **2950 ± 40**

Charcoal from underground antimony mine, coll under caved-in rock, Zopkhito deposit, Gebi village. Est cal age = 3100 ± 80BP.

TB-302. Zopkhito **3200 ± 170**

Charcoal from underground mine depth 20m from surface, vein no. 6, adit no. 80, antimony mine. Est cal age = 3400 ± 125BP.

TB-304. Tvibasheri, Abkhazian ASSR **3100 ± 70**

Wood, depth 20m, part of timbers from copper mine, Tvibasheri deposit, upper Kodori R. Est cal age = 3300 ± 125BP.

TB-310. Sagebi **3630 ± 50**

Charcoal from metallurgic slag, Sagebi village, left bank of Zopkhitura R. Est cal age = 3950 ± 63BP.

TB-334. Sagebi **3590 ± 60**

Charcoal, depth 1m, from antimony mine, left bank of Zopkhitura R. Est cal age = 3890 ± 63BP.

TB-333. Uravi **1470 ± 50**

Charcoal from metallurgic slag, depth 0.7m, right bank of Lukhuni Water R, Uravi village, Ambrolauri dist, Upper Racha. Est cal age = 1400 ± 22BP.

TB-335. Khirkhi **3120 ± 50**

Charcoal from antimony mine, Khirkhi deposit, Gebi village, right bank of Zopkhitura R. Est cal age = 3300 ± 125BP.

Great Mtskheta series, Georgian SSR

At end of 4th century BC Kartlian (Iberian) Kingdom with Mtskheta as its capital formed in E Georgia. Great Mtskheta, proof of which is documented in ancient writings, implies city and its vicinity. This series includes dates of wood and charcoal samples from Mtskheta dist. Hill-like settlement Samtavro I is situated within boundaries of contemporary town and dates from 12th to 6th centuries BC. Kalandadzisgora settlement of Narekvavi village has approximately same dates.

Samadlo is urbanized settlement belonging to early Hellenistic Age (4th to 3rd centuries BC) on right bank of Mtkvari R, W of Dzegvi village.

Fence with towers and counterforts built of air-dried bricks were recently found N of contemporary town on right bank of Aragvi R and is important for studying hist topography of ancient Mtskheta. Early feudal mounds were uncovered on farmland near Tsilkani village N of Mtskheta.

Samples subm by A Apakidze (head), A Kalandadze, Yu Gagoshidze, V Nikolaishvili, and T Giunashvili, Archaeol Inv Center, Acad Sci GSSR.

TB-244. Samtavro I **3010 ± 50**

Charcoal, depth 1m, remains of structure no. 1. Est cal age = 3200 ± 125BP.

TB-245. Samtavro I **2950 ± 50**

Charcoal, depth 2m, remains of structure no. 2. Est cal age = 3100 ± 80BP.

TB-258. Samtavro I **3030 ± 50**

Charcoal, depth 1.5m, remains of floor of burned structure. Est cal age = 3200 ± 125BP.

TB-259. Samtavro I **2560 ± 50**

Charcoal, depth 2.5 to 3m, remains of floor of burned structure no. 5, 1st bldg level. Est cal age = 2600 ± 102BP.

TB-271. Samtavro I **2570 ± 40**

Charcoal, depth 2 to 2.5 m, refuse pit no. 3, 3rd bldg level. Est cal age = 2600 ± 102BP.

TB-290. Samtavro I **2610 ± 60**

Charcoal, depth 0.6 to 1m, fragment of wooden pillar of structure no. 7. Est cal age = 2700 ± 102BP.

TB-278. Gartiskari **2430 ± 40**

Charcoal, depth 1.8m, from cultural layer of ancient fortification. Est cal age = 2460 ± 39BP.

TB-327. Gartiskari **2230 ± 50**

Charcoal, depth 2m, remains of wooden beams of interior floor of square tower. Est cal age = 2230 ± 49BP.

TB-418. Gartiskari **2590 ± 50**

Charcoal, depth 2m, remains of fallen wooden pillar in tower no. 2. Est cal age = 2700 ± 102BP.

TB-224. Narekvavi **2430 ± 40**

Charcoal, depth 1.7m, remains of structure, Narekvavi village, 5km from Mtskheta. Est cal age = 2460 ± 39BP.

TB-339. Narekvavi **2450 ± 50**

Charcoal, depth 1.3m, remains of structure no. 1, settlement Kalandadze gora-II. Est cal age = 2490 ± 39BP.

TB-94. Samadlo I **2300 ± 40**

Wood, depth 3m, piece of beam from stone structure with counterforts, 1st bldg horizon, Dzegvi village. Est cal age = 2310 ± 39BP.

TB-95. Samadlo I **2280 ± 40**

Wood, depth 1m, piece of beam from N stone wall of crypt, 1st bldg horizon, Dzegvi village. Est cal age = 2280 ± 39BP.

TB-96. Samadlo III **2390 ± 40**

Wood, depth 0.7m, piece of beam from stone of pre-Hellenistic layer, Dzegvi village. Est cal age = 2420 ± 39BP.

TB-305. Tsilkani **1890 ± 50**

Charcoal, depth 2.2m, refuse pit no. 1, Tsilkani village, 9 to 10km from Mtskheta. Est cal age = 1850 ± 33BP.

Shenako series

Samples from Highland-Tushetian Archaeol Expedition of Nishtako hill, Shenako village, Highland Tushetia, Akhmeta dist, Georgian SSR. Highland Tushetia is on N slope of Caucasian range, bordered on E by Daghestan ASSR and on N by Checheno-Ingush ASSR. Shenako terraced settlement was found on Nishtako hill, typical of mountainous regions, with cultural structures of different periods, including iron-smelting workshop. Lower layers of mound contain hitherto unknown mountain cultures. Samples subm by R Dolaberidze, State Mus Georgia.

TB-221. Shenako **1680 ± 50**

Charcoal, depth 0.8 m, Sq SD-43, 2nd layer, 1st terrace, SW slope, Nishtako hill. Est cal age = 1620 ± 41BP.

TB-222. Shenako **1640 ± 50**

Charcoal, depth 0.6m, Sq SD-42, 2nd layer, 1st terrace, SW slope. Est cal age = 1580 ± 41BP.

TB-229. Shenako **1970 ± 40**

Charcoal, depth 1.3m, Sq SD-43, 3rd layer, 1st terrace, SW slope. Est cal age = 1940 ± 33BP.

TB-267. Shenako **2140 ± 40**

Charcoal, depth 1.7 to 1.8m, Sq SD-32, 3rd layer, 1st terrace, SW slope. Est cal age = 2120 ± 49BP.

TB-268. Shenako **1990 ± 45**

Charcoal, depth 2m, Sq SD-33, 3rd layer, 1st terrace, SW slope. Est cal age = 1960 ± 33BP.

TB-269. Shenako **2090 ± 45**

Charcoal, depth 1.4m, Sq SE-83, 3rd layer, 2nd terrace, SW slope. Est cal age = 2070 ± 49BP.

TB-270. Shenako **2030 ± 40**

Charcoal, depth 2m, Sq SD-35, 3rd layer, 1st terrace, SW slope. Est cal age = 2000 ± 49BP.

TB-311. Shenako **1710 ± 40**

Charcoal, depth 1.3m, remainder of wall, N slope. Est cal age = 1650 ± 41BP.

TB-312. Shenako **760 ± 40**

Charcoal, depth 0.3m, remainder of wall, N slope. Est cal age = 730 ± 39BP.

TB-313. Shenako **830 ± 40**

Charcoal, depth 0.3m, remainder of wall, crest of Nishtako hill. Est cal age = 800 ± 39BP.

TB-314. Shenako **1000 ± 45**

Charcoal, depth 1.5m, remainder of wall, blacksmith's shop, crest of Nishtako hill. Est cal age = 950 ± 39BP.

Kobuleti series, Adjarian ASSR

Eastern Black Sea precoastal region (now W Georgia) was part of ancient Oikumena, where productive society originated very early. Later, rather advanced farming culture developed here and gave rise to famous Colchian civilization.

Group of archaeol mounds of several periods was found N and E of Kobuleti resort, on banks of Ochkhamuri and Chorokhi Rivers. Group includes early farming two-layer settlement, Ispani, underlying 2m peat, and multi-layer Namcheduri settlement which chronologically and culturally follows Ispani settlement from end of 4th millennium BC to end of 3rd or beginning of 2nd millennium BC. Samples subm by D A Khakhutaishvili, Archaeol Exped SW Georgia, Batumi Research Inst, Acad Sci GSSR.

TB-231. Ispani **3380 ± 45**

Wood, depth 1.3m from lower layer of peat covering Ispani settlement, 1km from town Kobuleti. Est cal age = 3600 ± 103BP.

TB-232. Ispani **4130 ± 50**

Wood, depth 2.4m, upper layer of settlement from same loc as TB-231. Est cal age = 4600 ± 108BP.

TB-233. Ispani **4590 ± 60**

Wood, depth 2.8 to 3m, lower layer of settlement from same loc as TB-231. Est cal age = 5130 ± 92BP.

TB-230. Namcheduri **3130 ± 45**

Coal, depth 4.5m, Sq 17, 6th layer, Sec III, ancient Colchian settlement, right bank of Ochkhamuri R, Namchedura hill, town Kobuleti. Est cal age = 3300 ± 125BP.

TB-306. Namcheduri **3440 ± 60**

Wood, Sec SO, Sq 25, 7th layer, from same loc as TB-230. Est cal age = 3700 ± 103BP.

TB-307. Namcheduri **2960 ± 60**

Coal, SW sec, Sq 33, 4th layer, from same loc as TB-230. Est cal age = 3110 ± 80BP.

TB-319. Namcheduri **2710 ± 40**

Wood, depth 2.5m, SW sec, Sq 39, 3rd layer, from same loc as TB-230. Est cal age = 2800 ± 102BP.

TB-320. Namcheduri **2960 ± 45**

Wood, depth 3.5m, SW sec, Sq 26, 5th layer, from same loc as TB-230. Est cal age = 3110 ± 80BP.

TB-321. Namcheduri **2890 ± 50**

Wood, depth 4m, SW sec, Sq 26, 5th layer, from same loc as TB-230. Est cal age = 3020 ± 80BP.

TB-323. Namcheduri **3350 ± 50**

Wood, depth 7m, SW sec, Sq 11, 6th layer, from same loc as TB-230. Est cal age = 3600 ± 103BP.

TB-324. Namcheduri **3000 ± 60**

Wood, depth 8m, SW sec, Sq 2, 6th layer, from same loc as TB-230. Est cal age = 3200 ± 125BP.

TB-332. Namcheduri **2920 ± 50**

Charred cereals (corn), depth 5m, SW sec, Sq 17, 5th layer, from same loc as TB-230. Est cal age = 3060 ± 80BP.

Askana, Mziani, and Charnali series

According to legend, Colchian tribes, in particular, Khalides were among first discoverers of iron and steel manufacture. In recent years, in foothills of E Black Sea coastal region, *ie*, ancient Colchis, archaeologists have found center of ancient iron metallurgy, with production sites yielding ca 400 artifacts. Askana II and Mziani from Askana and Mziani villages, respectively, Makharadze dist, Georgian SSR, are oldest workshops excavated here. Another workshop, Charnali, is in gorge of Charnali R, left tributary of Chorokhi R, Khelvachauri dist, Adjarian ASSR. Samples subm by D A Khakhutaishvili.

TB-234. Askana II **3180 ±45**

Coal, depth 0.5, from bottom of iron-smelting furnace no. 1, upper Tskaltsitela R. Est cal age = 3400 ± 125BP.

TB-235. Askana II **3080 ± 45**

Coal, depth 0.5m, from bottom of iron-smelting furnace no. 2, from same loc as TB-234. Est cal age = 3300 ± 125BP.

TB-401. Mziani II **2530 ± 50**

Coal, depth 0.3m, from iron-smelting furnace, Sample 1. Est cal age = 2600 ± 102BP.

TB-402. Mziani II **2890 ± 50**

Coal, depth 0.5m, from iron-smelting furnace, Sample 2, from same loc as TB-401. Est cal age = 3020 ± 80BP.

TB-403. Mziani II **3230 ± 50**

Coal, depth 1.2m, from floor of iron-smelting furnace, Sample 3, from same loc as TB-401. Est cal age = 3400 ± 125BP.

TB-404. Mziani III **2540 ± 50**

Coal, depth, 0.8m from floor level of iron-smelting furnace, Sample 1, from same loc as TB-401. Est cal age = 2600 ± 102BP.

TB-405. Mziani III **2850 ± 50**

Coal, depth 0.9m from floor level of iron-smelting furnace, Sample 2, from same loc as TB-401. Est cal age = 2970 ± 80BP.

TB-406. Mziani III **250 ± 45**

Coal, depth 0.3m from ground surface, charred board of table top, Sample 3, from same loc as TB-401. Est cal age = 290 ± 42BP.

TB-407. Mziani IV **2510 ± 50**

Coal, depth 0.5m, from iron-smelting furnace, Sample 1, from same loc as TB-401. Est cal age = 2600 ± 102BP.

TB-408. Mziani IV **3170 ± 45**

Coal, depth 0.3m, from base of pit of iron-smelting furnace, Sample 2, from same loc as TB-401. Est cal age = 3400 ± 125BP.

TB-286. Charnali II **2670 ± 50**

Coal, depth 1.5m, from bottom of iron-smelting furnace no. 1, Charnali site, S slope of gorge of Charnali R. Est cal age = 2700 ± 102BP.

TB-287. Charnali II **2720 ± 50**

Coal, depth 1.4m, from bottom of iron-smelting furnace no. 2, Charnali, E Slope, from same loc as TB-286. Est cal age = 2800 ± 102BP.

TB-288. Charnali III **2750 ± 50**

Coal, depth 1.4m from bottom of iron-smelting furnace no. 1, Charnali site, E slope, from same loc as TB-286. Est cal age = 2850 ± 80BP.

Kakheti series

Kakheti is in E Georgia on lower slopes of Caucasian range. This series includes samples coll at four sites: 1) Khramebi site, Nukriani village, Signakhi dist, burial mound of Gombori range; 2) burial Gora I, Alazani valley, Tsnori dist; 3) Pevrebi site, Melani village, Gurjaani dist, pit burial of lower tier of cemetery, S slope of Gombori range; 4) Udabno site, burial mound no. 1, right bank of Iori R, Udabno village; Zeiani site, Manavi village, Sagarejo dist. Samples subm by Sh Dedabrishvili (TB-242, -243) and K Pitskhelauri, Kakhetian Archaeol Expedition, Archaeol Inv Center, Acad Sci GSSR.

TB-242. Khramebi **4150 ± 50**

Wood, depth 3m, fragment of wooden cover of burial mound. Est cal age = 4600 ± 108BP.

TB-243. Gora I **4110 ± 50**

Wood, depth 2.5m, fragment of wooden cover of burial mound. Est cal age = 4500 ± 108BP.

TB-247. Pevrebi **3230 ± 45**

Wood, depth 2m, fragment of wooden cover of pit burial no. 15. Est cal age = 3400 ± 125BP.

TB-248. Pevrebi **3250 ± 45**

Wood, depth 1m, fragment of wooden cover of pit burial no. 38. Est cal age = 3500 ± 125BP.

TB-249. Pevrebi **3200 ± 40**

Wood, depth 1.7m, fragment of wooden cover of pit burial no. 42. Est cal age = 3400 ± 125BP.

TB-250. Pevrebi **2880 ± 40**

Wood, depth 1.7m, fragment of wooden cover of pit burial no. 49. Est cal age = 3010 ± 80BP.

TB-251. Pevrebi **2890 ± 40**

Wood, depth 1.5m, fragment of wooden cover of pit burial no. 52. Est cal age = 3020 ± 80BP.

TB-252. Pevrebi **2910 ± 40**

Wood, depth 1m, fragment of wooden cover of pit burial no. 53. Est cal age = 3050 ± 50BP.

TB-253. Pevrebi **2950 ± 40**

Wood, depth 1.5m, part of wooden cover of pit burial no. 57. Est cal age = 3100 ± 80BP.

TB-254. Pevrebi **3180 ± 45**

Wood, depth 1.5m, part of wooden cover of pit burial no. 59. Est cal age = 3400 ± 125BP.

TB-256. Pevrebi **3120 ± 45**

Wood, depth 1.5m, part of wooden cover of pit burial no. 68. Est cal age = 3300 ± 125BP.

TB-293. Pevrebi **2540 ± 60**

Wood, depth 0.3m, part of wooden cover of pit burial no. 75. Est cal age = 2600 ± 102BP.

TB-294. Pevrebi **3050 ± 80**

Wood, depth 1m, part of wooden cover of pit burial no. 76. Est cal age = 3200 ± 125BP.

TB-296. Pevrebi **3300 ± 110**

Wood, depth 0.4m, part of wooden cover of pit burial no. 84. Est cal age = 3500 ± 125BP.

TB-297. Pevrebi **3160 ± 60**

Wood, depth 2m, part of wooden cover of pit burial no. 86. Est cal age = 3400 ± 125BP.

TB-298. Pevrebi **3080 ± 90**

Wood, base of pit, part of wooden cover of pit burial no. 86. Est cal age = 3300 ± 125BP.

TB-308. Udabno **3030 ± 50**

Wood, depth 2m, part of wooden two-wheeled cart, burial mound no. 1. Est cal age = 3200 ± 125BP.

TB-328. Zeiani **4940 ± 80**

Wood, depth 4m, part of wooden cover of burial mound no. 1. Est cal age = 5540 ± 74BP.

TB-329. Zeiani **4740 ± 75**

Wood, depth 3.5m, burial mound no. 1. Est cal age = 5310 ± 92BP.

Nakalakevi series

Nakalakevi (Tsikhégoji) was one of centers of Colchian kingdom (W Georgia); later, in 4th to 8th centuries, Nakalakevi (Archaeopolis) became capital of Egrisian kingdom. This series includes samples from sites: 1) Nakalakevi, coll from king's bath, Nakalakevi village, Tskhakaya dist, Georgian SSR; 2) Shkhepi; Shkhepi castle is not far from Tskhakaya dist center (castle existed from 4th to beginning of 19th century); 3) Nojikhevi, 15km from Nakalakevi village. Samples coll during excavations in palace and bath, Nojikhevi village, Gegechkori dist, Georgian SSR. Samples subm by P Zakaraya, State Mus Georgia.

TB-261. Nakalakevi **1770 ± 35**

Coal, depth 1 to 1.5m, Sq AD-25, Lot IX, bath. Est cal age = 1710 ± 33BP.

TB-280. Nakalakevi **1630 ± 40**

Coal, depth 1m, from under brick wall. Est cal age = 1570 ± 41BP.

TB-424. Nakalakevi **1500 ± 45**

Coal, depth 3.2m, from foundation of E tower of fortress. Est cal age = 1430 ± 41BP.

TB-425. Nakalakevi **1860 ± 45**

Coal, depth 2.8m, from base of fence ruins. Est cal age = 1810 ± 33BP.

TB-426. Nakalakevi **1890 ± 40**

Coal, depth 3.5m, from vicinity of ancient gate. Est cal age = 1850 ± 33BP.

TB-279. Shkhepi **90 ± 40**

Coal, depth 0.5m, on floor of 1st story, main tower. Est cal age = 160 ± 42BP.

TB-284. Shkhepi **120 ± 40**

Coal, depth 1m, remains of burned wall, main tower. Est cal age = 180 ± 42BP.

TB-262. Nojokhevi **1100 ± 30**

Coal, depth 1 to 1.3m, bath. Est cal age = 1040 ± 33BP.

