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# Radiocarbon

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Kline Geology Laboratory Yale University New Haven, Connecticut 06511

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# NOTICE TO READERS AND CONTRIBUTORS

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

In recent years, *RADIOCARBON* has also been publishing technical and interpretative articles on all aspects of <sup>14</sup>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 In addition, we will be publishing compilations of published *and unpublished* dates along with interpretative text for these dates on a regional basis.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. 2, 1988	Jan 1, 1988	
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Half life of <sup>14</sup>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,  $5570 \pm 30$  yr, for the half life, This decision was reaffirmed at the 11th International Radiocarbon Conference in Seattle, Washington, 1982. Because of various uncertainties, when <sup>14</sup>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,  $5730 \pm 40$  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  $\Delta$  (Lamont VIII, 1961) for geochemical measurements of <sup>14</sup>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  $\Delta$  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  $\delta^{15}$ C =  $-19\%_{00}$ .

In several fields, however, age corrections are not possible.  $\delta^{14}C$  and  $\Delta$ , 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  $\Delta$  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

# 1987

# CLIMATIC IMPLICATIONS OF CHENIER DATES IN NORTHERN AUSTRALIA

# BRIAN G LEES

Department of Geography, Australian National University Canberra, ACT, Australia

# ANNEMARIE CLEMENTS

# School of Biological Sciences, University of Sydney, NSW, 2006, Australia

ABSTRACT. The characterization of late Holocene climates in northern Australia has, in the past, been based on local investigations. This examination of the chenier record of northern Australia indicates that there has been a statistically significant regional change in conditions between 1600–2800 years BP, possibly a period of relative aridity. Support for this conclusion may be found in the vegetation record from the Atherton Tableland where numerical comparisons of dryland fossil and modern pollen spectra suggest that rainfall may have been up to 50% higher during the period 7000 to 3000 BP.

Chenier plains are a form of beach-ridge plain characterized by ridges of shell or sand with broad inter-ridge areas of mud flat. They are particularly sensitive indicators of environmental change. Minor changes in localized hydrologic and sedimentation patterns are responsible for alternate chenier ridge and inter-chenier mud-flat progradation. The classic form of this type of beach-ridge plain is on the marginal deltaic plain of the Mississippi (Russell, 1953; Gould & McFarlane, 1959; Byrne, Leroy & Riley, 1959). These cheniers are formed during periodic shifts in the river mouth location, but delta switching is only one of several processes which can lead to the formation of chenier plains. Episodic erosion was initially seen as one of the necessary criteria for chenier genesis. The other criteria originally maintained were an effective alongshore current, a variable supply of sediment, and a stable or recessive sea level. Russell and Howe (1935) maintained that periodic variation in fluvial sediment supply is critical for the formation of cheniers which are the result of beach reworking along a retreating coastline. Gould and McFarlane (1959) argued that the Louisiana ridges were accretionary features along a stable coastline thus eliminating the erosional aspect of genesis. Subsequent investigations of some of the Louisiana cheniers by Coleman (1966) indicated that both conditions may have operated along different parts of the same ridge at the same time. Given a fairly constant marine hydraulic environment and a sedimentary environment in which cheniers could develop, fluctuations in alongshore sediment supply can result in the building of cheniers. Equally, given a fairly constant supply of sediment, an increase in the energy intensity of the marine hydraulic environment may lead to a change from mud-flat deposition to chenier development. The important feature of the environment in which chenier plains develop is a periodic variation in the balance between fluvial and marine forces.

Broad Holocene coastal plains with wide intertidal and supratidal flats interspersed with cheniers are common in northern Australia. These are mostly recent features. Rhodes (1980) and Rhodes et al (1980) identified periods of chenier development in the Gulf of Carpentaria between 4500-2900 yr BP, between 2000-1700 yr BP and between 1300 yr BP and the present. He postulated there was a lack of fine terrigenous material available for mud-flat progradation during these periods and suggested that these were periods of low fluvial input separated by periods of increased fluvial input when mud-flat progradation took place. An alternate hypothesis is proposed by Chappell and Grindrod (1984) who argue that increasing muddy sedimentation reduces shell production in the lower intertidal and subtidal source area of the cheniers in northeastern Princess Charlotte Bay, thus reducing the raw material supply for chenier building. Both explanations associate high mud input with the deposition of tidal flats and low mud input with chenier ridge production. This fluctuation in mud input to the system may reflect the fluvial response to changes in rainfall. It seems unlikely, given the few ridges on most chenier plains in comparison to the number of major storms most chenier plains must have experienced, that chenier building is the necessary result of high energy events such as the passage of a tropical revolving storm. Certainly, not all storms build cheniers (Chappell & Grindrod, 1984; Lourensz, 1981). The building of sandy cheniers may, nevertheless, be the result of a series of closely spaced storms during periods of reduced fluvial input. Unlike the eastern Australian coast, the northern Australian coast is compartmentalized into a series of marginal seas. The effect of storm-generated waves is restricted by this compartmentalization and even a general increase in the frequency of storms would not result in near-synchronous chenier building across northern Australia unless several succeeding storms followed similar tracks through each of the compartments. Available records (Lourensz, 1981)



Fig 1. Location diagram of Northern Australia

indicate that this is improbable. The building of cheniers by a sequence of storms can be considered a "local" variable occurring randomly.

In Rhodes' (1980) investigation of the coastline of the Gulf of Carpentaria he found that there were, at that time, insufficient data on upper Holocene climatic change for regional correlation. Other investigations of coastal depositional features in northern Australia that involve the dating of chenier plains include the delta of the Mary River at Point Stuart (Clarke, Wasson & Williams, 1979), Shoal Bay (Hickey, 1981), the delta of the Victoria River (Lees, 1985), the delta of the Normanby River in Princess Charlotte Bay (Chappell & Grindrod, 1984), and the delta of the South Alligator River (Woodroffe *et al*, 1985) (Fig 1). These studies range across northern Australia and provide a data base for testing regional, rather than local, environmental change.

Calibrated <sup>14</sup>C ages (Klein *et al*, 1982) of shell from 7 dated crosssections of northern Australian chenier plains from 6 studies are shown in Figure 2. None of the ages were obtained using shells of *Ostreidae*. Two of the transects from the Gulf of Carpentaria have been used: the Pandanus Yard transect and the Karumba transect described by Rhodes (1980). The other transects are from different coastal compartments. Patterns of time of chenier formation are being tested using a chi-square test statistic,  $\chi^2$ , and "Robinson" clump test statistic, R (named after John Robinson). The null hypothesis is that chenier ridges are formed by random, local events. Shells incorporated into chenier ridges lived at some time before they were deposited. However, it is assumed that the calibrated <sup>14</sup>C ages of the shells are reasonable estimates of the time of formation of the chenier ridges.

Six data sets are used in the analyses. The data set from Point Stuart is



Fig 2. Environmentally corrected and calibrated ages of cheniers in Northern Australia

excluded as only alternate chenier ridges were dated. The data set does not consist of discrete points in time due to the error bands associated with <sup>14</sup>C dating (Fig 2). The continuous variable, time, is divided into intervals. The time interval (window width) is chosen to maximize the observable differences and, hence, minimize the observed significant level of the chi-square statistic (Table 1). Plotting the data with a time interval of 200 years, there appear to be two clumps, at 1600 – 2800 years BP and at 400 – 800 years BP, respectively (Fig 3).

In order to apply a standard chi-square test, the sample size, the number of chenier plains 'observed' (Fig 3), should be sufficiently large, say 4 or 5 times the number of cells (the number of time intervals). Sometimes the rule of thumb is that the expected value, e, should be at least five, but this is unnecessarily conservative (Lindgren, 1976). In this case, e, the sum of occurrences of cheniers over the time interval (59) divided by the number of the time intervals (33) (Fig 3) is equal to 1.78; hence the calculated chisquare for this particular set of observations cannot be validly compared with the standard chi-square distribution. Further, the optimization of the time interval using the chi-square statistic also invalidates use of the standard chi-square statistic.

The distribution of chi-square and "Robinson" clump test statistics are generated by using randomization procedures so that measures of statistical significance can be applied. The procedure consists of randomization in each of the six observed data sets. For example, in the Princess Charlotte Bay data, there are four occurrence groups (Table 1), which are 400 - 800years, 1200 - 2800 years, 4200 - 5000 years, and 5800 - 6000 years BP. That is 2 lots of 200 years, 8 lots of 200 years, 4 lots of 200 years, and 4 lots of 200 years, respectively. The starting positions for each of the four occurrence groups are randomized with regard to time. The outcomes are bounded above by 6600 years BP, and below by 0 years BP. Randomizations outside this range that are produced are rejected and the procedure repeated until 1000 randomizations within the range have been calculated. From each full randomization the occurrence totals,  $\sigma$ , in 200-year time intervals across the 6 chenier plains, the chi-squared and the "Robinson" clump statistic, R, are calculated. The distribution of the statistics are based on 1000 full randomizations.

Time interval	Degrees of freedom	Chi-square	Significance level
100 yr	65	75.9	0.1-0.5
200 yr	32	44.5	0.05-0.1
400 yr	16	18.8	0.1-0.5
600 ýr	10	9.7	0.1 - 0.5
800 yr	8	9.0	0.1 - 0.5
1000 yr	6	7.7	0.1 - 0.5
2000 yr	3	3	0.1-0.5
4000 yr	1	1	0.1 0.9
8000 yr	0	Ô	0.0-0.5

TABLE 1

The effect of increasing the time interval (window width) on the chi-squared value



Fig 3. Occurrence pattern of cheniers in Northern Australia

The "Robinson" clump statistic, R, is the maxima of sums of consecutive occurrence of at least 3 cheniers out of a possible 6 cheniers in any 200-year time interval (at least half the sites have a chenier formed during the time interval). In the observed data set  $\chi^2 = 44.5$  and R = 26. A  $\chi^2 >$ 44.5 occurs 15 times in 1000 observations.  $R \ge 26$  occurs 16 times in 1000 observations. The peak at 1600 – 2800 years BP is statistically significant at ca 1.5%.