TB-263. Nojikhevi **1100 ± 30**

Coal, depth 1 to 1.5m, bath. Est cal age = 1040 ± 33BP.

TB-264. Nojikhevi **980 ± 30**

Coal, depth 0.5 to 1.5m, bath. Est cal age = 930 ± 39BP.

TB-265. Nojikhevi **990 ± 30**

Coal, depth 0.5 to 1.5m, bath. Est cal age = 940 ± 39BP.

TB-281. Nojikhevi **200 ± 40**

Coal, depth 0.6m, floor of palace chamber, Nojikhevi village. Est cal age = 250 ± 42BP.

TB-282. Nojikhevi **830 ± 40**

Coal, depth 0.5 to 0.7m, floor of palace chamber, Nojikhevi village. Est cal age = 790 ± 39BP.

TB-283. Nojikhevi **900 ± 40**

Coal, depth 1m, floor of palace chamber, Nojikhevi village. Est cal age = 860 ± 39BP.

Treligoremi series

TB-272. Treligoremi **2890 ± 40**

Coal, depth 5m, chamber no. 1, ancient settlement no. 1, Treligoremi site, Dighomi residential dist, Tbilisi, Georgian SSR. Samples subm by R Abramishvili and Sh Iremashvili, Archaeol Inv Center, Hist, Archaeol & Ethnog Inst, Acad Sci GSSR. Est cal age = 3020 ± 80BP.

TB-273. Treligoremi **2710 ± 40**

Coal, depth 3.5m, from same loc as TB-272. Est cal age = 2800 ± 102BP.

TB-410. Treligoremi **2510 ± 45**

Coal, depth 0.75 to 0.8m, chamber no. 50, ancient settlement no. 2, from same loc as TB-272. Est cal age = 2600 ± 102BP.

Anaklia series

TB-274. Anaklia **3870 ± 50**

Wood, depth 8m, fragment of pillar, ancient settlement, Dikha-gudzuba II, Chitatskari site, Anaklia village, Zugdidi dist, Georgian SSR. Samples subm by D Muskhelishvili, Archaeol Inv Center, Acad Sci GSSR. Est cal age = 4200 ± 109BP.

TB-275. Anaklia **3940 ± 50**

Wood, depth 7.5m, floor board, Sec NO, Sq D6, from same loc as TB-274. Est cal age = 4300 ± 109BP.

TB-276. Anaklia **3760 ± 50**

Cereals, depth 7.7m, remains of settlement, from same loc as TB-274. Est cal age = 4100 ± 63BP.

TB-93. Dedoplis mindori **2220 ± 40**

Wood, depth 2m, ceiling beams, altar hall of pagan temple, Dedoplis mindori site, Aradeti village, Kareli dist, Georgian SSR. Sample subm by I Gagoshidze, Hist, Archaeol & Ehnog Inst, Acad Sci GSSR. Est cal age = 2210 ± 49BP.

TB-223. Tetri-Tskaro **110 ± 30**

Wood, remains of ruined wall of old bldg, Tetri-Tskaro dist, S Georgia. Sample subm by N Tsivtsivadze, Georgian Literature Chair, Tbilisi State Univ. Est cal age = 170 ± 42BP.

TB-227. Vani **2310 ± 40**

Coal, depth 0.45cm, Adeishvili gora, Mtisdziri, Vani dist, W Georgia. Sample subm by O Lortkipanidze, Hist, Archaeol & Ethnog Inst, Acad Sci GSSR. Est cal age = 2320 ± 39BP.

TB-246. Bambebi **2640 ± 45**

Coal, depth 4m, burned house, ancient settlement, Bambebi site, left bank of Mtkvari R, Uplistsikhé village, Gori dist, Georgian SSR. Sample subm by D A Khakhutaishvili, Hist, Archaeol & Ethnog Inst, Acad Sci GSSR. Est cal age = 2700 ± 102BP.

TB-266. Tsalka **620 ± 40**

Charcoal, portable oven, daran (secret tunnel), Tsalka village, Tsalka dist, Georgian SSR. Sample subm by D Amiranashvili, Archaeol Inv Center, Acad Sci GSSR. Est cal age = 610 ± 28BP.

TB-285. Khorshi **3650 ± 50**

Coal, depth 0.5 to 0.6m, Khorshi village, Tskhakaya dist, Georgian SSR. Sample subm by G Grigolia, Archaeol Inv Center. Est cal age = 3970 ± 63BP.

TB-289. Zhinvali **3740 ± 70**

Coal, depth 2.5 to 3m, altar, Site XVI, Zhinvali village, Dusheti dist, Georgian SSR. Sample subm by R Ramishvili, Archaeol Inv Center. Est cal age = 4080 ± 63BP.

TB-326. Zhinvali **6300 ± 130**

Coal, depth 3.2m, charred logs, Site XXV, from same loc as TB-289. Est cal age = 6890 ± 85BP.

TB-291. Kobuleti **480 ± 40**

Wood, depth 3 to 4m, marshland, Kobuleti dist, Adjarian ASSR. Sample subm by I Melikadze, Mining Eng Inst, Acad Sci GSSR. Est cal age = 490 ± 53BP.

TB-292. Jiéti **2700 ± 50**

Charcoal, depth 2.5m, Sq D-20, Tr 4, remains of chamber 1, Jiétu site, Tsinsopeli village, Chiatura town, Georgian SSR. Sample subm by J Nadiradze, State Fine Arts Mus GSSR. Est cal age = 2800 ± 102BP.

TB-299. Ureki **2600 ± 200**

Wood, part of bronze axe handle (no. 953), burial pit 3, Ureki village, Makharadze dist, Georgian SSR. Sample subm by T Mikeladze, Archaeol Inv Center. Est cal age = 2700 ± 102BP.

TB-301. Kachagani **6630 ± 60**

Coal, depth 4.2m, at foot of wall 41, Khramis Didi Gora site, Kachagani village, Marneuli dist, Georgian SSR. Sample subm by D Gogelia, State Mus Georgia. Est cal age = 7250 ± 73BP.

TB-322. Kachagani **6700 ± 60**

Coal, depth 5.4m, Sq NV, ancient settlement, Kachagani village, Marneuli dist, Georgian SSR. Sample subm by T Kiguradze, State Mus Georgia. Est cal age = 7320 ± 73BP.

TB-315. Dzudzuni mgvimé **5700 ± 130**

Coal, 2nd layer, ancient cave settlement from Dzudzuni Mgvimé cave site, gorge of Kvirila R, Chiatura dist, Georgian SSR. Sample subm by L Zhorzhikashvili, Archaeol Inv Center. Est cal age = 6300 ± 170BP.

TB-316. Dzudzuni mgvimé **4600 ± 130**

Coal, 1st layer, ancient cave settlement, from same loc as TB-315. Est cal age = 5150 ± 92BP.

TB-317. Martkopi **3890 ± 50**

Wood, depth 0.8m, part of wooden cover, burial mound 3, Martkopi village, Gardabani dist, Georgian SSR; subm by O Japaridze, Archaeol Chair, Tbilisi State Univ. Est cal age = 4300 ± 109BP.

TB-325. Martkopi **4130 ± 80**

Wood, depth 1.2m, part of wooden cover, burial mound 4, from same loc as TB-317. Est cal age = 4600 ± 108BP.

TB-318. Chalagantené **6580 ± 60**

Coal, depth 1m, chamber of pottery kiln, Chalagantené settlement, Agdat dist, Azerbaijan SSR; subm by I Narimanov, Hist Inst, Acad Sci AzSSR. Est cal age = 7210 ± 73BP.

TB-330. Namashevi tsikhé **1650 ± 90**

Coal, depth 1m, Namashevi tsikhé site, Didi Gubi village, Tsulukidze dist, Georgian SSR; subm by V Japaridze, Archaeol Inv Center. Est cal age = 1590 ± 41BP.

TB-336. Tsikhia Gora **2220 ± 80**

Wood, depth 1.2m, chamber 15, Tsikhia Gora site, Kavtiskhevi village, Kaspi dist, Georgian SSR; subm by G Tskitishvili, Archaeol Inv Center. Est cal age = 2210 ± 49BP.

TB-337. Tsikhia Gora **2180 ± 60**

Coal, depth 1.2m, chamber 14, from same loc as TB-336. Est cal age = 2170 ± 49BP.

TB-411. Khrioki mitsebi **1000 ± 45**

Coal, depth 1.5m, remains of chamber, Khrioki mitsebi site, Vardisubani village, Dmanisi dist, Georgian SSR; subm by V Javaridze, Archaeol Inv Center. Est cal age = 950 ± 39BP.

TB-412. Khrioki mitsebi **1530 ± 45**

Coal, depth 1.6m, remnants of stone bldg, from same loc as TB-411. Est cal age = 1460 ± 41BP.

TB-413. Satsikhuris Gora **3310 ± 50**

Coal, hearth 4, Satsikhuris Gora site, Tsagvli village, Khashuri dist, Georgian SSR; subm by A Ramishvili, Archaeol Inv Center. Est cal age = 3500 ± 103BP.

TB-414. Kvintsikhis Gora **2520 ± 50**

Coal, at level of chamber foundation, sample 1, Kvintsikhis Gora site, Kveda-Sakhano village, Zestafoni dist, Georgian SSR; subm by V Japaridze. Est cal age = 2600 ± 102BP.

TB-415. Kvintsikhis Gora **2510 ± 50**

Coal, chamber, sample 2, from same loc as TB-414. Est cal age = 2600 ± 102BP.

TB-416. Sachkheré **4340 ± 60**

Coal, depth 1.1m, adobe floor of upper bldg level, remains of structure, Argveti village, Sachkheré dist, Georgian SSR; subm by G Pkhakadze, Archaeol Inv Center. Est cal age = 4800 ± 159BP.

TB-417. Sachkheré **4060 ± 40**

Coal, depth 1.9 to 2m, log from pit, from same loc as TB-416. Est cal age = 4500 ± 109BP.

TB-420. Satsikhuris Gora **3380 ± 50**

Coal, rectangular store room, upper level, Satsikhuris Gora site, Tsagvli village, Khashuri dist, Georgian SSR; subm by G Barabidze, Archaeol Inv Center. Est cal age = 3600 ± 103BP.

TB-421. Gali **2910 ± 50**

Coal, depth 0.6m, remains of structure, 1st coal layer, Pichori village, Gali dist, Abkhazian ASSR; subm by M Baramidze, Archaeol Inv Center. Est cal age = 3050 ± 80BP.

TB-422. Gedovani **15,700 ± 120**

Bone, depth 1.5m, 3rd layer, Ortvala cave, Gedovani village, Terjola dist, Georgian SSR; subm by M Nioradze, Archaeol Inv Center.

TB-423. Patardzeuli **340 ± 40**

Wood, from bottom of cave in rocks between Patardzeuli and Khashmi villages, Sagarejo dist; Georgian SSR; subm by R Akhaladze, Tbilisi State Univ. Est cal age = 370 ± 53BP.

TB-427. Ergeta **2520 ± 50**

Wood, depth 0.8m, Naakargamusi tomb, Ergeta village, Zugdidi dist, Georgian SSR; subm by T Mikeladze. Est cal age = 2600 ± 102BP.

Gabrichkogo series, Czechoslovakia

TB-428. Gabrichkogo **8420 ± 60**

Wood, oak log, depth 30m, in sand near bank of Danube R, Gabrichkogo village, Bratislava dist; subm by P Povinec, Comenius Univ, Bratislava.

TB-429. Gabrichkogo **7990 ± 45**

Wood, oak log, depth 30m, from same loc as TB-428.

TB-430. Gabrichkogo **8230 ± 60**

Wood, oak log, depth 30m, from same loc as TB-428.

HYDROLOGIC SAMPLES

The Georgian SSR is one of the richest regions of the world in number and variety of mineral water springs. This can be explained by complexity of the geologic history and structure of Georgia's territory, creating favorable conditions for the formation and outcropping of mineral waters of most diverse nature. Georgia has over 1500 mineral water springs with total flow rate of 95,000,000L per day. Of these springs 40% belong to bottling plants (Eristavi, 1966).

The Tbilisi ^{14}C Lab is studying ^{14}C and ^{3}H isotopes in carbonized mineral waters (Burchuladze *et al*, 1977, 1978) which are widely used for domestic and medicinal purposes. Much importance is given to origin, mixing of waters in different horizons, flow rate and extent of ^{14}C and ^{3}H concentration, which helps check pollution of mineral waters with sewage and rain waters. As a result of nuclear testing in the last 30 years, specific activity of ^{3}H and ^{14}C in the earth's atmosphere has sharply increased, making it possible to determine the age of mineral waters.

Two methods were used to extract carbonates from the mineral waters in order to determine ^{14}C directly at the spring:

1) trapping free carbonic acid by letting it pass through the sodium hydroxide solution;

2) separating carbonates dissolved in water through precipitation.

Analyses were made on samples of carbonized mineral waters from several Georgian districts—Borjomi, Pasanauri, Bolnisi, Tbilisi, Ujarma, Java, Tsagveri. Parameters, characterizing mineralization (M g/l), chemical composition, and age of water samples (Jaliashvili *et al,* 1968), are given below.

Georgian Mineral Water series

TB-181. Borjomi **≥45,500**

Gas, CO_2, well 25, Kvibisi village.

TB-182. Borjomi **≥45,500**

Water, $M_{7.1}$ $HCO_3 84/Na 93$, well 25, Kvibisi village.

TB-183. Borjomi **≥45,500**

Gas, CO_2, well 41, Vashlovani village.

TB-184. Borjomi **≥45,500**

Water, $M_{6.1}$ $HCO_3$87/Na86, well 41, Vashlovani village.

TB-185. Borjomi **≥45,500**

Gas, CO_2, well 54, Likani village.

TB-186. Borjomi **≥45,500**

Water, $M_{5.7}$ $HCO_3$90/Na83, well 54, Likani village.

TB-187. Pasanauri **31,100 ± 600**

Gas, CO_2, well 144, Pasanauri village.

TB-188. Pasanauri **36,900 ± 900**

Water, $M_{8.9}$ Cl58 $HCO_3$42/Na93, well 144, Pasanauri village.

TB-189. Bolnisi **18,400 ± 150**

Gas, CO_2, well 1, Bolnisi village.

TB-190. Bolnisi **20,900 ± 200**

Water, $M_{8.5}$ $HCO_3$32 $SO_4$12 Cl 12/Ag23 Na6 Ca10 Fe2, well 1, Bolnisi village.

TB-191. Tbilisi **≥45,500**

Gas, CO_2, well 8, Tbilisi.

TB-192. Tbilisi. **≥45,500**

Water, $M_{0.4}$ Cl49 $SO_4$18 $HCO_3$16/Na87, well 8, Tbilisi.

TB-193. Udjarma **≥45,500**

Water, $M_{8.6}$ Cl70 $HCO_3$28/Na98Ca1, well 10, Udjarma village.

TB-196. Tsagveri **33,800 ± 370**

Water, $M_{4.0}$ $HCO_3$86/Na47 Ca22 Mg21, well 1, Tsagveri village.

TB-194. Java, S Ossetian Autonomous region **31,300 ± 350**

Water, $M_{5.4}$ Cl58 $HCO_3$42/Na74 Mg14 Ca12, well 14, Java village.

TB-195. Java, S Ossetian Autonomous region **18,240 ± 260**

Water, $M_{6.3}$ HCO_3 52 Cl47/Na88 Ca11, well 1, Mskhlebi village.

General Comment: samples TB-181, -183, -191, and -193 do not contain radioactive hydrogen and carbon isotopes. These samples are result of durable movement of underground water in water-bearing horizon, which led to decay of these isotopes.

Samples TB-187, -189, -194, -195, and -196 evidently show mixing of waters with younger waters from overlying horizons; absence of tritium signifies that waters of surface origin were not involved in mixing.

SOIL SAMPLES

Dating soil samples provides reliable information on humus regime and rates of carbon biologic metabolism. In this study we determined ^{14}C of subtropical podzols. Samples were collected from several levels (II to IV) of Kodori R profile, Ochamchira and Gulripshi districts, Abkhazian ASSR.

We prepared humic acids that are substances of relatively stable character from soil samples. Dates obtained confirm characteristic active circulation of substances formed during podzol formation and mobility of humus. Dating the organic portion of soil helps confirm the origin of podzol formation processes on these levels. Our data clearly illustrate the main soil formation processes. Samples subm by T M Subeliani, Soil Sci, Agrochem & Land Reclamation Inst, GSSR Agric Ministry.

Abkhazian ASSR series

TB-201. Ganakhleba **470 ± 30**

Humic acid, 1st fraction, depth 0 to 10cm, Sec 11, 2nd level, Ganakhleba village, Gulripshi dist.

TB-202. Ganakhleba **330 ± 30**

Humic acid, 2nd fraction, depth 0 to 10cm, Sec 11, 2nd level.

TB-203. Ganakhleba **5600 ± 40**

Humic acid, 1st fraction, depth 50 to 60cm, Sec 11, 2nd level.

TB-205. Ganakhleba **3540 ± 40**

Humic acid, 1st fraction, depth 20 to 30cm, Sec 11, 2nd level.

TB-206. Atara **$\delta^{14}C = 22.9 \pm 0.3\%$**

Humic acid, 1st fraction, depth 0 to 15cm, Sec 2, 3rd level, Atara village, Ochamchira dist.

TB-208. Kindgi **$\delta^{14}C = 8.1 \pm 0.1\%$**

Humic acid, 1st fraction, depth 0 to 15cm, Sec 4, 4th level, Kindgi village, Ochamchira dist.

TB-209. Kindgi **460 ± 40**

Humic acid, 1st fraction, depth 20 to 30cm, Sec 4, 4th level.

TB-210. Atara **$\delta^{14}C = 10.5 \pm 0.15\%$**

Humic acid, 2nd fraction, depth 0 to 15cm, Sec 2, 3rd level.

TB-211. Atara **330 ± 40**

Humic acid, 1st fraction, depth 20 to 30cm, Sec 2, 3rd level.

TB-212. Noushi **$\delta^{14}C = 16.2 \pm 0.2\%$**

Humic acid, 1st fraction, depth 0 to 15cm, Sec 15, 3rd level, Noushi village, Gulripshi dist.

TB-213. Noushi **350 ± 40**

Humic acid, 1st fraction, depth 20 to 30cm, Sec 15, 3rd level.

TB-214. Kindgi **$\delta^{14}C = 7.0 \pm 0.1\%$**

Humic acid, 1st fraction, depth 0 to 10cm, Sec 4, 4th level.

TB-215. Kindgi **600 ± 40**

Humic acid, 1st fraction, depth 40 to 50cm, Sec 4, 4th level.

Mtskheta series, Georgian SSR

TB-365. Mtskheta **$\delta^{14}C = 24.1 \pm 0.3\%$**

Humic acid, depth 0 to 20cm, meadow-brown soil, Mukhrani village, Mtskheta dist; subm by Ts Kobaidze, Agric Inst GSSR.

TB-366. Mtskheta **250 ± 120**

Humic acid, depth 40 to 60cm, from same loc as TB-365.

TB-367. Mtskheta **$\delta^{14}C = 23.7 \pm 0.3\%$**

Humic acid, depth 0 to 20cm, brown soil, Ksovrisi village, Mtskheta dist; subm by Ts Kobaidze.

TB-368. Mtskheta **3400 ± 740**

Humic acid, depth 40 to 60cm, from same loc as TB-367.

GEOLOGIC SAMPLES

TB-86. Poti, Georgian SSR **7910 ± 60**

Peat, depth 18m, on right bank of Rioni R, near Poti town; subm by Ch Janelidze, Geog Inst, Acad Sci GSSR.