In order to test for the second clump at 400 - 800 years BP, the data contributing to the first significant clump was removed and the procedure repeated. The R  $\geq$  7 occurs at random with a probability of 19% and the  $\chi^2 \geq 20.1818$  occurs by chance only 37.9% of the time. This is not statistically significant, however, the data set for this most recent event is poor. The present beach/chenier ridge on the Victoria Delta was not dated and the data set from Point Stuart was excluded.

In conclusion, non-random chenier formation occurred between 1600 - 2800 years BP across northern Australia. The chenier record indicates a widespread, regional, change in climatic conditions between these dates.

Much of the work on Quaternary climatic change in Australia deals with comparatively large-scale changes in the Pleistocene; few studies incorporate the late Holocene record. This is due, in part, to the insensitivity of many of the indicators of climatic change used. As discussed above, local chenier records are ambiguous indicators of environmental change. However, at a regional level, and at the significance levels demonstrated, the published chenier record of northern Australia indicates significant environmental change in the late Holocene. The climate of northern Australia is characterized by marked wet and dry seasons. It is suggested that the period of regional chenier building is related to a reduction in the fluvial input to the coast, indicating a period of decreased wet season precipitation.

Other indications of such a change in environmental conditions at this time have been reported on a more local level. Numerical comparisons of dryland fossil and modern pollen spectra from the Atherton Tableland suggest that rainfall may have been up to 50% higher than present during the period 7000 to 3000 BP (Kershaw, 1981). Similarly, in a statistical investigation of the depositional history of two chenier plains in North Queensland, Chappell and Thom (1986), using the Kolmogorov-Smirnov statistic, identified two periods of abnormally high rates of chenier formation. These were between 1700 and 2200 BP, and 4210 and 5090 BP. However, these results must be viewed with caution as this particular test involved the generation of an 'n' of 5 by using 3 transects through the Gulf of Carpentaria chenier plain and 2 transects through the Princess Charlotte Bay chenier plain.

In Central Australia, Wasson (1976) notes changes in conditions ca 2500 BP on the Cobar Plain, at ca 2300 BP in the Strzelecki Dunefield, and between ca 2200 and ca 2800 BP in the Simpson Dunefield (Wasson, 1984). All of these represent the onset of dune-sand accumulation. Wasson (1984) argues that this was a period of lowered temperatures and precipitation coupled with an increase in the variability of the climate.

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# <sup>14</sup>C TRACED IN KRAKÓW AFTER THE CHERNOBYL ACCIDENT

# TADEUSZ KUC

# Institute of Physics and Nuclear Techniques, University of Mining and Metallurgy, al Mickiewicza 30, 30-059 Kraków, Poland

ABSTRACT. Results of the <sup>14</sup>C measurements in atmospheric CO<sub>2</sub> in the first half of 1986 are presented. CO<sub>2</sub> samples were systematically collected in Kraków in two-week cycles and, after conversion to benzene, measured in a liquid scintillation spectrometer. <sup>14</sup>C activity and <sup>13</sup>C/<sup>12</sup>C ratio are reported as  $\delta^{14}$ C and  $\delta^{13}$ C<sub>PDB</sub>, respectively. For about three weeks after April 26, 1986 (the Chernobyl accident) an increase of ~9% above the normal level for Kraków was observed. A rough estimate of the <sup>14</sup>C release to the lower atmosphere during the accident gave a value 900 Ci, which is ~1.8 × 10<sup>5</sup> of the total activity released to the atmosphere.

#### INTRODUCTION

We have been measuring carbon isotope concentration in the Kraków region for about three years. Results of the first two years are presented in Kuc (1986). The sampling location is in Kraków (50° 3′ N, 19° 54′ E) not far from the city center and close to recreation and sports grounds. Kraków and its suburbs belong to a densely populated and industrialized area.

An accident in the Chernobyl Nuclear Power Station made monitoring of natural radioisotope background in Spring 1986 especially interesting. During this period, besides <sup>14</sup>C in atmospheric CO<sub>2</sub>, other radioisotopes were also monitored (Duliński *et al*, in press).