TB-88. Kulevi, Georgian SSR **4060 ± 50**

Peat, depth 5m, 1.5km S of Kuleti village, Khobi dist; subm by Ch Janelidze.

TB-98. Pichora, Abkhazian ASSR **5010 ± 50**

Wood, depth 3m, from marine basal sediments, Pichora village, Gali dist; subm by Ch Janelidze.

Supsa series, Georgian SSR

TB-225. Supsa **1940 ± 50**

Decomposed wood, depth 19m, left bank of Rioni R, Supsa village, Lanchkhuti dist; subm by Ch Janelidze.

TB-226. Supsa **960 ± 40**

Decomposed wood, depth 9m, from same loc as TB-225.

TB-228. Supsa **1940 ± 40**

Decomposed wood, depth 19m, from same loc as TB-225.

TB-236. Mestia, Georgian SSR **1030 ± 40**

Decomposed peat, depth 1.75m, gorge of Nakra R, Mestia dist; subm by Ch Janelidze.

TB-237. Mestia **2410 ± 40**

Decomposed peat, depth 1.25m, basin of Nenskra R, Dombai-Lara marsh; subm by N Margalitadze, Bot Inst, Acad Sci GSSR.

TB-238. Borjomi, Georgian SSR **5810 ± 50**

Decomposed peat, depth 10m, marsh, Dabadzevi plateau, Borjomi dist; subm by N Margalitadze.

TB-257. Sevan, Armenian SSR **3350 ± 45**

Peat, depth 5.1 to 5.2m, coll on shore of Sevan Lake, Bolshoy Sevan village, subm by M Tumanian, State Univ, Yerevan.

Gagra series, Abkhazian ASSR

TB-348. Gagra **2130 ± 45**

Peat, depth 0.90m, coastal area, Alakhadze village, Gagra dist; subm by Ch Janelidze.

TB-350. Gagra **1930 ± 45**

Peat, depth 1m, from same loc as TB-348.

TB-351. Gagra **2300 ± 45**

Peat, depth 1.25, from same loc as TB-348.

TB-349. Kazbegi, Georgian SSR **4420 ± 50**

Wood, depth 7m, coll on left bank of Tergi R, Ketrisi village, Kazbegi dist; subm by Ch Janelidze.

Sukhumi series, Abkhazian ASSR

Since 1979 research has been carried out in the coastal area of Sukhumi and adjoining shelf to estimate modern engineering geologic conditions and to prepare long-term predictions for change of these conditions during a period determined by economic tasks or amortization time (50 to 100 yr) of man-made structures.

Mollusk shells were collected from boring wells uncovering Holocene sediments in order to reconstruct paleogeog conditions of sediment accumulation of homogeneous lithologic layers.

All samples are mollusk shells, unless otherwise indicated. Samples subm by V G Jeiranashvili and R A Jokhadze, Sukhumi Group, Hydrogeol Party of 7th dist, Gidrospetsgeologia Prod Corp, USSR Geol Ministry.

TB-341. Sukhumi **5180 ± 60**

Sample 1, well 42, depth 16 to 17.5m.

TB-342. Sukhumi **5590 ± 60**

Sample 2, well 42, depth 33 to 34m.

TB-343. Sukhumi **5380 ± 60**

Sample 3, well 42, depth 48.6 to 50.2m.

TB-344. Sukhumi **5690 ± 60**

Sample 4, well 42, depth 57 to 58m.

TB-345. Sukhumi **5720 ± 60**

Sample 3, well 42, depth 62 to 63m.

TB-346. Sukhumi **9310 ± 80**

Peat, well 721, depth 26.2 to 26.7m.

TB-347. Pitsunda **6210 ± 60**

1st sea level, depth 1.2m, Pitsunda resort, Gagra dist.

TB-352. Sukhumi **6430 ± 60**

Peat, Sample 1, well 61, depth 8m, 1st sea level.

TB-353. Sukhumi **4040 ± 50**

Sample 1, well 717, depth 3.1 to 3.8.

TB-354. Sukhumi **6060 ± 60**

Sample 2, well 717, depth 6 to 6.9m.

TB-355. Sukhumi **6050 ± 60**

Sample 3, well 717, depth 6.9 to 8.1m.

TB-356. Sukhumi **7960 ± 70**

Sample 4, well 717, depth 9.2 to 11.2m.

TB-357. Sukhumi **4370 ± 60**

Sample 1, well 716, depth 1.4 to 1.7.

TB-358. Sukhumi **6060 ± 60**

Sample 2, well 716, depth 3 to 4m.

TB-359. Sukhumi **6480 ± 60**

Sample 3, well 716, depth 5 to 6m.

TB-360. Sukhumi **6540 ± 60**

Sample 4, well 716, depth 7.1 to 8.2m.

TB-361. Sukhumi **3340 ± 50**

Sample 1, well 723, depth 4.5 to 6m.

TB-362. Sukhumi **5540 ± 60**

Sample 2, well 723, depth 10.5 to 11m.

TB-363. Sukhumi **7630 ± 80**

Sample 3, well 723, depth 13 to 13.7m.

TB-364. Sukhumi **8690 ± 80**

Sample 4, well 723, depth 18 to 18.4m.

TB-369. Sukhumi **6520 ± 70**

Well 50, 1st sea level, depth 18 to 19m.

TB-370. Sukhumi **10,900 ± 100**

Well 724, 1st sea level, depth 32.6 to 33.1m.

TB-371. Sukhumi **4670 ± 60**

Peat, sample 1, well 100, 1st sea level, depth 8.3 to 8.5m.

TB-372. Sukhumi **6590 ± 70**

Peat, sample 2, well 100, 1st sea level, depth 11.1 to 11.3m.

TB-373. Sukhumi **7500 ± 70**

Well 41, depth 14 to 15m.

TB-374. Sukhumi **7860 ± 70**

Well 48, depth 38 to 39m.

TB-377. Sukhumi **7140 ± 70**

Sample 1, well 49, depth 16 to 17m.

TB-375. Sukhumi **7310 ± 70**

Sample 2, well 49, depth 22 to 23m.

TB-376. Sukhumi **6690 ± 70**

Well 50, depth 20 to 21m.

TB-378. Sukhumi **6920 ± 70**

Well 63, depth 24 to 25m.

TB-379. Sukhumi **7210 ± 70**

Sample 1, well 93, depth 15 to 16m.

TB-380. Sukhumi **10,180 ± 90**

Sample 2, well 93, depth 25 to 26m.

TB-381. Sukhumi **13,500 ± 130**

Well 97, depth 13 to 14m.

TB-382. Sukhumi **3360 ± 50**

Well 702, depth 0.7 to 2.2m.

TB-383. Sukhumi **7840 ± 70**

Well 709, depth 7 to 8.6m.

TB-384. Sukhumi **2510 ± 50**

Well 718, depth 3.9 to 5.2m.

TB-385. Sukhumi **6540 ± 60**

Sample 1, well 722, depth 3.2 to 4.3m.

TB-386. Sukhumi **7040 ± 70**

Sample 2, well 722, depth 5.4 to 6.1.

TB-387. Sukhumi **7500 ± 70**

Sample 3, well 722, depth 10.3 to 11.3m.

TB-388. Sukhumi **3850 ± 50**

Sample 1, well 724, depth 5 to 7.2m.

TB-389. Sukhumi **5720 ± 60**

Sample 2, well 724, depth 10 to 11.5m.

TB-390. Sukhumi **5760 ± 60**

Well 725, depth 11.3 to 11.8m.

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UNIVERSITY OF WAIKATO RADIOCARBON DATES I

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The radiocarbon dating laboratory at Waikato was established in 1975, primarily as a research tool in the fields of geomorphology, volcanology, tephrostratigraphy, coastal studies, and paleolimnology, to cope with the increasing supply of late Quaternary lake sediment, wood, peat, and shell samples submitted by University staff and postgraduate students undertaking research in the North Island of New Zealand. The method employed is scintillation counting of benzene using the procedures and vacuum systems designed by H A Polach for the Australian National University (ANU) Radiocarbon Dating Research Laboratory (Hogg, 1982). This date list reports on samples submitted by University of Waikato researchers and assayed in the Waikato laboratory mainly between 1979 and 1985. Other dates on material submitted by individuals working in other organizations in New Zealand, and overseas, are to be reported later.

When necessary, combustible samples are boiled in both dilute NaOH and dilute H_3PO_4 to remove humic acid contaminants and inorganic carbon. Carbonate samples are leached in dilute HCl, dried, crushed, and analyzed by XRD methods to determine the relative proportions of calcite and aragonite. Benzene is synthesized using the three well-established chemical steps: oxidation of sample carbon to carbon dioxide, conversion to acetylene, and catalytic trimerization to benzene (eg, Noakes, Kim & Stipp, 1965; Polach & Stipp, 1967; Polach, Gower & Fraser, 1972; Tamers, 1975). Carbon dioxide is generated by combustion in a silica combustion tube, and purified using a purification train including $AgNO_3$, hot CuO (600 °C), KI in I_2, $Hg(NO_3)_2$, and chromic acid. The CO_2 is desiccated by a series of ethanol slush traps (at −80 °C) and a silica gel column and the CO_2 condensed by liquid N_2 traps. The CO_2 is converted to C_2H_2 using a stainless steel reaction vessel based on the design of Polach, Gower & Fraser (1972). Acetylene is trimerized to benzene using Noakes' catalyst, sealed in silica catalyst columns and cleaned between samples by flushing with air at 500 °C. Undersized samples are diluted with dead CO_2 prior to C_2H_2 generation to standardize benzene synthesis reactions. The dead CO_2 is obtained from coal for combustible samples, or from ancient limestone for carbonates.

Synthesized benzene samples are transfered into 5ml, low-K glass vials (constructed after the design of Polach, 1969), into which 75mg of scintillator (t-butyl PBD) has been weighed. The vials are then sealed with teflon stoppers and the benzene weight (ca 4.5g) accurately determined. Machined aluminium caps (black anodized) are then slid over the teflon stoppers and butted against the glass vials to reduce cross-talk between the counter photomultiplier tubes. Sample activities are determined in either an LKB 1211 scintillation counter, factory modified by Wallac ("Kangaroo

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Package") for low level ^{14}C determinations, or a Packard Tri-Carb, similarly modified for low level counting. Eight samples and two reference standards (sealed ANU sucrose and AR benzene) are interspersed in a chain and automatically cycled over a period of 14 days with a counting interval of 20 minutes, with each sample being counted for a minimum of 1980 minutes. Background levels vary between counters and vials and range from 0.72 cpm/gC to 0.96 cpm/gC. Modern activities (A_{on}) also vary, ranging from 8.11 cpm/gC to 9.80 cpm/gC. The laboratory working standard is ANU sucrose, with the normalized oxalic activity calculated using the conversion factor determined from an international cross-calibration exercise conducted by H A Polach of ANU ($D^{14}C$ = 508.1 ± 2.0‰ Currie & Polach, 1980).

Radiocarbon dates presented are *conventional radiocarbon ages* as defined by Stuiver & Polach (1977) with ages expressed in years BP ± 1 standard deviation. The counting error includes the statistical uncertainties of the sample, background, and reference standards and, in addition, errors in estimating the $\delta^{13}C$ (in the few samples where this was not measured), and in the ANU sucrose/oxalic acid conversion factor. ^{13}C determinations for each sample were performed on a Micromass 602C mass spectrometer. Interlaboratory comparisons are reported in Table 1. Sample descriptions and interpretations are based upon information received from the submitters.

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TABLE 1
Interlaboratory check samples

19,925 ± 300

Wk-1. Benzene cross-check #24 *Est $\delta^{13}C$ = −25‰*

ANU-1310. 19,600 ± 300

9450 ± 100

Wk-526. Lab cross-check (NPL-64) *$\delta^{13}C$ = −31.7‰*

ANU-03. 9410 ± 100, 9800 ± 220

$\frac{A_{sn}}{A_{on}}$ = **1.2444 ± 0.0056‰**

Wk-742. Lab cross-check (ACT VII) *$\delta^{13}C$ = −23.2‰*

Reported A_{sn}/A_{on} values from participating labs (M Stuiver, pers commun, 1986):

Quaternary Isotope Laboratory (M Stuiver): 1.2460 ± 0.0022‰
Participating Lab A: 1.2506 ± 0.0019‰
Participating Lab B: 1.2538 ± 0.0040‰

tion and operation of our laboratory. We are particularly grateful to H A Polach for helping to design the original vacuum systems, for providing the ANU sucrose standard, and for organizing a fellowship to help in the training of one of the authors (AGH). We thank the University Grants Committee of New Zealand for contributing to the cost of the scintillation counters. J E Noakes of the University of Georgia willingly provided the catalyst and M Stuiver the international calibration standard ACT VII. For technical assistance in the laboratory between 1975 and 1985, we thank E Raynor, P Chevis, A Brennan, A Limmer, J Smeaton, M Lawrence, and V Lockwood. Mass spectrometric determinations were carried out by A Thomas and W Schick. Finally, special thanks are due A T Wilson who founded the laboratory, and J D McCraw and K M Mackay who encouraged its development.

GEOLOGIC SAMPLES

New Zealand

Most dates reported here relate to the deposition of distal airfall tephras in lakes and peats in central and northern North Island, New Zealand (Sec 1). The tephras were erupted from rhyolitic and andesitic sources in the Taupo Volcanic Zone or from Mt Egmont or Mayor Island (Fig 1). They are useful as datable stratigraphic marker beds for a wide variety of purposes (eg, Pullar, 1973; Self & Sparks, 1981; Howorth *et al,* 1981; Pillans *et al,* 1982; McGlone, Howorth & Pullar, 1984; Harper, Howorth & McLeod, 1986), and as a "window" into volcanic processes, volcanic history, and the composition and evolution of magmas (eg, Walker, 1980, 1981a, b; Hodder, 1981, 1983; Froggatt, 1982; Wilson *et al,* 1984; Blake, Smith & Wilson, 1986). The preservation of tephra deposits in suitable organic sediments potentially allows their stratigraphic and chronologic relationships to be determined more accurately and possibly in much greater detail than might be obtained from subaerial exposures, particularly at distal localities where relatively thin tephras can be difficult to trace with certainty because of postdepositonal mixing and weathering processes (eg, Hodder & Wilson, 1976; Howorth, Froggatt & Robertson, 1980; Lowe *et al*, 1980; Hogg & McCraw, 1983; Lowe, 1986a). Lakes and peat bogs of late Quaternary age in North Island, particularly in the Waikato region (Fig 1), have proved ideal sites for preserving multiple tephra layers, including fine-grained deposits only a few millimeters thick (Lowe, Hogg & Hendy, 1981; Green & Lowe, 1985; Lowe, 1986a; Pl 1). Ongoing paleoenvironmental studies of the Waikato lakes have utilized the time-stratigraphic framework provided by the tephras, and include Green (1979), Boubée (ms), Green *et al* (1984), McGlone, Nelson & Todd (1984), Lowe (1985, 1986b), McCabe (ms), Kellett (ms), and Green & Lowe (1985).

The dates in Section 1 were determined on lake sediment (dy or gyttja) and peat from cores obtained with a modified Livingstone piston corer (Rowley & Dahl, 1956; Green, 1979) and with a modified D-section Russian/Jowsey peat corer (Jowsey, 1966), except where noted. The samples are grouped into series named after the lake or peat bog cored (Fig 1), and

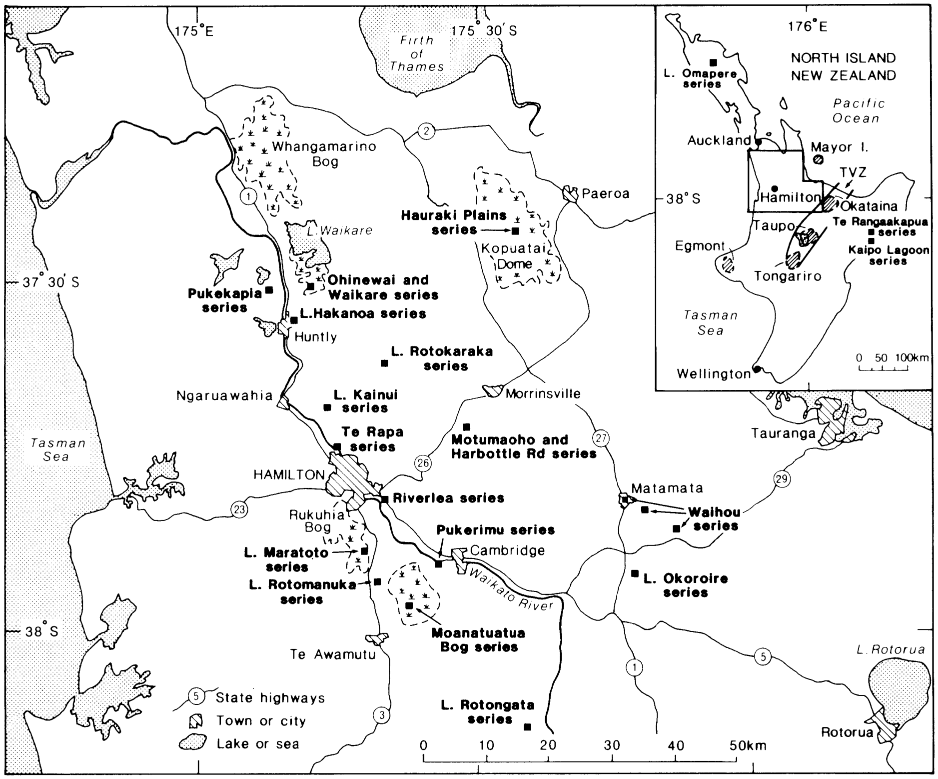

Fig 1. Locations of sample series in the Waikato region, New Zealand. Inset shows locations of other series and the main tephra-producing volcanoes (hatched) active in the late Quaternary period. TVZ = Taupo Volcanic Zone (after Cole & Nairn, 1975). *Note:* Mt Egmont is also known as Mt Taranaki.

arranged stratigraphically with samples closest to the surface listed first. Most samples came from five lakes; stratigraphic columns showing the sampling positions with respect to identified tephras are given in Figure 2. Most samples consist of slices of sediment (usually 1-2cm thick in the lake cores, 2-5cm or occasionally thicker in the peats) from above or below a tephra layer. Such slices of sediment, deliberately kept as thin as possible, represent an accumulation interval and, hence, may reduce date accuracy (with respect to the age of deposition of the tephras). This possible reduction in accuracy is offset by the tight stratigraphic control that the continuous cores provide, and by the availability of dates for many of the tephras in other environments (see below), thus acting as independent monitors of error (*cf* Mathewes & Westgate, 1980). To provide sufficient material for dating, slices of lake sediment from two or more suitable cores (taken within the same lake) were commonly combined into a composite sample (Green & Lowe, 1985). In some samples with very low carbon content, the slices from above and below the tephra have been combined as a "straddle" sample, providing an average age for the tephra. Where tephras are closely

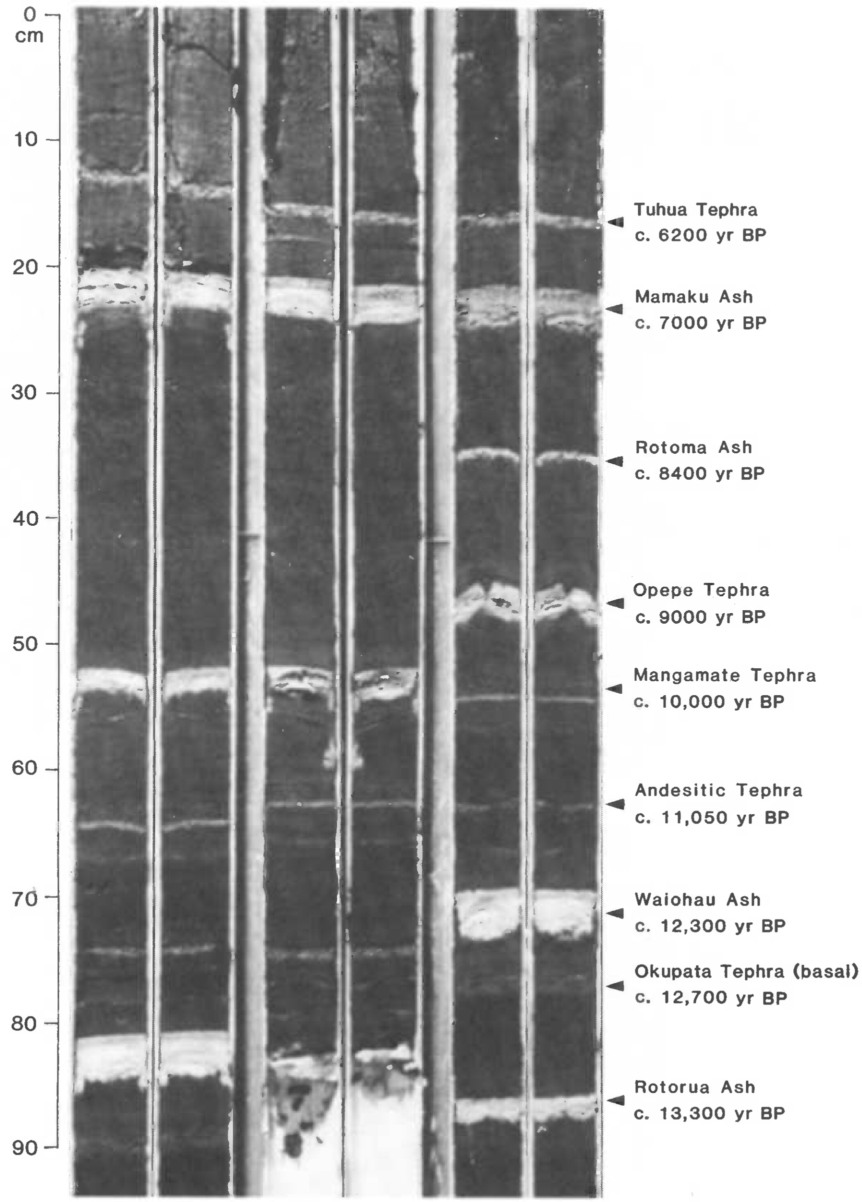

Plate 1. Three longitudinally sliced cores from Lake Rotomanuka, near Hamilton, showing ash-grade tephra layers preserved within dark, fine-grained organic lake sediment. The tephras are derived from five volcanic centers located 110 to 180km from Lake Rotomanuka (Fig 1). Photograph: RR Julian and W Forbes.

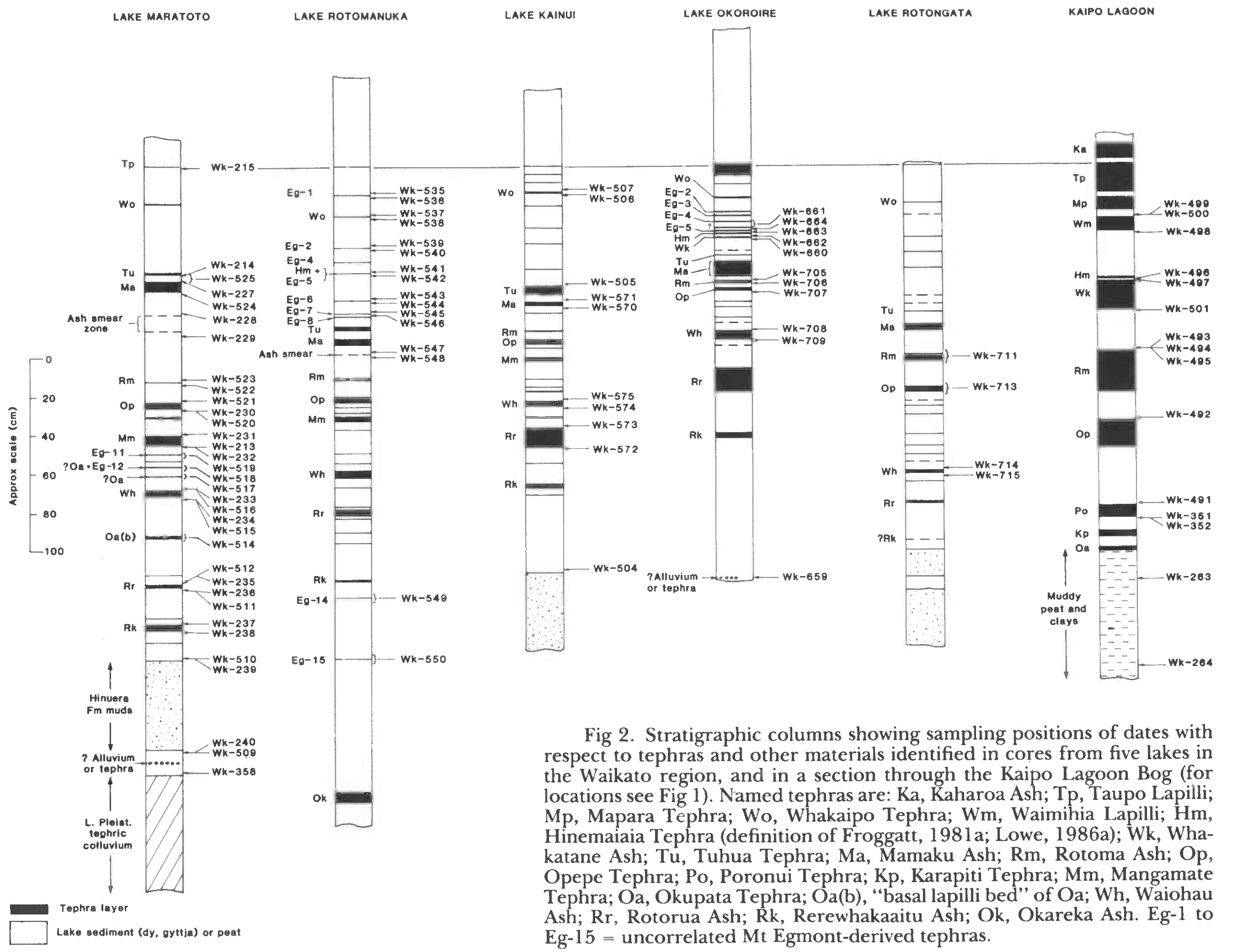

Fig 2. Stratigraphic columns showing sampling positions of dates with respect to tephras and other materials identified in cores from five lakes in the Waikato region, and in a section through the Kaipo Lagoon Bog (for locations see Fig 1). Named tephras are: Ka, Kaharoa Ash; Tp, Taupo Lapilli; Mp, Mapara Tephra; Wo, Whakaipo Tephra; Wm, Waimihia Lapilli; Hm, Hinemaiaia Tephra (definition of Froggatt, 1981a; Lowe, 1986a); Wk, Whakatane Ash; Tu, Tuhua Tephra; Ma, Mamaku Ash; Rm, Rotoma Ash; Op, Opepe Tephra; Po, Poronui Tephra; Kp, Karapiti Tephra; Mm, Mangamate Tephra; Oa, Okupata Tephra; Oa(b), "basal lapilli bed" of Oa; Wh, Waiohau Ash; Rr, Rotorua Ash; Rk, Rerewhakaaitu Ash; Ok, Okareka Ash. Eg-1 to Eg-15 = uncorrelated Mt Egmont-derived tephras.

spaced in the cores, the entire layer of sediment between two adjacent tephras (*ie*, "bridging" the tephras) was occasionally sampled. The date thus obtained applies equally to both tephras, giving a maximum age for one, and a minimum for the other (eg, Lowe, 1986a).

Except for Lakes Purimu and Maungaratariti (Wk-426, -842), none of the lakes sampled have calcareous rocks in their catchments; hence, the "hard-water effect" frequently encountered in such environments in Europe, Scandinavia, North America, and elsewhere (eg, Ogden, 1967; Olsson, 1979; Mathewes & Westgate, 1980) does not arise.

Most of the tephras have been correlated with named eruptive units elsewhere using diagnostic mineralogic and chemical criteria, together with stratigraphic and age relationships (Lowe *et al*, 1980; Green & Lowe, 1985; Lowe & Hogg, 1986; Lowe, 1986a, c, and work in progress). Although most of the rhyolitic tephras (from Taupo, Okataina, and Mayor Island sources, Fig 1) were dated previously (Healy, 1964; Vucetich & Pullar,

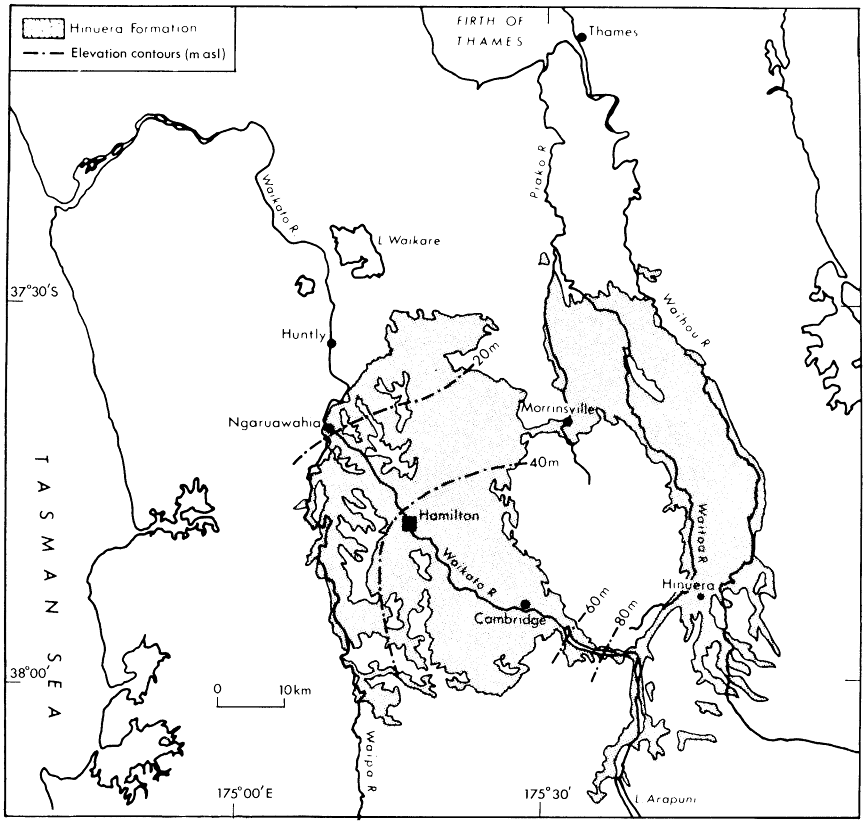

Fig 3. The distribution of the Hinuera Formation in the Hamilton Basin (left) and the Hauraki Basin. Contours show the alluvial fan form. From Selby (1982), based on Hume, Sherwood & Nelson (1975).

1964, 1969, 1973; Grant-Taylor & Rafter, 1966; Pullar & Heine, 1971; Topping & Kohn, 1973; McCraw, 1975; Nairn, 1980; Froggatt, 1981a, b; Hogg & McCraw, 1983), many have only one or two dates. The andesitic tephras (from Tongariro and Egmont sources, Fig 1) have a rather complex stratigraphy with relatively few available dates (Topping, 1973; Neall, 1972, 1979; Neall & Geddes, 1981; Neall & Alloway, 1986). In the lake cores, many of the tephras derived from the Mt Egmont volcano have not yet been positively correlated with named eruptives, so they are informally designated as "Eg-1", "Eg-2", etc, in the date list (Fig 2).

The dates listed in Section 2 were obtained on carbonaceous matter associated with the Hinuera Formation, an extensive low-angle fan of volcanogenic alluvium that was deposited in several phases in the Waikato and Hauraki basins before and during the last stade (isotope stage 2) of the last glaciation (Fig 3; Schofield, 1965; Hume, Sherwood & Nelson, 1975; McGlone, Nelson & Hume, 1978; Cuthbertson, ms; Selby, 1982; Green & Lowe, 1985). The aggradation of the Hinuera Formation resulted in the formation of most of the lakes noted above (McCraw, 1967; Lowe & Green, 1987). Therefore, some of the dates obtained for material from the lower parts of cores from these lakes provide information on the age of Hinuera Formation sedimentation. These dates could be grouped in Section 2, but have been retained in Section 1 because of their stratigraphic relationship to the overlying dates associated with the tephras.

In Section 3, the samples comprise materials associated with peat bog growth or local sedimentation that postdates the deposition of the Hinuera Formation, *ie*, < ca 15,000 BP. Samples in both Sections 2 and 3 are grouped into series according to geographic location, and, where appropriate, arranged stratigraphically with uppermost samples shown first.

Map location grid references refer to the national 1000m grid of the New Zealand 1:50,000 topographic map series, NZMS 260 (1st ed).

1. Dates Associated with Deposition of Airfall Tephras in Lakes and Peat Bogs

Lake Maratoto series

Organic lake sediment (humic copropel, dy-gyttja) coll by piston corer from Lake Maratoto, 10km S of Hamilton (37° 53′ S, 175° 18′ E) (S15/130663). Coll and subm by D J Lowe and J D Green, School Sci, Univ Waikato. Coll in 4 sampling sets in 1979 (Mo/A), 1980 (Mo/C), 1981 (Mo/D), and 1982 (Mo/E).

1730 ± 60
Wk-215. Mo/A5 *Est* $\delta^{13}C = -28‰$

Comment: diluted, 82% sample. (DJL): date is max for Taupo Pumice Fm (Taupo Lapilli Member).

6210 ± 70
Wk-214. Mo/A4 $\delta^{13}C = -28.4‰$

Comment (DJL): date is max for Tuhua Tephra Fm.

5800 ± 70

Wk-525. Mo/E1 $\delta^{13}C = -28.8‰$

Comment (DJL): sample bridges two tephra layers; date is max for Tuhua Tephra Fm and min for Mamaku Ash Fm. Date is younger than expected for eruption of Mamaku Ash. This may be due to overthick sample (given a very slow sedimentation rate) or possibly to sample contamination in core.

6830 ± 90

Wk-227. Mo/C12 $\delta^{13}C = -27.0‰$

Comment: diluted, 57% sample. (DJL): date is min for Mamaku Ash Fm.

7920 ± 80

Wk-524. Mo/E2 $\delta^{13}C = -29.8‰$

Comment (DJL): date is max for Mamaku Ash Fm and may overestimate eruption age. See comment for Wk-228.

8170 ± 90

Wk-228. Mo/C11 $\delta^{13}C = -29.7‰$

Comment: diluted, 72% sample. (DJL): date is max for Mamaku Ash Fm. Date considered perhaps ca 1000 yr too old, with regard to eruption of Mamaku Ash, as mineralogic evidence shows sample contaminated by underlying Rotoma Ash Fm (Green & Lowe, 1985).

7650 ± 160

Wk-229. Mo/C14 $\delta^{13}C = -30.0‰$

Comment: diluted, 34% sample. (DJL): date is min for Opepe Tephra Fm and younger than expected for eruption of Opepe Tephra (by ca 1000 to 1500 yr?), possibly due to compression of sediment in core between Mamaku and Opepe tephras.

8350 ± 100

Wk-523. Mo/E3 $\delta^{13}C = -30.7‰$

Comment: diluted, 72% sample. (DJL): date is min for Rotoma Ash Fm; differs from previous ones on eruption of this tephra, ca 7000 to 7300 BP (Pullar & Heine, 1971; Pullar, Birrell & Heine, 1973), but is closer to date of (NZ1945) 8860 ± 120 BP given by Nairn (1980). Dates 8000 to 9000 BP considered more reliable, but specific eruption age remains uncertain.

8370 ± 90

Wk-522. Mo/E4 $\delta^{13}C = -31.3‰$

Comment: diluted, 78% sample. (DJL): date is max for Rotoma Ash Fm. See comment for Wk-523.

8670 ± 110

Wk-521. Mo/E5 $\delta^{13}C = -31.2‰$

Comment: diluted, 62% sample. (DJL): date is min for Opepe Tephra Fm.

Wk-230. Mo/C13 **9370 ± 210** *$\delta^{13}C = -31.6‰$*

Comment: diluted, 33% sample. (DJL): date is max for Opepe Tephra Fm.

Wk-520. Mo/E6 **8930 ± 100** *$\delta^{13}C = -31.1‰$*

Comment: diluted, 72% sample. (DJL): date is max for Opepe Tephra Fm.

Wk-231. Mo/C10 **9700 ± 140** *$\delta^{13}C = -30.9‰$*

Comment: diluted, 52% sample. (DJL): date is min for Mangamate Tephra Fm (?Te Rato Lapilli Member).

Wk-213. Mo/A3 **10,120 ± 100** *Est $\delta^{13}C = -27‰$*

Comment: diluted, 82% sample. (DJL): date is max for Mangamate Tephra Fm (?Te Rato Lapilli Member).

Wk-232. Mo/C9 **10,000 ± 120** *$\delta^{13}C = -31.9‰$*

Comment: diluted, 76% sample. (DJL): date is max for Mangamate Tephra Fm (?Te Rato Lapilli Member).

Wk-519. Mo/E7 **10,100 ± 100** *$\delta^{13}C = -31.9‰$*

Comment: diluted, 86% sample. (DJL): sample straddles tephra layer; date is average for uncorrelated tephra from Egmont, Eg-11.

Wk-518. Mo/E8 **11,050 ± 130** *$\delta^{13}C = -32.1‰$*

Comment: diluted, 68% sample. (DJL): sample straddles two (?) intermixed andesitic tephras visible as a single "speckled" layer; date is average for tephras tentatively identified as unnamed member of Okupata Tephra Fm (from Tongariro) and uncorrelated tephra from Egmont, Eg-12. Volcanoes apparently erupted approx contemporaneously.

Wk-517. Mo/E9 **11,700 ± 180** *$\delta^{13}C = -34.6‰$*

Comment: diluted, 47% sample. (DJL): sample straddles tephra layer; date is average for unnamed Member of (?) Okupata Tephra Fm.

Wk-233. Mo/C8 **12,200 ± 230** *$\delta^{13}C = -35.0‰$*

Comment: diluted, 42% sample. (DJL): date is min for Waiohau Ash Fm. Date is older than previous dates obtained on charcoal from this tephra between ca 11,100 to 11,800 BP (generally accepted age is ca 11,300 BP, Pullar & Heine, 1971; Pullar & Birrell, 1973). Sample conceivably contaminated by redeposited older organic material (eg, Olsson & Florin, 1980; Björck & Håkansson, 1982), but Green & Lowe (1985) and Lowe & Hogg (1986) suggest instead that charcoal dates may underestimate real age of Waiohau eruption by several hundred years at least, *ie*, Waiohau Ash age probably closer to ca 12,000 BP than 11,000 BP. See dates in other series below.

12,300 ± 190
Wk-516. Mo/E10 $\delta^{13}C = -31.6‰$

Comment: diluted, 47% sample. (DJL): date is min for Waiohau Ash Fm. See comment for Wk-233.