# SAMPLING TECHNIQUE

For the last three years samples were continuously collected at twoweek intervals at ca 20m above the ground level, on the roof of our Institute building, where an inlet to the sampling assembly is mounted. Collection is performed by continuously passing the pumped air through a column with silicagel (ca 800g) for trapping water and then through a stainless steel container filled with a molecular sieve, 4 Å, in which  $CO_2$  is separated and sorbed. The volume of the pumped air, usually ca 15m<sup>3</sup> per sample, is measured by a gas meter at the inlet. The flow rate is controlled by a flow indicator mounted at the outlet. A simple water pump is used for pumping. In case of a drop in tap-water pressure, pumping is switched to an electrically driven membrane pump.

Recovery, cleaning, conversion to benzene, and finally measurement of  $CO_2$  are after the procedure routinely used (Grabczak *et al*, 1983).

<sup>14</sup>C activity is reported as  $\delta^{14}$ C according to the notation used in radiocarbon laboratories, and necessary  $\delta^{13}$ C mass spectrometer measurements are carried out. Details of technical problems are described in Kuc (1986).

# <sup>14</sup>C FROM ATMOSPHERIC CO<sub>2</sub>

Measurement results of <sup>14</sup>C in the form of  $\delta^{14}$ C together with  $\delta^{13}$ C<sub>PDB</sub> are listed in Table 1, and a plot of the  $\delta^{14}$ C vs time is shown in Figure 1.

An abrupt "jump" in  $\delta^{14}$ C values was noticed in two samples, POW-88 and POW-89, collected within four weeks from April 21 to May 19. These two samples show a distinctly higher level of atmospheric <sup>14</sup>C activity from neighboring ones.



Fig 1. Time plot of  $\delta^{14}\mathrm{C}$  of atmospheric  $\mathrm{CO}_2$  collected in Kraków, February–September 1986

For the seven-day period, April 28 to May 5, three additional samplings of <sup>14</sup>C were taken using the second sampling assembly. The duration of each collection was about two days. The basic aim of these additional measurements was to obtain control results to those obtained in routine monitoring and to detect, if possible, the highest <sup>14</sup>C activity. Results are marked in Figure 1 as three short bars.

TABLE 1
Isotopic composition of carbon in atmospheric CO2 in Kraków after the
Chernobyl accident

Sample	Colln date	$\delta^{14}C$	$\delta^{13}C$
	(year, month, day)	(‰)	(‰)
POW-82	1986 1/27-2/10	197 + 10	-10.16
-83	2'/10-2'/24	$166 \pm 11$	-9.87
-84	$2^{\prime}/24-3^{\prime}/10$	$166 \pm 11$	-10.66
-85	3/11-3/24	$179 \pm 9$	_9.95
-86	3/24-4/7	163 + 9	-9.68
-87	4/7-4/21	174 + 9	-9.76
-88	$\frac{4}{21-5}$	247 + 9	_9.99
-89	5/5 - 5/19	$\frac{1}{261} \pm \frac{1}{11}$	-9.49
-90	5/21-6/2	$120 \pm 9$	-9.72
-91	6/2-6/16	$167 \pm 11$	-8.90
-92	6/16-6/30	$179 \pm 11$	-8.64
-93	6/30-7/14	$218 \pm 12$	-9.08
-94	7/14 - 7/28	$228 \pm 12$	-9.04
-95	7/28-8/11	$202 \pm 11$	-9.96
-96	8/11-8/26	$156 \pm 11$	-9.32
-97	8/26-9/8	$212 \pm 12$	-8.93
-98	9/8-9/22	$158 \pm 8$	-9.45

In general, slightly lower values of the two-day collections compared to the two-week sampling most likely come from the different sampling height above the ground level. In the case of the three collections, sampled air was sucked in at the height of ca 2m where the influence of  $CO_2$  respired by green plants and that generated by decomposition of organic matter was much greater.

The third and last result is remarkably lower and correlates well with the plot of total  $\beta^-$  activity of air particulates which shows the local minimum between May 1 and 5 (Duliński et al, in press). The same tendency is visible for atmospheric moisture.

# ESTIMATION OF THE <sup>14</sup>C RELEASE AT CHERNOBYL

It would be interesting to assess the <sup>14</sup>C activity released into the atmosphere during the Chernobyl accident, even with an accuracy that can be made to an order of magnitude only.

The laboratory closest to the accident site that could measure atmospheric<sup>14</sup>CO<sub>9</sub> was located in Kraków, in a straight distance of ca 740km from Chernobyl.

Results presented in the preceding section enable us to separate the net effect detected in Kraków, assuming that only samples POW-88 and POW-89 (collected from April 21 to May 19) were contaminated by Chernobyl. All the rest represent the normal level of <sup>14</sup>C in the Kraków atmosphere and these values can be smoothed, eg, by spline functions (Reinsch, 1967, 1971). The smooth curve is taken for further calculations as the background level of <sup>14</sup>C.

After drawing a histogram (Fig 1) the calculated excess of the <sup>14</sup>C activity is ca 10% of modern carbon. This figure represents a mean value for a two-week sampling period (14C was collected for two weeks at a constant speed) and is close to the summer-winter variation (Kuc, 1986).

The duration of the immediate Chernobyl contamination was not longer than 23 days (April 26 to May 19) and certainly not shorter than ca 9 days. The <sup>14</sup>C activity after May 5 is very close to that observed after April 21 which indicates the inflow of the similarly contaminated air masses also in the second week of May. The long lasting release of <sup>14</sup>C during the accident can be explained by production of <sup>14</sup>CO<sub>2</sub> as a result of burning the reactor graphite which comprises <sup>14</sup>C produced in  $(n, \gamma)$  reaction with <sup>13</sup>C.

It is obvious that "Chernobyl" <sup>14</sup>CO<sub>2</sub> above Polish territory is only a

Duration of the radioactive emission	~10 days
Estimated total radioactivity released Estimated release of <sup>14</sup> C Increase of the <sup>14</sup> C level in atmospheric COs in	50 MCi 3.5% of the present in the reactor (USSR report, 1986) 900 Ci ~10 pmc = ~9% of background
Kraków Duration of the <sup>14</sup> C contamination in Kraków	≲3 weeks

TABLE 2 Some parameters of the radioactive release at Chernobyl

# Tadeusz Kuc

fraction of the total release. According to the Polish meteorological service, the radioactive cloud reached a height of  $\sim$ 3km and prevailing wind directions indicated that Poland received about one day of the "Chernobyl emission," while the duration of the radioactive releases was approximately ten days.

If we assume that 10% of the total Chernobyl releases caused an observed 9% increase of <sup>14</sup>C above the area close to the Polish territory (~300,000km<sup>2</sup>) we can roughly estimate the total <sup>14</sup>C "production" during the accident. The value obtained in this way is 900 Ci, which compared with the activity of all other radioisotopes estimated in the USSR report (1986) to ~50 MCi, is negligibly small ( $1.8 \times 10^{-5}$ ). Some parameters of the radioactive release are comprised in Table 2.

It should be noted that in the above discussion only the "immediate ground level" contamination was considered by using the simplest model, disregarding the radioactivity penetrating the upper part of the atmosphere. The accuracy of the obtained value is expected to be within one order of magnitude.

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# <sup>14</sup>C BACKGROUND LEVELS IN AN ACCELERATOR MASS SPECTROMETRY SYSTEM

# J S VOGEL, D E NELSON, and J R SOUTHON

# Department of Archaeology, Simon Fraser University Burnaby, British Columbia V5A 1S6 Canada

ABSTRACT. The levels and sources of the measurement background in an AMS <sup>14</sup>C dating system have been studied in detail. The relative contributions to the total background from combustion, graphitization, storage, handling, and from the accelerator were determined by measuring the <sup>14</sup>C concentrations in samples of anthracite coal ranging in size from 15 $\mu$ g to 20mg. The results show that, for the present system, the uncertainty in the background is greater than that due to measurement precision alone for very old or for very small samples. While samples containing 100 $\mu$ g of carbon can yield useful <sup>14</sup>C dates throughout the Holocene, 200 to 500 $\mu$ g are required for dating late Pleistocene materials. With the identification of the procedures that introduce contamination, the level and uncertainty of the total system background should both be reducible to the point that 100 $\mu$ g of carbon would be sufficient for dating most materials.

## INTRODUCTION

The efficiency of accelerator mass spectrometry (AMS) for the direct counting of radioisotopes has greatly reduced the sample sizes required for obtaining <sup>14</sup>C ages. In our system, the total detection efficiency is ca 1%, inclusive of all steps from isolating the carbon as  $CO_2$  to the detection of the accelerated <sup>14</sup>C ions (Nelson *et al*, 1986). In principle, this efficiency is sufficient to allow measurement of samples containing only a few tens of micrograms of carbon without placing serious counting statistical limitations on the measurement uncertainty. For example, with 1% efficiency, only 40µg of 6000-year-old carbon are required to provide 1% counting statistics.

The capability to analyze such small samples will clearly be useful in a number of disciplines, and appropriate methods for doing so must be developed and tested. We have found that the catalytic graphitization of  $CO_2$  onto an iron powder substrate (Vogel *et al*, 1984) can provide graphite specimens suitable for analysis from samples containing as little as  $15\mu$ g of carbon. However, for such small samples, the possibilities of contamination are proportionately greater than for large samples. This means that the contributions to the background from the entire measurement process must be carefully examined.

The background level for an AMS-determined <sup>14</sup>C concentration has three components: 1) the contamination of the sample *in situ* before selection, 2) the contamination of the sample during preparation, and 3) the machine or detection background. The problems in 1) are dependent on the sample and the methods of purification used to isolate the carbon of interest, and are not discussed further here. In this study, we have evaluated the amounts and the sources of contaminants introduced in burning the samples to  $CO_2$  and in producing the graphite specimens for analysis. We have also estimated the contribution to the background from the accelerator system. For very small samples, we find that the background becomes the dominant portion of the final age uncertainty.