12,500 ± 190
Wk-234. Mo/C7 $\delta^{13}C = -35.6‰$

Comment: diluted, 47% sample. (DJL): date is max for Waiohau Ash Fm. See comment for Wk-233.

12,450 ± 200
Wk-515. Mo/E11 $\delta^{13}C = -32.4‰$

Comment: diluted, 44% sample. (DJL): date is max for Waiohau Ash Fm. See comment for Wk-233.

12,700 ± 200
Wk-514. Mo/E12 $\delta^{13}C = -33.4‰$

Comment: diluted, 46% sample. (DJL): sample straddles tephra layer; provides average age of "basal lapilli" bed (?) of Okupata Tephra Fm (as denoted by Topping, 1973).

12,800 ± 150
Wk-512. Mo/E14 $\delta^{13}C = -33.2‰$

Comment: diluted, 68% sample. (DJL): date is min for Rotorua Ash Fm. Thick sample slice may reduce reliability. See comment for Wk-511.

12,900 ± 310
Wk-235. Mo/C6 $\delta^{13}C = -32.5‰$

Comment: diluted, 26% sample. (DJL): date is min for Rotorua Ash Fm.

12,600 ± 230
Wk-236. Mo/C5 $\delta^{13}C = -35.6‰$

Comment: diluted, 33% sample. (DJL): date is max for Rotorua Ash Fm. Date is younger than expected. See comment for Wk-511.

13,450 ± 120
Wk-511. Mo/E15 $\delta^{13}C = -31.9‰$

Comment (DJL): date is max for Rotorua Ash Fm. Agrees closely with near-source date on this tephra of (NZ1615) 13,450 ± 250 BP (Nairn, 1980). Taking other dates on Rotorua Ash, and those on adjacent tephras (Waiohau, Rerewhakaaitu) into account, age of eruption thought to be near ca 13,300 BP.

Wk-237. Mo/C4 — **14,700 ± 220** — $\delta^{13}C = -31.6‰$

Comment: diluted, 55% sample. (DJL): date is min for Rerewhakaaitu Ash Fm.

Wk-238. Mo/C3 — **14,700 ± 180** — $\delta^{13}C = -30.5‰$

Comment: diluted, 78% sample. (DJL): date is max for Rerewhakaaitu Ash Fm.

Wk-510. Mo/E16 — **15,850 ± 130** — $\delta^{13}C = -28.5‰$

Comment (DJL): dates fm of present-day Lake Maratoto and cessation of final episode of deposition of Hinuera Fm at this site.

Wk-239. Mo/C2 — **16,300 ± 250** — $\delta^{13}C = -29.7‰$

Comment: diluted, 52% sample. (DJL): dates fm of present-day Lake Maratoto and cessation of final episode Hinuera Fm deposition at this site.

Wk-240. Mo/C1 — **16,900 ± 470** — *Est* $\delta^{13}C = -30‰$

Comment: diluted, 28% sample. (DJL): dates beginning of final episode of Hinuera Fm deposition at this site, which resulted in fm of present-day Lake Maratoto. Sample is gyttja deposited in relatively short-lived "proto-Lake Maratoto" formed by penultimate episode of Hinuera Fm sedimentation. This gyttja contains indistinct band of grayish sandy mud with pumice lapilli that is most likely reworked volcanogenic alluvium. However, lapilli might represent uncorrelated airfall tephra. If so, its stratigraphic position below Rerewhakaaitu Ash suggests (?) Okareka Ash Fm (Fig 2; Vucetich & Pullar, 1969); thus, age obtained (also Wk-509, -358) would be min. Elsewhere, Okareka Ash is undated but thought to be ca 17,000 BP (Nairn, ms).

Wk-509. Mo/E17 — **16,200** $^{+360}_{-340}$ — $\delta^{13}C = -25.9‰$

Comment: diluted, 35% sample. (DJL): dates beginning of final episode of Hinuera Fm deposition at this site that resulted in fm of present-day Lake Maratoto. Sample is gyttja deposited in relatively short-lived "proto-Lake Maratoto" formed by penultimate episode of Hinuera Fm sedimentation. See comment for Wk-240.

17,050 ± 200

Wk-358. Mo/D1 $\delta^{13}C = -29.9‰$

Comment: diluted, 78% sample. (DJL): dates fm of "proto-Lake Maratoto" by penultimate episode of deposition of Hinuera Fm alluvium in this area. See comment for Wk-240.

General Comment (DJL): Wk-213, -214, -215 are first dates obtained on airfall tephras in Hamilton Basin. Ages generally accord with stratigraphy (increase down core), and dates on tephras closely match those on same tephras elsewhere, except as noted (Lowe *et al,* 1980; Hogg & McCraw, 1983; Green & Lowe, 1985). Dates on Okupata Tephra and uncorrelated Egmont tephras (Wk-517, Wk-518, Wk-519) are consistent with sparse dates on related eruptive sequences nearer source (Topping, 1973; Neall & Alloway, 1986). Deposition of Hinuera Fm at Lake Maratoto ca 16,000 to 17,000 BP agrees with ages in McGlone, Nelson & Hume (1978) and McGlone, Nelson & Todd (1984). Dates also give rates of sedimentation during lake's developmental history (average ca 0.1 to 0.2mm/yr; Green & Lowe, 1985)—similar average rates are evident for most other Hinuera-dammed lakes (see below).

Lake Rotomanuka series

Organic lake sediment (dy, gyttja, or dy-gyttja) coll by piston corer (Pl 1) from Lake Rotomanuka, 15km S of Hamilton (37° 55′ S, 175° 19′ E) (S15/136615). Coll 1983 by D J Lowe, J D Green, and C H Hendy; subm by D J Lowe and J D Green.

2560 ± 80

Wk-535. Rot/D-1 $\delta^{13}C = -29.9‰$

Comment: diluted, 57% sample. (DJL): date is min for uncorrelated tephra from Egmont, Eg-1.

2350 ± 80

Wk-536. Rot/D-2 $\delta^{13}C = -29.5‰$

Comment: diluted, 58% sample. (DJL): date is max for uncorrelated tephra from Egmont, Eg-1.

2560 ± 60

Wk-537. Rot/D-3 $\delta^{13}C = -29.5‰$

Comment: diluted, 77% sample. (DJL): date is min for Whakaipo Tephra Fm. Date (and Wk-538) supports identification of this tephra as Whakaipo (based upon chem analysis of glass, Lowe, 1986a) rather than older Waimihia Fm reported by Lowe *et al* (1980).

2860 ± 60

Wk-538. Rot/D-4 $\delta^{13}C = -29.9‰$

Comment: diluted, 88% sample. (DJL): date is max for Whakaipo Tephra Fm and agrees closely with near source dates on this tephra (Vucetich & Pullar, 1973).

3610 ± 60

Wk-539. Rot/D-5 $\delta^{13}C = -28.8‰$

Comment (DJL): date is min for uncorrelated tephra from Egmont, Eg-2.

3750 ± 70

Wk-540. Rot/D-6 *Est* $\delta^{13}C = -29.9‰$

Comment (DJL): date is max for uncorrelated tephra from Egmont, Eg-2. Also sets upper age limit for indistinct tephra, Eg-4, which sporadically occurs below Eg-2 in some cores from lake.

4490 ± 70

Wk-541. Rot/D-7 $\delta^{13}C = -29.4‰$

Comment (DJL): sample overlies layer of two(?) apparently admixed tephras; date is min for Hinemaiaia Tephra (definition of Froggatt, 1981a; Lowe, 1986a), and for uncorrelated tephra from Egmont, Eg-5. Date also gives lower age limit to overlying Eg-4 tephra. Supports dates on Hinemaiaia Tephra reviewed in Lowe (1986a).

4470 ± 70

Wk-542. Rot/D-8 $\delta^{13}C = -29.6‰$

Comment (DJL): sample underlies layer of two(?) apparently admixed tephras; date is max for Hinemaiaia Tephra (definition of Froggatt, 1981a; Lowe, 1986a), and uncorrelated tephra from Egmont, Eg-5. Supports dates on Hinemaiaia Tephra reviewed in Lowe (1986a).

5280 ± 80

Wk-543. Rot/D-9 $\delta^{13}C = -30.2‰$

Comment: diluted, 77% sample. (DJL): date is min for uncorrelated tephra from Egmont, Eg-6.

5210 ± 90

Wk-544. Rot/D-10 $\delta^{13}C = -29.9‰$

Comment: diluted, 72% sample. (DJL): date is max for uncorrelated tephra from Egmont, Eg-6.

5850 ± 80

Wk-545. Rot/D-11 $\delta^{13}C = -30.3‰$

Comment: diluted, 84% sample. (DJL): date is min for uncorrelated tephra from Egmont, Eg-7.

5850 ± 80

Wk-546. Rot/D-12 $\delta^{13}C = -29.5‰$

Comment: diluted, 75% sample. (DJL): sample bridges two tephra layers; date is max for uncorrelated tephra from Egmont, Eg-7 (overlies sample) and min for uncorrelated Egmont tephra, Eg-8 (underlies sample).

Wk-547. Rot/D-13 **7980 ± 150**
$\delta^{13}C = -31.1‰$

Comment: diluted, 36% sample. (DJL): sample occurs about midway between Mamaku Ash and Rotoma Ash and overlies (*cf* Wk-548 which underlies) indistinct, discontinuous layer of tephra-like material. Indistinct layer was originally thought to represent separate eruptive event but is now considered to be reworked from adjacent Mamaku and/or Rotoma tephras (either naturally or in coring procedure). Date gives approx age limits for Mamaku Ash Fm (max) and Rotoma Ash Fm (min)–*cf* Wk-228.

Wk-548. Rot/D-14 **8030 ± 200**
$\delta^{13}C = -30.8‰$

Comment: diluted, 29% sample. (DJL): date gives approx age limits for Mamaku Ash Fm (max) and Rotoma Ash Fm (min). See comment for Wk-547.

Wk-549. Rot/D-15 **14,750 ± 130**
$\delta^{13}C = -22.7‰$

Comment (DJL): sample straddles tephra layer; date is average for uncorrelated Egmont tephra, Eg-14, occurring 7cm below Rerewhakaaitu Ash Fm in core.

Wk-550. Rot/D-16 **14,650 ± 240**
$\delta^{13}C = -24.7‰$

Comment: diluted, 47% sample. (DJL): date is max for uncorrelated Egmont tephra, Eg-15, that occurs ca 30cm below Rerewhakaaitu Ash in core. Date younger than expected, being similar to reliable dates on Rerewhakaaitu Ash (14,700 BP, see Lake Maratoto series); possibly due to contamination of sample by younger carbon in coring procedure or to relatively high sedimentation rate in lake in this early postglacial period (*cf* Green & Lowe, 1985).

General Comment (DJL): dates on distal Egmont-derived tephras in this series contribute greatly to relatively few dates available nearer source and may help to establish distribution patterns and correlations of eruptives from Egmont volcano.

Lake Kainui series

Organic lake sediment coll by piston corer from Lake Kainui (also known as Lake D), 15km NW of Hamilton (37° 41′ S, 175° 14′ E) (S14/072892). Coll 1982 by D J Lowe, J D Green, and C H Hendy and subm by D J Lowe, Earth Sci, Univ Waikato.

Wk-507. Lake D-12 **2010 ± 80**
Est $\delta^{13}C = -28‰$

Comment: diluted, 49% sample. (DJL): date is min for Whakaipo Tephra Fm, younger than expected. See comment for Wk-538.

3030 ± 70

Wk-506. Lake D-11 $\delta^{13}C = -28.0‰$

Comment: diluted, 53% sample. (DJL): date is max for Whakaipo Tephra Fm.

5800 ± 90

Wk-505. Lake D-10 $\delta^{13}C = -28.8‰$

Comment: diluted, 56% sample. (DJL): date is min for Tuhua Tephra Fm.

7140 ± 110

Wk-571. Lake D-5 $\delta^{13}C = -29.2‰$

Comment: diluted, 47% sample. (DJL): date is min for Mamaku Ash Fm.

7200 ± 120

Wk-570. Lake D-4 $\delta^{13}C = -29.1‰$

Comment: diluted, 40% sample. (DJL): date is max for Mamaku Ash Fm.

11,800 ± 230

Wk-575. Lake D-9 $\delta^{13}C = -31.6‰$

Comment: diluted, 33% sample. (DJL): date is min for Waiohau Ash Fm. See comment for Wk-233.

11,700 ± 270

Wk-574. Lake D-8 $\delta^{13}C = -32.3‰$

Comment: diluted, 29% sample. (DJL): date is max for Waiohau Ash Fm. See comment for Wk-233.

12,350 ± 210

Wk-573. Lake D-7 $\delta^{13}C = -32.1‰$

Comment: diluted, 42% sample. (DJL): date is min for Rotorua Ash Fm, younger than expected (by ca 1000 yr?); may be due to disturbed top and base of tephra (has *in situ* gas pockets, tephra-infilled cracks in gyttja). See comment for Wk-511.

12,650 ± 230

Wk-572. Lake D-6 $\delta^{13}C = -31.1‰$

Comment: diluted, 37% sample. (DJL): date is max for Rotorua Ash Fm, younger than expected. See comment for Wk-573.

15,150 $^{+680}_{-630}$

Wk-504. Lake D-1 $\delta^{13}C = -26.3‰$

Comment: diluted, 15% sample. (DJL): dates fm of Lake Kainui and cessation of deposition of Hinuera Fm sediments at this site. Age consistent with previous determinations elsewhere (McGlone, Nelson & Hume, 1978; Green & Lowe, 1985).

General Comment (DJL): ages generally accord well with previous determinations except those noted as younger than expected.

Lake Okoroire series

Organic lake sediment coll by piston corer from Lake Okoroire, 5km N of Tirau (37° 55′ S, 175° 48′ E) (T15/555611). Coll 1984 by D J Lowe, C H Hendy and M Ouellet and subm by D J Lowe. *Note:* minimal sample material was available for this series. Samples Wk-661 to -664 each bridge two closely spaced tephras, thus applying equally to both tephras (Fig 2).

3950 ± 90
Wk-661. Ok-6 *$\delta^{13}C = -30.6‰$*

Comment: diluted, 42% sample. (DJL): date is max for uncorrelated tephra from Egmont, Eg-4, and min for uncorrelated tephra of uncertain source.

3810 ± 140
Wk-664. Ok-5 *$\delta^{13}C = -30.6‰$*

Comment: diluted, 20% sample. (DJL): date is max for uncorrelated tephra of uncertain source and min for uncorrelated tephra from Egmont, Eg-5.

3510 ± 150
Wk-663. Ok-4 *$\delta^{13}C = -30.2‰$*

Comment: diluted, 21% sample. (DJL): date is max for uncorrelated tephra from Egmont, Eg-5, and min for Hinemaiaia Tephra Fm (definition of Froggatt, 1981a; Lowe, 1986a). Date younger than expected as it is inconsistent with succession of dates on overlying and underlying sediments (Wk-660, -661, -664) and, hence, may be unreliable (contaminated by younger carbon?).

4260 ± 140
Wk-662. Ok-3 *$\delta^{13}C = -31.7‰$*

Comment: diluted, 23% sample. (DJL): date is max for Hinemaiaia Tephra Fm (definition of Froggatt, 1981a; Lowe, 1986a) and min for Whakatane Ash Fm.

4850 ± 80
Wk-660. Ok-2 *$\delta^{13}C = -32.1‰$*

Comment: diluted, 55% sample. (DJL): date is max for Whakatane Ash Fm (Lowe, 1986a).

7520 ± 130
Wk-705. Ok-7 *$\delta^{13}C = -31.5‰$*

Comment: diluted, 44% sample. (DJL): date is min for Rotoma Ash Fm; gives max limit for Mamaku Ash Fm as sample is within a few cm of base of

Mamaku Ash Fm (Fig 2). Younger than expected for Rotoma Ash (probably ca 8000 to 9000 BP), but expected for Mamaku Ash range (see comment for Wk-523). Sedimentation rate in lake was probably very low at this time, so sample slice, although only 2cm thick, may span ca 1000 yr.

7920 ± 130
Wk-706. Ok-8 $\delta^{13}C = -31.5‰$

Comment: diluted, 44% sample. (DJL): date is max for Rotoma Ash Fm; gives min age for Opepe Tephra Fm, as sample is within a few cm of top of Opepe Tephra Fm (Fig 2). See comment for Wk-705.

8700 ± 130
Wk-707. Ok-9 $\delta^{13}C = -32.4‰$

Comment: diluted, 49% sample. (DJL): date is max for Opepe Tephra Fm.

10,220 ± 160
Wk-708. Ok-10 $\delta^{13}C = -27.0‰$

Comment: diluted, 47% sample. (DJL): date is min for Waiohau Ash Fm; younger than expected for this tephra, dated between ca 11,000 and 12,500 BP elsewhere. See comment for Wk-233.

11,570 ± 130
Wk-709. Ok-11 $\delta^{13}C = -27.3‰$

Comment: diluted, 68% sample. (DJL): date is max for Waiohau Ash Fm. See comment for Wk-233.

15,850 ± 320
Wk-659. Ok-1 $\delta^{13}C = -20.0‰$

Comment: diluted, 32% sample. (DJL): date is min for fm of Lake Okoroire (base of lake sediments not seen) and gives upper limit to deposition of Hinuera Fm sediments in this area (see comment for Waihou series). Sparse white pumice grains at base of sample may represent uncorrelated tephra layer. If so, may be Okareka Ash Fm, based solely upon stratigraphic position relative to Rerewhakaaitu Ash Fm in core (Fig 2; Vucetich & Pullar, 1969), and thus could give upper age limit for this possible tephra. See comment for Wk-240.

General Comment (DJL): dates, except Wk-663, accord with stratigraphy. In dating tephra eruptions, degree of resolution that can be achieved through dating associated lake sediment is limited when sample material is restricted and sedimentation rates are slow (*ie,* ca 0.1 mm/yr or less).

Lake Rotongata series

Organic lake sediment coll by piston corer from Lake Rotongata, Arapuni Dist (38° 08′ S, 175° 36′ E) (T16/380376). Coll 1985 by D J Lowe, C H Hendy, and M Ouellet and subm by D J Lowe.

Wk-711. Rn-1/2 **8000 ± 170** $\delta^{13}C = -32.5‰$

Comment: diluted, 34% sample. (DJL): sample straddles tephra layer; date is average for Rotoma Ash Fm. See comment for Wk-523.

Wk-713. Rn-3/4 **8990 ± 220** $\delta^{13}C = -33.0‰$

Comment: diluted, 28% sample. (DJL): sample straddles tephra layer; date is average for Opepe Tephra Fm.

Wk-714. Rn-5 **11,840 ± 340** $\delta^{13}C = -24.1‰$

Comment: diluted, 22% sample. (DJL): date is min for Waiohau Ash Fm. See comment for Wk-233.

Wk-715. Rn-6 **11,990 ± 230** $\delta^{13}C = -25.8‰$

Comment: diluted, 35% sample. (DJL): date is max for Waiohau Ash Fm.

Lake Omapere series

Organic lake sediment or wood fragments coll by piston corer from five sites in Lake Omapere, near Kaikohe, North Auckland (35° 21′ S, 173° 47′ E) as part of joint New Zealand-Japan project in paleolimnology organized by S Horie, chairman of Special Working Group of Societas Internationalis Limnologiae (Lowe, 1984). Coll 1984 by D J Lowe, J D Green, J A T Boubée, S Bergin, and S Horie and subm by D J Lowe and J D Green.

Wk-625. Om-4 **1190 ± 90** $\delta^{13}C = -27.4‰$

Lake sediment at loc P5/827494. *Comment:* diluted, 33% sample. (DJL): dates soft brown gyttja overlying greenish gray clay layer ca 20cm below surface of sediments in Lake Omapere. Gray clay seems to represent increased erosion in catchment, possibly forming present-day lake by blockage of drainage (Lowe & Green, 1987). Such erosion is likely to reflect deforestation, either by natural causes or possibly in response to Polynesian cultural activities (*cf* McGlone, 1983) as date obtained is around time of earliest known settlement of Polynesians in New Zealand (Davidson, 1981). See also general comment for Lake Hakanoa series, below.

Wk-604. Om/E1-30B **5410 ± 150** *Est* $\delta^{13}C = -25‰$

Lake sediment at loc P5/827494. *Comment:* diluted, 24% sample. (DJL): sample overlies diffuse tephra layer (lab no. 7) tentatively identified as Mamaku Ash Fm; date is min. If tephra is Mamaku, age is younger than expected (see Wk-227) but could easily be explained by excessively thick sample slice (5cm). See Wk-626.

8030 ± 330

Wk-626. Om/E1-40 $\delta^{13}C = -25.4‰$

Lake sediment at loc P5/827494. *Comment:* diluted, 14% sample. (DJL): sample underlies diffuse tephra layer (lab no. 7) tentatively identified as Mamaku Ash Fm. Date is max, age is consistent with range for this tephra in Waikato lakes (see series above), and supports identification as Mamaku Ash.

>35,000

Wk-590. Om-2 $\delta^{13}C = -25.5‰$

Lake sediment at loc P5/827494. *Comment:* diluted, 15% sample. (DJL): sample underlies airfall tephra 10cm thick (lab nos. 1, 2) provisionally identified as Rotoehu Ash (member of Rotoiti Breccia Fm, Nairn, 1972). Date agrees with previous dates of ca 42,000 BP (Pullar & Heine, 1971) and est age of ca 50,000 BP (McGlone, Howorth & Pullar, 1984).

>35,000

Wk-589. Om-3 *Est* $\delta^{13}C = -25‰$

Lake sediment at approx loc P5/821505. *Comment:* diluted, 26% sample. (DJL): sample at ca 1m depth in core. Dates thin, slightly gritty layer within grayish, muddy gyttja.

>35,000

Wk-588. Om/D1-225 $\delta^{13}C = -28.6‰$

Lake sediment at loc P5/821505. *Comment:* diluted, 25% sample. (DJL): sample straddles thin, intermittently occurring tephra (?) layer (lab no. 6) at ca 2.2m depth that marks change in sediments from grayish mud above to brownish gyttja below.

>30,000

Wk-587. Om/C2-247 $\delta^{13}C = -24.5‰$

Lake sediment at loc P5/827494. *Comment:* diluted, 24% sample. (DJL): sample straddles uncorrelated white rhyolitic ash layer (lab no. 3) at ca 2.5m depth in core; date is average for tephra.

>35,000

Wk-586. Om-1 $\delta^{13}C = -24.3‰$

Lake sediment at loc P5/821505. *Comment:* diluted, 46% sample. (DJL): sample straddles uncorrelated white rhyolitic ash layer (lab no. 4) at ca 4m depth in core; date is average for tephra.

>35,000

Wk-585. Om/C2-400 $\delta^{13}C = -21.7‰$

Basal lake sediment at loc P5/827494. *Comment:* diluted, 44% sample. (DJL): dates fm of initial "proto-Lake Omapere." As initial lake basin was thought to be formed by lava flow blocking drainage (Bell & Clarke, 1909; Cotton, 1958), sample should date eruption of lava (from Te Ahuahu, Maungakawakawa, or other volcano).

>30,000
Wk-584. Om/C2-417 $\delta^{13}C = -22.5‰$

Small fragments of conifer wood (either *Podocarpus totara/hallii* or *Dacrydium cupressinum* or *Libocedrus;* R Patel, pers commun, 1984) and assoc carbonaceous material in paleosol-like muds underlying basal lake sediments at loc P5/827494. *Comment:* diluted, 53% sample. (DJL): date is max age for inundation of pre-lake surface by proto-Lake Omapere at this site.

>35,000
Wk-581. Om/E1-470 $\delta^{13}C = -26.3‰$

Wood fragments in peat underlying basal lake sediments at loc P5/821501. *Comment* (DJL): date is max for inundation by proto-Lake Omapere at this site, and age of sub-lake peat bog.

>35,000
Wk-583. Om/A2-160 $\delta^{13}C = -26.2‰$

Wood (*Agathis australis*?) underlying basal lake sediments at loc P5/840502. *Comment* (DJL): date is max for inundation of pre-lake surface by proto-Lake Omapere at this site.

General Comment (DJL): changes in nature of lake sediment, range of ages obtained, and sparse tephras preserved, suggest that lake has existed only intermittently in Omapere basin with gaps in depositional record. Modern lake was possibly formed only ca 1000 BP. Dates on Mamaku (?) Ash, Rotoehu Ash, and the older tephras (probably all derived from Taupo Volcanic Zone) are first obtained on rhyolitic tephras in Northland other than late Holocene Kaharoa Ash and Taupo Pumice deposits (Pullar, Kohn & Cox, 1977; Stewart, Neall & Syers, 1984).

Kaipo Lagoon series

Peat containing abundant coarse roots coll from two sites at outlet of Kaipo Stream, draining Kaipo Lagoon, Urewera National Park (38° 41′ S, 177° 11′ E) (W18/740720). Kaipo Lagoon is 73ha ombrogenous shrub bog at 1100m alt surrounded by mature silver beech (*Nothofagus menziesii*) and red beech (*N fusca*) (Lowe & Hogg, 1986). Coll and subm 1982 by N B Rogers, D J Lowe, and A G Hogg, School Sci, Univ Waikato. Samples are from site 1 unless noted. Some samples were split into coarse (handpicked roots) and fine (fine peat residual after root extraction) fractions, each being dated separately.

2910 ± 60
Wk-499. K-I1 $\delta^{13}C = -25.7‰$

Coarse root fraction of K-I (for residual fine peat fraction, see Wk-500). *Comment:* diluted, 91% sample. (DJL): date is min for Waimihia Lapilli Member of Waimihia Fm.

3040 ± 50

Wk-500. K-I2 $\delta^{13}C = -26.4‰$

Residual fine peat fraction of K-I (for coarse root fraction, see Wk-499). *Comment* (DJL): date is min for Waimihia Lapilli Member of Waimihia Fm. Similarity of date to Wk-499 indicates that material is probably autochthonous.

3250 ± 70

Wk-498. K-H $\delta^{13}C = -26.4‰$

Bulk peat. *Comment:* diluted, 71% sample. (DJL): date is max for Waimihia Lapilli Member of Waimihia Fm.

4490 ± 60

Wk-496. K-G $\delta^{13}C = -26.9‰$

Bulk peat. *Comment* (DJL): sample bridges two tephras; date is max for Hinemaiaia Tephra Fm (definition of Froggatt, 1981a; Lowe, 1986a) and min for Whakatane Ash Fm.

4530 ± 60

Wk-497. K-Gg $\delta^{13}C = -26.4‰$

Bulk peat from site 2, 10m S of site 1. *Comment* (DJL): date is max for Hinemaiaia Tephra Fm (definition of Froggatt, 1981a; Lowe 1986a) and min for Whakatane Ash Fm.

4860 ± 70

Wk-501. K-J $\delta^{13}C = -26.4‰$

Bulk peat from site 2, 10m S of site 1. *Comment:* diluted, 73% sample. (DJL): date is max for Whakatane Ash Fm.

5440 ± 170

Wk-493. K-F1 $\delta^{13}C = -25.8‰$

Coarse root fraction of K-F (for residual fine peat fraction, see Wk-494). *Comment:* diluted, 23% sample. (DJL): date is min for Rotoma Ash Fm; significantly younger than Wk-494, suggesting natural contamination of peat overlying tephra. Thus, date is unreliable for eruption of Rotoma Ash.

7380 ± 80

Wk-494. K-F2 $\delta^{13}C = -26.8‰$

Residual fine peat fraction of K-F (for coarse root fraction, see Wk-493). *Comment* (DJL): date is min for Rotoma Ash Fm; nearer previous dates on this tephra but still appears anomalously young. See comment for Wk-523.

7560 ± 100

Wk-495. K-Ff $\delta^{13}C = -26.2‰$

Bulk peat from site 2, 10m S of site 1. *Comment:* diluted, 57% sample. (DJL): date is min for Rotoma Ash Fm; may be anomalously young for eruption of this tephra. See comment for Wk-523.

Wk-492. K-E **8710 ± 80**
$\delta^{13}C = -26.7‰$

Bulk peat. *Comment* (DJL): date is min for Opepe Tephra Fm.

Wk-491. K-C **9560 ± 80**
$\delta^{13}C = -27.0‰$

Bulk peat. *Comment* (DJL): date is min for Poronui Tephra Fm. First date for this tephra (with Wk-351, -352).

Wk-351. K-B1 **10,160 ± 130**
$\delta^{13}C = -29.4‰$

Coarse root fraction of K-B (for residual fine peat fraction, see Wk-352). *Comment:* diluted, 61% sample. (DJL): date is max for Poronui Tephra Fm (see comment for Wk-491). Also gives close estimate of min age of Karapiti Tephra Fm (ca 10,100 BP), which is only a few cm below sample (see Figs 2 and 4). Date agrees with Wk-352; hence, likely to be reliable.

Wk-352. K-B2 **9960 ± 90**
$\delta^{13}C = -28.5‰$

Residual fine peat fraction of K-B (for coarse root fraction, see Wk-351). *Comment* (DJL): date is max for Poronui Tephra Fm (see comment for Wk-491) and est of min age of underlying Karapiti Tephra Fm (see comment for Wk-351).

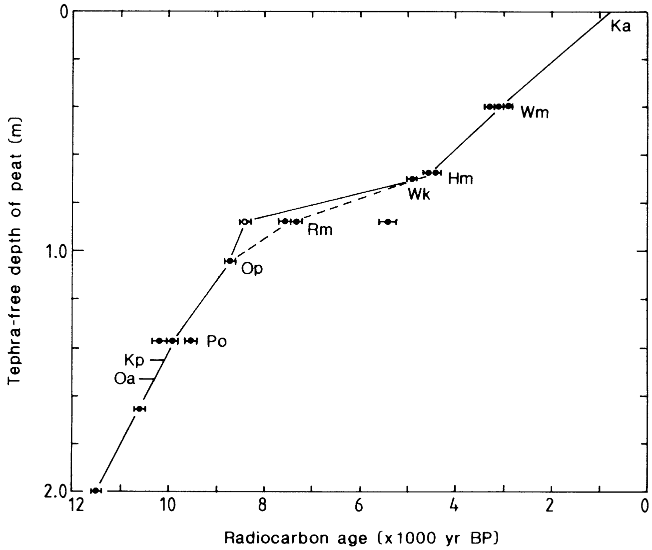

Fig 4. Peat accumulation rate curve for the Kaipo Lagoon Bog based on dates in the Kaipo Lagoon series (closed circles). Tephra abbreviations are given in Figure 2. The dates on Rotoma Ash (Rm) are considered anomalously young; hence, the preferred sedimentation rate curve (solid line) is drawn through the dates obtained on this tephra in the Lake Maratoto series (open circle, Wk-522, -523). After Lowe & Hogg (1986).

10,600 ± 90
Wk-263. K-A $\delta^{13}C = -29.6‰$

Bulk peat. *Comment* (DJL): date is max for lowermost tephra, probably member of Okupata Tephra Fm, at 2.3m depth in section.

11,500 ± 80
Wk-264. K-K $\delta^{13}C = -29.1‰$

Bulk peat. *Comment* (DJL): sample at 2.7m depth in section; date is max for inception of peat growth in Kaipo Lagoon.

General Comment (DJL): apart from three dates assoc with deposition of Rotoma Ash (Wk-493 to -495), which are considered anomalously young, dates on other tephras generally accord with previous determinations (Lowe & Hogg, 1986). Difference between Wk-493 (coarse root fraction) and -494 (residual fine peat) suggests that where contamination is suspected in bogs, fine peat fractions may produce more reliable dates than roots or bulk samples. Plot of peat accumulation rates (Fig 4) for Kaipo Lagoon bog shows slow rates overall (average 0.19mm/yr). However, average rate between ca 11,500 and ca 8700 BP was 0.37mm/yr but from ca 8700 BP to bog surface (ca 700 BP) was much slower 0.13mm/yr. Lowe & Hogg (1986) suggest that this pattern may relate to climatic change, but that variations in local conditions could also have been important influences.

Moanatuatua Bog series

Samples of peat and wood fragments coll by Russian/Jowsey peat sampler from Moanatuatua Peat Bog at Muir Rd near Ohaupo in Hamilton Basin (37° 57′ S, 175° 22′ E) (S15/180581). Coll 1982 by D J Lowe, R S P Lane, and A G Hogg and subm by D J Lowe and A G Hogg. Moanatuatua Bog is oligotrophic, high moor, restiad bog with mesotrophic margins, up to ca 12m thick, and covers ca 85km^2 (Davoren, 1978).

5850 ± 70
Wk-562. Muir-137 & 139 $\delta^{13}C = -27.7‰$

Comment (DJL): sample between two tephra layers; date is min for uncorrelated tephra (Mamaku Ash Fm?) at ca 6.2m depth and approx max for uncorrelated tephra at ca 6.0m depth.

10,650 ± 140
Wk-561. Muir-150 & 151 $\delta^{13}C = -28.0‰$

Comment (DJL): sample bridges two tephra layers; date is max for uncorrelated tephra at ca 9.3m depth, min for uncorrelated tephra at ca 9.4m depth. Base of bog at ca 10.8m.

12,800 ± 110
Wk-531. Muir-168 & 170 $\delta^{13}C = -27.4‰$

Comment (DJL): sample straddles tephra layer tentatively identified as Waiohau Ash Fm at ca 10.7m depth; date is average (see comment for Wk-233). Base of bog at ca 10.9m.

12,950 ± 110

Wk-530. Muir-48 $\delta^{13}C = -28.0‰$

Comment (DJL): sample overlies tephra, probably Rotorua Ash Fm, at ca 10.9m depth; date is min. Base of bog at ca 11.0m.

13,300 ± 110

Wk-529. Muir-50 $\delta^{13}C = -28.6‰$

Comment (DJL): sample comprises muddy peat and underlies tephra, probably Rotorua Ash Fm, at ca 10.9m; date is max. Also dates start of peat growth at this site (base of bog at ca 11.0m). See also Wk-116 (Waikato Swamp series).

General Comment (DJL): first dates on tephras in bogs in Hamilton Basin. Dates also indicate that average rate of peat growth of Moanatuatua bog at this site has been ca 1mm/yr (growth rate may not have been uniform, however).

Hauraki Plains series

Peat cored from Kopuatai Peat Dome of Hauraki Plains Swamp, Hauraki Plains (37° 25′ S, 175° 34′ E) at three sites. Coll 1977–1980 by A G Hogg, D J Lowe, and L Gaylor and subm by A G Hogg. Kopuatai Dome is largest raised (domed) bog in natural condition left in New Zealand (Irving, Skinner & Thompson, 1984). Hauraki Plains Swamp is oligotrophic, high moor restiad bog covering ca 240km^2 and is up to ca 12m thick (Davoren, 1978).

6280 ± 70

Wk-106. HP2 $\delta^{13}C = -27.6‰$

Coll 1977 from 6.0 to 6.3m below surface of bog at T13/377162. *Comment:* diluted, 84% sample. (AGH): date is max for Tuhua Tephra Fm.

6070 ± 80

Wk-241. HP3 $\delta^{13}C = -28.0‰$

Coll 1980 from 5.9m below surface of bog at T13/373190. *Comment:* diluted, 79% sample. (AGH): date is min for Tuhua Tephra Fm.

6440 ± 80

Wk-242. HP4 $\delta^{13}C = -28.2‰$

Coll 1980 from 6.0m below surface of bog at T13/373190. *Comment:* diluted, 87% sample. (AGH): date is max for Tuhua Tephra Fm.

6060 ± 80

Wk-244. HP5 $\delta^{13}C = -27.3‰$

Coll 1980 from 5.9m below surface of bog at T13/366188. *Comment* (AGH): date is min for Tuhua Tephra Fm.

6710 ± 80

Wk-243. HP6 $\delta^{13}C = -27.9‰$

Coll 1980 from 6.0m below surface of bog at T13/366188. *Comment* (AGH): date is max for Tuhua Tephra Fm; probably overestimates age of eruption because of excessive sample size.

9360 ± 100

Wk-102. HP1 $\delta^{13}C = -27.6‰$

Coll 1977 from base of Hauraki bog (9.7 to 10.0m depth) at T13/377162. *Comment* (AGH): marks initial formation of bog at this site.

General Comment (DJL): dates agree with that for Tuhua Tephra at Lake Maratoto (Lowe *et al,* 1980; Hogg & McCraw, 1983). Dates indicate average growth rate for bog has been ca 1mm/yr.

Te Rangaakapua series

Peat coll from pit dug into subalpine bog containing tephra beds at Te Rangaakapua, Urewera National Park (38° 31′ S, 177° 12′ E) (W17/765894). Coll 1984 by W B Shaw and subm by W B Shaw and D J Lowe, School Sci, Univ Waikato. Each sample ca 4cm thick and separated from overlying and underlying tephra layers by ca 2 to 3cm of peat, *ie,* not immediately adjacent to either tephra.

3660 ± 70

Wk-610. TR1 $\delta^{13}C = -25.4‰$

Comment: diluted 72% sample. (DJL): date is max limit for overlying Waimihia Lapilli Member of Waimihia Fm, and min limit for underlying Whakatane Ash Fm.

5510 ± 70

Wk-611. TR2 $\delta^{13}C = -26.0‰$

Comment: diluted, 80% sample. (DJL): date is max limit for overlying Whakatane Ash Fm and min for underlying Rotoma Ash Fm.

General Comment (DJL): dates are broadly consistent with previous results for these tephras (Lowe & Hogg, 1986; Lowe, 1986a), given position of samples with respect to tephras.

8560 ± 80

Wk-612. Mata-2/132-138 $\delta^{13}C = -25.5‰$

Peat cored with motorized Giddings auger from shallow peat bog at end of Pohlen Rd, Matamata (37° 47′ S, 175° 47′ E) (T14/562762). Coll 1984 by D J Lowe and M McLeod, and subm by D J Lowe. *Comment* (DJL): date is min for Mamaku Ash Fm (?) (possibly reworked); dates inception of peat growth at this site.

1920 ± 110

Wk-425. Rotokare-1 $\delta^{13}C = -31.6‰$

Grayish lake sediment cored from Lake Rotokare, near Eltham, Taranaki (39° 27′ S, 174° 24′ E) (V17/219904). Coll 1980 by C H Hendy and subm by D J Lowe and C H Hendy. *Comment:* diluted, 26% sample. (DJL): date is min for andesitic tephra at ca 1.3m depth (tentatively correlated with Mangatawai Tephra (?) of Topping, 1973 or Kaupokonui tephra (?) of Neall & Geddes, 1981); estimates rate of sedimentation in lake (ca 1.5mm/yr); date is min for fm of lake (base of lake sediments not seen).

2. *Dates Associated with Deposition of Alluvium of Hinuera Formation*

Motumaoho series

Logs and peat from exposure on Hamilton to Morrinsville Rd (SH 26), 100m S of junction with Harbottle Rd (37° 42′ S, 175° 29′ E). Coll 1975 and subm by H S Gibbs, Earth Sci Dept, Univ Waikato. Samples occur either within or overlying Hinuera Fm sediments at three sites (A, C, F). Peat 1 layer, 300 to 330cm below surface; peat 2 layer, 50cm below peat 1 layer, *ie,* 380cm below surface. See also Harbottle Rd series.