<sup>1</sup> Vycor Laboratory Glassware, Corning Glass Works, Corning, New York

# J S Vogel, D E Nelson, and J R Southon TECHNIQUE

The contributions to the background were determined by preparing and measuring the <sup>14</sup>C concentration of <sup>14</sup>C-free material in exactly the same manner as was used for all other samples. The material used was anthracite coal (obtained from a deep mine in Pennsylvania) which had been pulverized and processed through the standard acid/base washes (Nelson & Hobson, 1982). This anthracite powder received occasional further acid rinses to desorb any atmospheric CO<sub>2</sub>. For combustion to CO<sub>2</sub>, the pretreated samples were sealed in evacuated 7mm diameter Vycor<sup>1</sup> tubes along with 0.25 to 1g of wire-form copper oxide. Both the Vycor tubes and the copper oxide used in the combustion were heated in air to 900° C prior to use in order to assure that any surface carbon was oxidized. A group of ten loaded tubes was placed in a muffle furnace heated to 900° C and held at that temperature for 1/2 to 1 hour.

The resulting CO<sub>2</sub> was processed in our graphitization apparatus shown in Figure 1. The Vycor tubes were broken inside a bellows and the  $CO_2$  collected in a small (5.8ml) volume equipped with a solid-state pressure transducer for measuring the quantity of gas. The CO<sub>2</sub> was then transferred to one of the four reaction vessels, where the iron catalyst had already been re-reduced in hydrogen. The usual catalyst iron was 99% pure, spherical, -200 mesh powder. An amount of ultra-pure hydrogen in excess of the stoichiometric amount needed for complete reduction was added to the sample CO2. An oven at ca 650° C was placed around the catalyst end of the reactor while a cold finger was placed at the other end to trap the water resulting from the reaction. Two graphitizations per reactor per day were possible. The resultant graphite-coated iron powder was stored in small glass bottles until needed. For measurement, the graphite on iron was pressed into 1.1mm diameter dimples in aluminum sample holders. For "large" samples, 200 to 400µg of carbon were used in a single sample holder. Ultra-small samples ( $<100\mu$ g) were placed on a bed of silver in the dimple before being pressed.

The <sup>14</sup>C and <sup>13</sup>Č extracted from the samples were simultaneously accelerated and detected in a continuous dual beam mode as described in Nelson *et al* (1984, 1986). Negative carbon ion beams of up to  $55\mu$ a were obtainable on some days, but the usual ion source output was more often 20 to  $40\mu$ a. All measurements were obtained with respect to identically prepared samples of the NBS oxalic acid standard for which the <sup>14</sup>C count rates were typically 50 to 75 per second. Most of the anthracite sample measurements consisted of three 20-minute 'runs.' These runs were performed over a period of 8 to 12 hours along with the other samples in the 20-sample wheel.

# MACHINE BACKGROUND

The background level due to the accelerator system should be low, as the ion identification technique of AMS implies a low probability of mis-





taking other ions for <sup>14</sup>C. Only <sup>14</sup>C or specially scattered <sup>13</sup>C could be counted as sample <sup>14</sup>C, and all other ions were easily separated in the filtering system. The level of this machine background would be best found by using a natural graphite which needed no sample preparation and which was known to have absolutely no <sup>14</sup>C concentration. Since we did not have access to graphite which is known to be free of <sup>14</sup>C, we have used spectroscopic graphite of unknown provenance as well as graphite which we produced from old materials of well known ages to estimate our machine background.

In our system, up to 750nA of <sup>13</sup>C<sup>4+</sup> have been analyzed simultaneously with the <sup>14</sup>C, and scattered <sup>13</sup>C could be expected to be a serious background problem. However, measurements showed that the contribution from this source was equivalent to a <sup>14</sup>C age of ca 60 to 65 kyr (ca 0.04% modern). The major component of the background was real <sup>14</sup>C. This contaminant <sup>14</sup>C must be inherent to the graphite, be added during handling, or come from portions of the ion source other than the sample material. Although we could not distinguish which of these three was responsible for our machine background, sample cross-talk in the ion source was discounted by measuring the <sup>14</sup>C concentration of a small anthracite sample which was placed next to the NBS oxalic acid standard in the sample wheel. The sample did not increase its <sup>14</sup>C concentration during the measurement program, but displayed the usual decrease in concentration as the surface contaminant layer was sputtered away. This surface contamination was observed on many anthracite samples and appeared to be an artifact of the pressing. A comparison of the machine background derived from the unprocessed graphite with the total system background obtained from large samples of processed old materials is presented in Table 1. We have assumed that our machine background was ca 55 kyr.