16,630 ± 670
Wk-65. A/2 *Est* $\delta^{13}C = -25‰$

Peat in Hinuera sediments, upper 8cm of peat 1 layer, at site A, S14/276860. *Comment:* diluted, 69% sample.

16,600 ± 750
Wk-66. A/3 *Est* $\delta^{13}C = -25‰$

Peat in Hinuera sediments, 8 to 15cm of peat 1 layer, at site A, S14/276860. *Comment:* diluted, 72% sample.

15,400 ± 1200
Wk-67. A/4 *Est* $\delta^{13}C = -25‰$

Peat in Hinuera sediments, 20 to 30cm of peat 1 layer, at site A, S14/276860. *Comment:* diluted, 39% sample.

16,710 ± 480
Wk-70. C/2 *Est* $\delta^{13}C = -25‰$

Peat in Hinuera sediments, peat 1 layer, at site C, S14/275860, 50m W of site A.

17,050 ± 540
Wk-74. Site F/1 *Est* $\delta^{13}C = -25‰$

Log in peat layer 2 at site F, S14/276861, 70m NNW of site A.

General Comment (HSG): dates are in broad agreement with each other and are approx for last period of deposition of Hinuera-2 sediments by ancestral Waikato R in Morrinsville Gap.

Te Rapa series

Peat from Eastern Sanitary Interceptor, Te Rapa, Hamilton (37° 44′ S, 175° 15′ E) (S14/081826). Coll 1975 by C S Nelson and D Cope and subm by C S Nelson, Earth Sci Dept, Univ Waikato.

39,900 $^{+3300}_{-2400}$
Wk-37. CSN-1 *Est* $\delta^{13}C = -25‰$

Bore 2, 30m below Waikato R level on W bank.

>40,000
Wk-38. CSN-2 *Est* $\delta^{13}C = -25‰$

Bore 6, 30m below Waikato R level of W bank, 10m from bore 2.

General Comment (CSN): first dates for Hinuera-1 alluvial deposits of Hinuera Fm in Hamilton Basin. Wk-37 also yielded preliminary U/Th age of <65,000 BP (C H Hendy *in* McGlone, Nelson & Hume, 1978).

Riverlea series

Carbonaceous mud and sand with occasional poorly preserved woody fragments from three carbonaceous strata within fluvial pumiceous silts, sands, and gravelly sands of Hinuera Fm at site opposite Riverlea Wreckers near Hamilton on Hamilton to Cambridge hwy (37° 49′ S, 175° 20′ E) (S14/162744). Coll 1981 and subm by C S Nelson.

18,250 ± 180
Wk-393. W3 *Est* $\delta^{13}C = -25‰$

Carbonaceous mud, 0.25m thick, 3.5 to 3.75m below Hinuera surface. *Comment* (CSN): dates closing period of active aggradation of Hinuera sedimentation in Hamilton Basin.

20,200 ± 210
Wk-392. W2 *Est* $\delta^{13}C = -25‰$

Carbonaceous pumice sands, 0.5m thick, 10.75 to 11.25m below Hinuera surface. *Comment* (CSN): dates active aggradation phase of Hinuera sedimentation in Hamilton Basin.

21,300 ± 240
Wk-391. W1 *Est* $\delta^{13}C = -25‰$

Woody, carbonaceous sands, ca 0.7m thick, ca 14.5 to 15m below Hinuera surface. *Comment* (CSN): dates active aggradation phase of Hinuera sediments in Hamilton Basin.

General Comment (DJL): dates accord with stratigraphy and generally agree with previous determinations on Hinuera-2 sedimentation in Hamilton Basin (McGlone, Nelson & Hume, 1978).

Waihou series

Peat occurring as lenses within pumiceous silts, sands, and gravels of Hinuera Fm, exposed either within rd cuttings and quarries or obtained from drill cores. Sampled at four sites near Matamata in Waihou R valley. Coll 1979 by A S Cuthbertson and subm by C S Nelson.

19,400 ± 200
Wk-216. C3 $\delta^{13}C = -28.2‰$

Peat ca 2.5m below ground surface from quarry near Matamata on Matamata to Tauranga hwy (37° 49′ S, 175° 45′ E) (T14/572716). *Comment* (ASC): upper age of Hinuera sedimentation in central S Hauraki Lowlands.

18,400 ± 200
Wk-217. C2 $\delta^{13}C = -26.8‰$

Peat within layer 6.2 to 7.0m below ground surface from rd cutting near Omahine Stream Bridge on Matamata to Tauranga hwy (37° 51′ S, 175′ 52′ E) (T15/628677). *Comment* (ASC): upper age of Hinuera sedimentation in central S Hauraki Lowlands.

23,900 ± 400
Wk-218. Bore 37 $\delta^{13}C = -25.9‰$

Peat lens, 0.8m thick, 28.1m below land surface, obtained from drill core in center of Matamata Township (37° 48′ S, 175° 46′ E) (T14/542732). *Comment* (ASC): lower age of Hinuera sedimentation in central S Hauraki Lowlands.

>40,000
Wk-274. S36 $\delta^{13}C = -27.6‰$

Peat lens, 2m thick, ca 20m below land surface, from section exposed along Waiomou Stream on Matamata to Tauranga hwy (37° 51′ S, 175° 53′ E) (T15/621680). *Comment* (ASC): date may represent boundary between Hinuera-1 and Hinuera-2 depositional periods.

General Comment (DJL): dates indicate period when ancestral Waikato R entered Hauraki (Matamata) basin (Cuthbertson, ms).

Lake Rotokaraka series

Lake sediment overlying or within sandy muds to muddy sands of Hinuera Fm obtained with piston corer from Lake Rotokaraka, Whitikahu, Hamilton Basin (37° 37′ S, 175° 20′ E) (S14/166965). Coll 1983 by D J Lowe, C H Hendy, and L J Gaylor and subm by D J Lowe.

13,800 ± 370
Wk-567. A/4-2.2 $\delta^{13}C = -26.6‰$

Comment: diluted, 24% sample. (DJL): sample 20cm thick at base of lake sediment. Dates fm of modern Lake Rotokaraka and last depositional event of Hinuera Fm at this site. Also estimates age for uncorrelated andesitic (?) tephra ca 15cm above base of lake sediment column. Date is younger than expected as Rerewhakaaitu Ash, ca 14,700 BP, occurs in lake sediment 1.5m above sample.

15,900 ± 630
Wk-568. A/4-2.8 $\delta^{13}C = -25.5‰$

Comment: diluted, 18% sample. (DJL): dates proto-Lake Rotokaraka that existed between last and 2nd to last depositional episodes of Hinuera Fm deposition at this site.

16,600 ± 260
Wk-569. A/4-3.7 $\delta^{13}C = -25.7‰$

Comment: diluted, 52% sample. (DJL): dates proto-Lake Rotokaraka that existed between 2nd to last and 3rd to last depositional episodes of Hinuera Fm at this site.

General Comment (DJL): establishes chronology for succession of Hinuera-2 depositional episodes at this site (see Lake Maratoto series and Green & Lowe, 1985).

17,500 ± 540
Wk-59. *Est* $\delta^{13}C = -25‰$

Sample from peat layer, 3 to 10cm thick, 5m below top of Hinuera Fm at Hamilton Refuse site, Rototuna, Hamilton (37° 44′ S, 175° 16′ E) (S14/102830). Coll 1974 by T M Hume and C S Nelson and subm by C S Nelson. *Comment* (CSN): near upper age on Hinuera Fm alluvial deposits (Hinuera-2) within Hamilton Basin at this site.

17,790 ± 290
Wk-169. $\delta^{13}C = -31.2‰$

Peat in layer approx in middle of Hinuera Fm silts and sands, total thickness 7.3 to 11.5m, forming highest of series of degradational terraces, at site 3km SE of Karapiro Hall, Karapiro (37° 56′ S, 175° 35′ E) (T15/370593). Coll 1978 and subm by H S Gibbs, Earth Sci Dept, Univ Waikato. *Comment* (HSG): dates time ancestral Waikato R broke through Karapiro Gorge.

15,700 ± 200
Wk-566. LA/1-2.6 $\delta^{13}C = -23.9‰$

Lake sediment, ca 5.5 to 5.7m below sediment surface, cored from Leeson's Pond, Tauhei to Motumaoho Rd, Hamilton Basin (37° 39′ S, 175° 28′ E) (S14/287929). Coll 1983 by D J Lowe and L Gaylor and subm by D J Lowe. *Comment:* diluted, 61% sample. (DJL): base of lake sediment not seen. Date is min for fm of Leeson's Pond and estimate of last deposition of Hinuera Fm sediments in this part of Hamilton Basin. Sedimentation rate for period between Wk-566 and Rerewhakaaitu Ash, ca 14,700 BP, at 4.5m depth is relatively fast (0.7mm/yr) compared with later rates (see General Comment for Lake Maratoto series).

17,600 ± 190
Wk-614. Rototuna-1 $\delta^{13}C = -26.5‰$

Peat with twigs underlying lake sediment, ca 6.6 to 6.8m below sediment surface, cored in drained "Rototuna lake," Lake Tunawhakapeka with motorized Giddings auger near Rototuna, Hamilton (37° 43′ S, 175° 17′ E) (S14/116853). Coll 1984 by D J Lowe and L Gaylor and subm by D J Lowe. *Comment:* diluted, 88% sample. (DJL): sample overlies gritty mud, Hinuera Fm. Dates fm of Lake Tunawhakapeka and is min age for deposition of Hinuera Fm at this site.

Waikare series

Carbonaceous mud and sand from drill cores at two sites (nos. 5, 13) in Ohinewai Peatland near Lake Waikare (37° 30′ S, 175° 12′ E). Coll 1979–1980 by A J Todd and subm by C S Nelson, Earth Sci Dept, Univ Waikato.

17,800 ± 200
Wk-280. P43 $\delta^{13}C = -28.3‰$

Sample from 10.9m depth at site 13 (S13/035109) in lacustrine mud. *Comments* (AJT): dates late Pleistocene mud underlying modern surface peats and unconformably overlying Pleistocene fluvial gravelly sands. (DJL): mud unit found in proto-Lake Waikare formed by deposition of Hinuera Fm sediments (McGlone, Nelson & Todd, 1984).

Wk-226. P42 **>40,000** $\delta^{13}C = -29.8‰$

Sample from 25.7m depth at site 5 (S13/039097) in coarse volcaniclastic sands, alluvium, in either Karapiro or Puketoka Fm that antedate Hinuera Fm sediments. *Comments* (AJT): dates Quaternary fluvial sequence in Lower Waikato Basin. (DJL): date is max for Hinuera Fm deposition at this site (McGlone, Nelson & Todd, 1984). See also Ohinewai Peatlands series.

Pukerimu series

Peat and peaty mud in section through terrace at ca 40m asl, ca 10m above Waikato R, Pukerimu Lane, off Cambridge to Ohaupo Rd, Pukerimu dist (37° 54′ S, 175° 26′ E) (S15/241642). Higher terrace, at ca 60m asl, forms main Hinuera Surface. Coll 1985 by D J Lowe and M Lowe and subm by D J Lowe.

Wk-726. Pukerimu-4 **22,900 ± 350** $\delta^{13}C = -25.7‰$

Carbonaceous mud, gyttja-like, at top of layer, ca 0.6m thick, ca 2.2m below terrace surface. Layer underlies gravelly sand, Hinuera Fm, and overlies sticky blue clay, overbank flood deposit (?), Hinuera Fm. *Comment:* diluted, 82% sample. (DJL): date is max for latest episode of Hinuera-2 sedimentation, overlying deposits, in Hamilton Basin.

Wk-725. Pukerimu-3 **22,700 ± 290** $\delta^{13}C = -27.0‰$

Carbonaceous mud, gyttja-like, at base of layer, ca 0.6m thick, ca 2.8m below terrace surface (see Wk-726). *Comment* (DJL): date supports Wk-726.

Wk-724. Pukerimu-2 **>40,000** *Est* $\delta^{13}C = -25‰$

Peaty pumiceous mud layer, ca 0.2m thick, at ca 3.8m depth below terrace surface. Overlain by sticky blue clay, underlain by cross-bedded pumiceous sands and gravelly muds of Hinuera Fm. *Comment:* diluted, 25% sample. (DJL): date indicates that underlying sediments represent Hinuera-1, or earlier, deposits through which Waikato R has re-entrenched.

Wk-723. Pukerimu-1 **>40,000** *Est* $\delta^{13}C = -25‰$

Peat with small wood fragments at base of peat layer, ca 1m thick, ca 7.5m below terrace surface, at rd level. Peat layer underlies sands and muds of Hinuera Fm and overlies bluish ignimbrite, gleyed Puketoka Fm (?). *Comment* (DJL): date suggests that overlying sediments up to Wk-725, -726 represent Hinuera-1 deposits, in agreement with Wk-724.

General Comment (DJL): dates agree with stratigraphy. Wk-723 and -724 add to two previous dates on Hinuera-1 sediments in Hamilton Basin (see Te Rapa series). Wk-725 and -726 indicate that overlying sediments in this terrace, and higher terrace at 60m asl, represent Hinuera-2 sedimentation (McGlone, Nelson & Hume, 1978). Thus, section apparently shows contact between Hinuera-1 and Hinuera-2 sediments, first such subaerial exposure known in Hamilton Basin.

3. *Dates Associated with Peat Bog Growth or Local Sedimentation that Postdates Deposition of Hinuera Fm, ie, <ca 15,000* BP

Lake Hakanoa series

Wood or organic lake sediment coll by piston corer from Lake Hakanoa, Huntly (37° 33′ S, 175° 10′ E) (S13/018033). Coll 1982 (Hak-1) and 1984 (HK 1-3) and subm by B McCabe, D J Lowe, and C H Hendy. Hk 1-3 samples, coll by BMcC, date silt band within organic sediment column and Hak-1, coll by DJL, BMcC & CHH, is derived from base of column.

750 ± 50
Wk-608. HK-3 $\delta^{13}C = -29.0‰$

Lake sediment overlying silt layer. *Comment:* diluted, 75% sample.

1020 ± 50
Wk-607. HK-2 $\delta^{13}C = -31.0‰$

Lake sediment from within silt layer. *Comment:* diluted, 82% sample.

1240 ± 60
Wk-606. HK-1 $\delta^{13}C = -32.3‰$

Lake sediment underlying silt layer. *Comment:* diluted, 55% sample.

General Comments (BMcC): dates deposition of silt band that accompanied deforestation in catchment surrounding Lake Hakanoa and change in $\delta^{13}C$ of lake sediment. (DJL): postulated deforestation may relate to natural events or to Polynesian cultural influence (*cf* McGlone, 1983). Polynesians inhabited many sites adjacent to such lakes in Waikato district in last millenium (Pick, 1968; Shawcross, 1968; Bellwood, 1978; Lowe *et al,* 1984).

2040 ± 50
Wk-424. Hak-1 $\delta^{13}C = -26.9‰$

Wood (kauri?) within gritty muds overlain by ca 1m of Taupo Pumice Alluvium and ca 0.9m of lake sediments. *Comment* (DJL): date is approx for deposition of Taupo Pumice Alluvium; dates fm of Lake Hakanoa (Lowe & Green, 1987). Average sedimentation rate in lake, ca 2mm/yr, is ca 10 times faster than average rate in Hinuera-dammed lakes (see General Comment for Lake Maratoto series).

Pukekapia series

Peat from drained swamp E of Pukekapia Rd near Lake Rotongaro, Huntly Dist (37° 30′ S, 175° 8′ E) (S13/982089). Coll 1974 and subm by H S Gibbs. Peat is ca 2.4m thick and overlies silty base.

3760 ± 110

Wk-61. S4 *Est* $\delta^{13}C = -25‰$

Sample from 2.07 to 2.17m below peat surface.

4040 ± 120

Wk-60. S2 *Est* $\delta^{13}C = -25‰$

Sample from 2.27 to 2.34m below peat surface.

General Comment (HSG): date is approx for commencement of peat fm at this site (see also Ohinewai Peatlands series and McGlone, Nelson & Todd, 1984).

Ohinewai Peatlands series

Peat from drill cores at two sites (nos. 5, 9) in Ohinewai Peatland, near Ohinewai (37° 30′ S, 175° 12′ E). Coll 1981 by A J Todd and subm by C S Nelson. Ohinewai Peatlands are near Lake Waikare, cover 15km^2, and are mesotrophic with some oligotrophic characteristics (Davoren, 1978). Peat has average thickness of 6 to 9m, max 11.5m, and overlies lacustrine mud deposited in proto-Lake Waikare (McGlone, Nelson & Todd, 1984).

2310 ± 60

Wk-356. P87 $\delta^{13}C = -29.3‰$

Sample from 0.4m depth at site 9 (S13/044100). *Comment* (AJT): date is min for surface peat fm in Lower Waikato Basin.

3290 ± 60

Wk-359. P88 $\delta^{13}C = -27.9‰$

Sample from 3.4m depth at site 9 (S13/044100). *Comment* (AJT): improves age definition of surface peat in Lower Waikato Basin.

5820 ± 60

Wk-281. P86 $\delta^{13}C = -27.7‰$

Sample from 6.5m depth at site 9 (S13/044100). Base of peat at 6.9m. *Comment* (AJT): dates base of surface peat of Lower Waikato Basin.

4950 ± 70

Wk-224. P40 $\delta^{13}C = -28.3‰$

Sample from 1.2m depth at site 5 (S13/039097). *Comment* (AJT): provides peat accumulation rate in Ohinewai bog, Lower Waikato Basin.

7100 ± 80

Wk-225. P41 $\delta^{13}C = -29.1‰$

Sample from 4.1m depth at site 5 (S13/039097). *Comment* (AJT): provides peat accumulation rate in Ohinewai bog, Lower Waikato Basin.

General Comment (DJL): dates provide chronology for palynologic study by McGlone, Nelson & Todd (1984). See also Waikare series.

Harbottle Road series

Tree stumps in silty sands overlying peat layers on Hinuera Fm sediments in exposure on Hamilton to Morrinsville Rd, SH 26, at two sites, B, F

(37° 42′ S, 175° 27′ E) (see Motumaoho series for additional stratigraphic details). Coll 1975 and subm by H S Gibbs.

6410 ± 290

Wk-68. B/1 *Est* $\delta^{13}C = -25‰$

Tree stump in silty sand 170cm below terrain surface and 130cm above peat layer 1, at site B (S14/276860), 8m W of site A. *Comment:* diluted, 49% sample.

7000 ± 170

Wk-73. E/1 *Est* $\delta^{13}C = -25‰$

Tree stump in silty sand at 300cm depth and lying above peat layer 1, at site E (S14/276861), 70m N of site A.

General Comment (HSG): dates are much younger than dates on underlying peat and wood assoc with Hinuera Fm sediments (see Motumaoho series); this suggests that silty sands are locally reworked deposits rather than from ancestral Waikato R.

Waikato Swamps series

Basal peat or wood cored with Hiller corer from Rukuhia and Moanatuatua Peat Swamps, near Hamilton (Fig 1). Wk-114 to -116 coll 1977 by A T Wilson and K Thompson and subm by A T Wilson, Chemistry Dept, Univ Waikato; other samples coll 1982–1983 as noted. Rukuhia bog, like Moanatuatua (see Moanatuatua series) is ombrogenous oligotrophic high moor bog with mesotrophic fringes, up to 12m thick, and covers ca 64km^2 (Davoren, 1978).