#### PREPARATION CONTAMINATION

We measured the contamination arising in each step of the preparation process as listed in Table 2 by varying the amounts of carbon used in

Estimation of machine background			
Material	Measured activity	Derived machine background	Equivalent age BP
Graphite*	$0.00128 \pm 0.00056$		53.5 kyr
Best graphitized anthracite Graphitized	$0.00142 \pm 0.00023$		52.7
calcite**	$0.00125 \pm 0.00060$		53.6
Graphitized 58 kyr wood† Graphitized 45 kyr	$0.00155 \pm 0.00012$	0.00089	56.4
wood‡	$0.00446 \pm 0.00030$	0.00081	57.2

TABLE 1
Estimation of machine background

\* Graphite rod of unknown provenance

\*\* Icelandic doublespar

† QL-195

‡QL-1543, SFU-TO2

AMS carbon samples			
Type of contamination	Carbon source	Measur contribut	ed tion
Combustion	Adsorbed gas on Vycor	$1.5 \pm 1.0$	μg mod μg mod
Graphitization	Memory effect	$0.36 \pm 0.19$ < 0.1	$\mu g \mod $ % mod
Storage Handling Total	Adsorbed CO2 CO <sub>2</sub> /'dirt'	< 0.2 < 0.1 $2.2 \pm 1.1$	$\mu g \mod \mu g \mod \mu g \mod \mu g \mod \mu$

 TABLE 2

 Sources and contributions of contamination in sub-milligram

 AMS carbon samples

the individual steps and by determining the <sup>14</sup>C content of the resulting graphite. While contamination could result from the inclusion of carbon of any age, we made the assumption that most of the extraneous carbon would come from dirt or adsorbed gases having an essentially modern age. Some contribution of dead carbon could be expected from chemicals and catalysts used in the processing; but small amounts of old carbon negligibly affect the <sup>14</sup>C concentration determination. Hence, contamination will be discussed as an equivalent amount of modern material added to the anthracite samples. For the small anthracite samples discussed here, the measured <sup>14</sup>C concentration was considerably more than the machine background and we made the approximation that the measured <sup>14</sup>C was due entirely to the contamination of the sample.

The variation in total system background with sample size is plotted in Figure 2 for amounts of carbon from  $10\mu$ g to 20mg. For anthracite samples of  $<300\mu$ g, the data represent one <sup>14</sup>C concentration determination. The larger samples have two or more measurements for each with only the average value plotted here. Two trends were evident in the data: a constant level of <sup>14</sup>C concentration for samples >500 $\mu$ g and a linear inverse relation to sample size for smaller pieces of anthracite.

The total system background concentration for large samples was, on average,  $0.48 \pm 0.16\%$  modern (equivalent to 43 kyr <sup>14</sup>C age) and did not vary with sample size. The anthracite we were using must have become contaminated through handling or pretreatment before combustion. This conclusion was further supported by the background levels measured for geologic calcite and those determined by inference from known-age wood, as shown in Table 1. The source of this coal contaminant is still under investigation, and we speculate that standard pretreatment procedures may not be adequate for coal to be used as a background material for AMS <sup>14</sup>C determinations.

For samples  $<500\mu$ g, the total system background behaved as if the samples were contaminated with a constant amount of modern material. The best fit of the data to a linear inverse mass relation showed that total contamination equivalent to  $2.2 \pm 1.1\mu$ g of modern material was added during processing. The sample processing was then carefully analyzed to determine the contributions of each procedure to this total system background.



Fig 2. The total system background expressed as a  $^{14}$ C concentration *vs* anthracite sample weight from  $10\mu$ g to 20mg. Samples above the  $500\mu$ g in size showed a relatively constant concentration. Smaller samples had a concentration inversely proportional to their weight and were best fit by concentration (% mod) =  $2.2 \pm 1.1\mu$ g divided by the sample size in micrograms.

# Contamination During Graphitization

The contribution from graphitization can be separated from other sources of contamination by graphitizing small aliquots of the  $CO_2$ obtained from large anthracite samples. The contamination added during graphitization included not only the reaction of the  $CO_2$  with hydrogen over the iron catalyst, but also the transport and the measurement of the  $CO_2$ . In Figure 3, the <sup>14</sup>C concentration *vs* the inverse mass of the graphitized carbon is shown for nine large sample combustions. Each group of graphitizations was fit to a linear inverse relation to mass, and the average slope (the introduced contamination) was found to be  $0.36 \pm 0.19\mu$ g. The average intercept of the individual fits was  $0.45 \pm 0.20\%$  modern, in good agreement with the >500 $\mu$ g data set shown in Figure 2. (Sample C839 was discarded in finding the average intercept because the gas handling system was known to have been badly contaminated with younger organic carbon at the time of its processing.)