10,250 ± 90

Wk-114. *Est* $\delta^{13}C = -25‰$

Peat from base of Rukuhia bog, 8.3m depth (37° 54′ S, 175° 18′ E) (S15/076694).

10,750 ± 90

Wk-115. $\delta^{13}C = -28.4‰$

Peat from base of Rukuhia bog, 9m depth (37° 54′S, 175° 18′ E) (S15/119691).

11,800 ± 120

Wk-116. Moana #1 $\delta^{13}C = -28.6‰$

Peat from base of Moanatuatua bog, 10m depth (37° 57′ S, 175° 22′ E) (S15/187608). See also Wk-529, Moanatuatua bog series.

General Comment (ATW): dates are max for peat fm at these sites.

10,600 ± 90

Wk-553. GC1-1(RJ) $\delta^{13}C = -28.5‰$

Basal peat cored by Russian/Jowsey corer from 7.5m below surface of Rukuhia peat bog 400m W of Lake Maratoto, near Hamilton (37° 54′ S, 175° 18′ E) (S15/123660). Coll 1983 by D J Lowe and L Gaylor and subm by D J Lowe. *Comment* (DJL): dates start of peat growth at this site.

12,550 ± 110
Wk-508. GC3-2 $\delta^{13}C = -25.9‰$

Rimu root wood (*Dacrydium cupressinum;* L Donaldson, pers commun, 1983) embedded in upper part of late Pleistocene colluvium underlying peat in arm of Rukuhia bog at N end of Lake Maratoto, near Hamilton (37° 54′ S, 175° 19′ E) (S15/663130). Wood at ca 6m below peat surface, ca 0.8m below base of peat, 5.2m depth, and sampled with motorized Giddings auger. Coll 1983 by D J Lowe, J D Green, and L Gaylor and subm by D J Lowe. *Comment* (DJL): gives approx age when growth of Rukuhia peat overwhelmed rimu tree, *in situ*?, at this site (Lowe, 1985).

15,200 ± 130
Wk-534. RJ1-4 $\delta^{13}C = -27.7‰$

Basal woody peat overlying Hinuera Fm sediments cored by Russian/Jowsey corer from 7.2m below surface of Rukuhia peat bog on SW shoreline of Lake Maratoto, near Hamilton (37° 54′ S, 175° 19′ E) (S15/126657). Coll 1983 by D J Lowe, J D Green, M A Chapman, and T G Northcote and subm by D J Lowe. *Comment* (DJL): dates initial development of marginal peat around Lake Maratoto shoreline soon after fm of lake basin by deposition of Hinuera Fm (see Lake Maratoto series). Such growth may indicate that effective rainfall increased at this time (Green & Lowe, 1985).

General Comment (DJL): most of dates indicate that major parts of Rukuhia and Moanatuatua bogs developed after ca 10,000 to 12,000 BP, possibly in response to climatic change with marked increase in net precipitation. Somewhat earlier date of ca 15,000 BP (Wk-534) is interpreted as initial localized peat growth near Lake Maratoto that later spread outwards and contributed to development of main body of Rukuhia bog (Green & Lowe, 1985; see also McGlone, Nelson & Hume, 1978). Dates indicate that main body of Rukuhia bog has had average growth rate ca 1.2 to 1.4mm/yr.

(98.6 ± 1.3)% modern
Wk-426. Purimu-2/1 $D^{14}C = -13.7 \pm 13.1‰$ $\delta^{13}C = -28.0‰$

Peaty lake sediment 0.9m below lake sediment surface cored from Lake Purimu, near Waipukurau, Hawkes Bay (40° 08′ S, 176° 29′ E) (Q14/464718). Coll 1980 by C H Hendy and subm by D J Lowe and C H Hendy. *Comment:* diluted, 19% sample. (DJL): catchment contains calcareous rocks hence "hard-water effect" may apply. Gives est rates of sedimentation in Lake Purimu and min age of lake fm; base of lake sediments not seen.

2620 ± 90
Wk-842. Maungarataiti-1 $\delta^{13}C = -27.6‰$

Woody lake sediment ca 2.9m below lake sediment surface cored from Lake Maungarataiti, near Hunterville, ca 50km E of Wanganui (39° 54′ S, 175° 31′ E) (S15/282431). Coll 1986 by C H Hendy and subm by D J Lowe and C H Hendy. *Comment:* diluted, 47% sample. (DJL): region contains calcareous sediments hence "hard-water effect" may apply. Gives est rates of sedimentation in Lake Maungaratatiti and min age of lake fm; base of lake sediments not seen but presence of wood suggests that it might be close (Lowe & Green, 1987).

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[RADIOCARBON, VOL 29, No. 2, 1987, P 303–306]

NOTES AND COMMENTS

PREPARATION OF SMALL SAMPLES FOR ^{14}C ACCELERATOR TARGETS BY CATALYTIC REDUCTION OF CO

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Graphite in various forms has become the standard target for accelerator ^{14}C dating. Graphite has been made by catalytic graphitization of charcoals (Lowe, 1984). Thin films of graphite have also been produced by thermal cracking (Beukens & Lee, 1981), electric discharge (Andrée *et al,* 1984; Wand, Gillespie & Hedges, 1984). Vogel *et al* (1984) pointed out the ease of graphite formation on iron from CO_2 and H_2 mixtures at ca 600°C. The deposition reactions of carbon from the CO, H_2, and CO_2 equilibria are well known (Wagman *et al,* 1945) and well studied. Formation of graphite from CO_2 was discussed extensively by Boudouard (1902) and Schenck and Zimmerman (1903), and was known to chemists in France in 1851. We have used a related method, where graphite forms away from the iron, by using a higher temperature, and reduction of CO_2 to CO over Zn in the presence of H_2 (Jull *et al,* 1986) as an alternative to the use of Fe alone. The object of this paper is to point out an even simpler graphite preparation system, which eliminates hydrogen. The decomposition reaction of CO (Boudouard, 1902) takes place according to reaction (1).

$$2CO \rightleftarrows CO_2 + C\ (gr) \tag{1}$$

If carbon is introduced as CO_2, and is reduced to CO by hot Zn and any CO_2 formed due to reaction (1) is reduced to CO by the hot Zn, then the reaction proceeds in one direction. This method uses a small-volume system, which can be of any size but is typically 5 to 10cc. Using a 5cc system, reduction of CO samples of as small as 0.7cc has been achieved. The apparatus is shown in Figure 1. As mentioned, two reactions occur in the system. CO_2 is reduced to CO over ~30mg Zn at ca 500°C, and the CO disproportionates to graphite over the iron (~1mg) at typically 700°C. Deposition occurs at temperatures as low as 450°C. The graphite is separate from the iron, suggesting a vapor-phase intermediate.

The gas pressure is monitored, and 100% reaction is easily observable, as we wait until the gas pressure is zero. This takes from 2 to 10 hours, depending on several factors. It is clear that the reaction is pressure- and temperature-dependent; however, variations in reaction rate appear to be complex, and apparently dependent on the catalyst. The amount of Fe catalyst used can be very small (<1mg) without measurable effect on the reac-

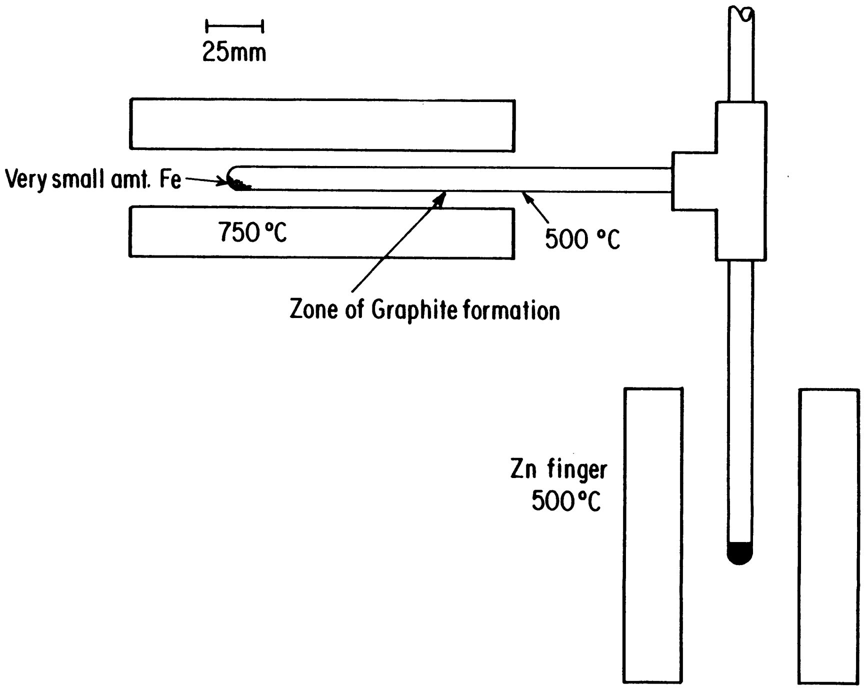

Fig 1. Diagram of small reduction line for graphite production. The horizontal tube contains 1mg iron catalyst; the vertical tube, 30–60mg zinc.

tion rate. In general, pressures approaching one atmosphere result in a complete reaction in 2 to 4 hours. We have also experimented with a small, sealed tube reduction at the University of California, Riverside, using Fe and Zn in the same tube. The graphite produced appears to be equivalent to the graphites made in the above apparatus (Slota & Taylor, 1986).

The graphite powder is collected, weighed, and ca ~1mg (if available) is pressed into a standard target holder for accelerator ^{14}C analysis. A diagram of the press arrangement is shown in Figure 2. Samples as small as 0.3mg have been successfully analyzed. A series of pressed graphites from this procedure have been studied for $^{12}C^-$ beam current. Results of an initial series of 45 targets gave a mean current of 4.2μA, lower than observed previously (7μA) by Jull *et al* (1986). However, modification of the press arrangement to incorporate an Al plug behind the graphite lead to better pressure transfer to the graphite. C^- currents are now ca 10μA. Blanks are 0.35 ± 0.15% modern C, giving a 2σ age limit of >46,000 yr BP.

X-ray diffraction, $^{12}C^-$, and isotopic fractionation data show that the CO-produced graphite has similar characteristics to graphite produced from CO/H_2 mixtures (Jull *et al*, 1986). ^{14}C dates run using these graphites have produced precisions of better than ±1% in $^{14}C/^{13}C$ ratio (in 50 min measuring time), and our best data are now approaching ±50 ^{14}C years. We plan to report more fully on our techniques and on accuracy and precision

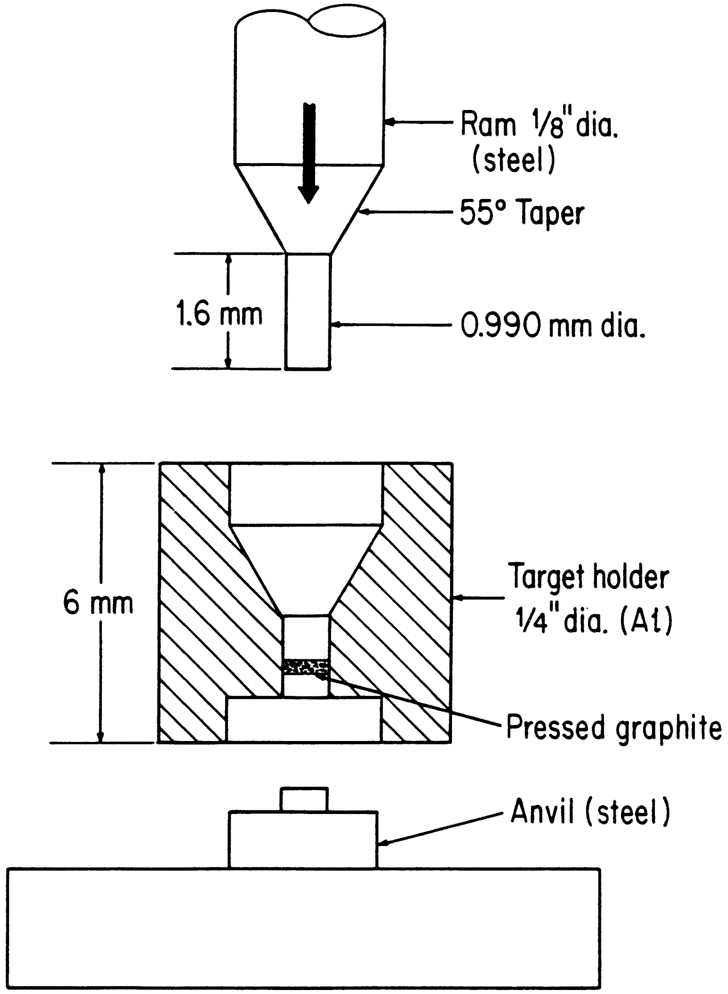

Fig 2. Target press arrangement

in the near future; the purpose of this note is to point out an extremely simple graphite preparation method without the need for hydrogen as a reducing agent.

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[Radiocarbon, Vol 29, No. 2, 1987, P 307-308]

DISCUSSION

THE QUESTION OF DIFFUSE SECONDARY GROWTH OF PALM TREES: A COMMENT

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In a recent paper (Wiesberg & Linick, 1983), the authors investigated the $\Delta^{14}C$ levels in the stem of a coconut palm (*Cocos nucifera* L) to determine whether diffuse secondary growth occurred. The authors concluded that "there was no diffuse secondary growth over the entire mature stem during the last 25 years of growth, with the exception of a restricted zone in the center at medium height," though they did not define what they meant by a "mature" stem.

The palm was apparently planted ca 1860, and had developed a conical basal part up to ca 2m height, a virtually cylindrical part up to ca 13m, and a conical part above this. The authors assumed a constant rate of height growth, though this was not critical for their analysis. Samples were taken from the center and the periphery of the stem at various heights between 2.5m and 17.5m, from which the "wood" fraction was extracted for $\Delta^{14}C$ determination. Up to a height of 12.4m the $\Delta^{14}C$ levels were fairly constant, mostly between -20 and $+20$ $\Delta^{14}C$‰, and the levels then rose sharply, reaching $+420$ $\Delta^{14}C$‰. in the top sample. The $\Delta^{14}C$ levels were slightly higher in the samples from the center of the stem, at least in the upper parts of the stem. The pattern of $\Delta^{14}C$ levels up the stem was interpreted as showing a gradual rise in $\Delta^{14}C$, in accordance with the prevailing atmospheric $\Delta^{14}C$ levels since 1860, up to a height of ca 15m, above which the rise in $\Delta^{14}C$ was attributed to the bomb effect following nuclear weapons testing since 1955.

Unfortunately, the authors did not attempt to obtain precise dates for the formation of the stem at various heights, though it has been observed that coconut stems can be dated reasonably accurately from the number of leaf scars and by applying a growth rate of ca 12 leaves y^{-1} (Corner, 1966; Child, 1974). The height growth of stems changes markedly during the life of the palm (Child, 1974).

It is, therefore, uncertain whether the observed dramatic rise in $\Delta^{14}C$ levels above 15m height is simply recording the contemporary changes in atmospheric $\Delta^{14}C$, or whether there has been transport of more recent carbon to lower parts of the stem which may have undergone secondary thickening. Without accurate dating at particular heights, the results of this study are ambiguous and cannot be taken as a refutation of the hypothesis that secondary thickening is occurring in the upper part of the stem.

In their introduction (p 806), the authors state "an ideally cylindrical growth is almost proof of the absence of secondary growth; unfortunately, the opposite does not hold true." It is not clear from the description of the coconut stem whether this was entirely conical or partly cylindrical and, therefore, where secondary growth might be present. In one place (p 807) the authors state that "Despite the fact that the stem was *not cylindrical,* there was no pronounced secondary growth over most parts of the stem," while they later state that (p 808) "It is worth noticing that the high activity is coincident with the upper limit of the *cylindrical* part of the stem and the bottom of the conical part." It seems probable that if there was any secondary growth, this should cease at the transition from the conical to the cylindrical part of the stem.

The conical base of the stem was not investigated though this is evidently a possible zone for secondary growth. Waterhouse and Quinn (1978) showed that the basal cone of the stem of *Archontophoenix cunninghamiana* (Wendl) Wendl et Drude underwent sustained diameter growth.

While it is clear that ^{14}C determinations may help to solve such problems as secondary growth in palms, it is apparent that in this study there was insufficient information to reject the hypothesis.

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[RADIOCARBON, VOL 29, NO. 2, 1987, P 309–310]

REPLY

L H G WEISBERG and T W LINICK

It is difficult to understand the criticism expressed by Julian Ash because our findings do not depend so much on precise dates for the formation of the stem. He gives no argument why our statement that "there was no diffuse secondary growth over the entire mature stem during the last 25 years of growth, with the exception of a restricted zone in the center at medium height" may be wrong.

The rise in ^{14}C above 15m and the almost complete absence of excess ^{14}C below that height are so drastic that it seems justified to maintain our original conclusion.

Ash questions "whether the observed dramatic rise in $\Delta^{14}C$ levels above 15m height is simply recording the contemporary changes in atmospheric $\Delta^{14}C$, or whether there has been transport of more recent carbon to lower parts of the stem which may have undergone secondary thickening."

The main problem seems to be the term "secondary thickening" which should not be applied to growth of cells which originate from the primary apical meristem.

Surely, the formation of new wood in palms may last some years until it becomes mature. The terms "mature" and "immature" are open for discussion, but may be defined easily by means of the incorporation or not of recent photosynthetic products as traced, eg, by radiocarbon. As we found a sharp limit of enhanced ^{14}C activity, which proves the viability of this definition, all growth of the stem has to be considered primary in nature. In a group of palms the maturation is a long-lasting process; according to Waterhouse and Quinn (1978) it should be termed, "sustained primary growth."

It is unrealistic and contradictory to experience to paint a picture in which the palm ceased to grow in height, say 20 years before it was cut, but continued to grow in width. A palm that stops growing taller is already dying—the normal flowering and fructification implies the formation of new axillary buds and, thus, new leaves and wood.

We have no clear indication of the time span of formation of the wood in *Cocos nucifera,* but we expect a figure of about five years, coinciding more or less with the mean life of an individual leaf (Child, 1974); the bulk of the tissue should form, however, in a much shorter interval.

The main doubt about diffuse secondary growth still originates from the high ^{14}C activity found at 9.4m which shows that there is the possibility of incorporation of new photosynthates into old tissue. We suggested that "it may be that the stem undergoes at a certain age a distinct modification in the center, only then assuming its final state. This zone may be correlated with the formation of the hard peripheral sclerotic zone composed of congested, dark vascular bundles and ground parenchymatic tissue." If so, then the old trunk at any height may be a mixture of photosynthates of different ages. But we want to point out that there is another possibility to explain the high activity at 9.4m. Higher up in the trunk there were injuries caused by insects and the high ^{14}C level may be due to a response of the plant in order to re-establish the continuity of the bundles. This would also explain why the high $\Delta^{14}C$ value was found only in a very restricted zone.

We agree with Ash that the base of the stem is evidently a zone for (diffuse) secondary growth because adventitious roots are continually produced from the base of the stem (Child, 1974). However, the criticism by Ash about the description of the trunk does not hold because he gives an exact figure of the stem, apparently derived from our Figure 2, which shows the dimensions of the stem. Thus, the stem was not totally cylindrical; only the main part was almost cylindrical.

We agree that there are still many questions that could well be investigated by means of ^{14}C measurements, taking advantage of the unique radiocarbon situation due to atmospheric nuclear weapon tests.

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