The contamination introduced during graphitization was expected to arise predominantly from memory effects of the apparatus. The adsorbed  $CO_2$  or CO on the walls of the apparatus exchanges with the gas in a sample processed later. We attempted to reduce this effect using water vapor as a



Fig 3. Total system background vs the inverse of the graphitized sample size. The anthracite was combusted as large (>1mg) samples and the CO<sub>2</sub> was divided into smaller samples before graphitization.

'cleansing' agent. This was suggested to us by Michael Andrée (pers commun, 1984) and is supported by adsorption theory (de Boer, 1968, p 32). Whenever any part of the apparatus was not in use, it was filled with 20 to 25 Torr of water vapor at ambient temperature. The vapor was evacuated at regular intervals or at the start of the next graphitization. The effect of this procedure was tested by processing anthracite samples directly after processing NBS standard oxalic acid samples, with and without the use of the water vapor cleansing between samples. The cleansing reduced these anthracite backgrounds by factors of 1.5 to 2. The average <sup>14</sup>C concentration of all large anthracite samples was reduced from 0.59  $\pm$  0.24% modern to 0.44  $\pm$  0.13% modern by the use of this technique.

We have tried using a number of elements in different forms as graphitizing catalysts. Our usual catalyst was -200 mesh, spherical iron powder of 99% purity. Spherical powders produce the more desirable graphite coating on the catalyst which makes the handling of small samples much easier. One of the likely impurities in the iron, however, would be carbon. Iron placed in the ion source directly from the bottle produced carbon ion beams which were 3 to 4% as intense as beams from graphite-coated iron. These ion beams were long lasting, indicating that the carbon was integral to the iron powder. The <sup>14</sup>C concentration of this carbon was found to be 1.5% modern. The initial reduction of the iron before catalysis must remove much of this carbon, or we could not have measured very low <sup>14</sup>C concentrations as we did for the calcite and graphite listed in Table 1. As long as the relative amounts of iron and graphite were similar (within a factor of 2) for all samples, backgrounds, and standards, the contribution of this carbon was small, adding <0.1% modern to the measured <sup>14</sup>C concentration of a sample.

# Contamination During Storage and Handling

The contamination of the stored graphite by adsorbed gases was checked by comparing the <sup>14</sup>C concentration of an anthracite sample which had been stored in a small bottle for  $1\frac{1}{2}$  years with the <sup>14</sup>C concentration measured when the sample was first produced. Within the uncertainties of the measurements, there was no detectable difference between the earlier and the later measurements. The uncertainties placed an upper limit on this level of contamination of ca  $0.2\mu$ g modern carbon equivalent.

The contamination of a sample arising from the handling necessary for placing it in the ion source was checked by dividing a processed graphite into a very small sample (ca  $50\mu$ g) and a large sample (> $600\mu$ g). The concentrations were measured only after the surface had been sputtered for a few minutes, our usual procedure. The difference between the measured concentrations of the two placed an upper limit on the handling contamination of < $0.1\mu$ g modern carbon equivalent.

# Contamination During Combustion

The measured contaminant levels of the preparation stages discussed so far account for  $0.7 \pm 0.3 \mu g$  of the  $2.2 \pm 1.1 \mu g$  total system background for very small samples. The remaining  $1.5 \pm 1.0 \mu g$  of modern equivalent carbon must come from the only part of the process not discussed so far: the combustion to CO<sub>2</sub>.

To test if the copper oxide were the source of the contamination, we tried two approaches. For three very small samples of anthracite, the oxide was substituted with ultra-pure oxygen at 300 Torr. These data are shown in Figure 2, and are indistinguishable from samples combusted with copper oxide. Further, changing the amount of oxide used for combustion by a factor of five did not change the measured <sup>14</sup>C concentration of small anthracite samples within the limits of the measurements.

The only remaining component of the combustion procedure was the Vycor tube. As one would expect that the heating of the tubes to 900° C in air prior to loading them would remove any carbonaceous impurities, we had not expected these to cause problems. However, a literature search revealed that Vycor has some alarming properties. It is the most porous of the commercial glasses and is designed to be so (Nordberg, 1944). The effective surface area is 120 to 200m<sup>2</sup> per gram (Emmett & DeWitt, 1943; Schwertz, 1949) with an average pore size of 30 to 60A leading to fractal type surfaces (Dozier, Drake & Klafter, 1986). At dry ice temperatures, 1g of Vycor is capable of adsorbing 50cc of CO<sub>2</sub> at 1atm partial pressure (Emmett & DeWitt, 1943). These properties suggested that the combustion tubes might indeed be the cause of the observed combustion contamination and that we would be wise to use a substitute. However, only Vycor and

quartz can withstand the preferred 900° C combustion temperature, and quartz is second only to Vycor for permeability (Eitel, 1966, p 11). Boutton *et al* (1983) report non-quantitive yields (50–80%) from several organic materials combusted in Pyrex tubes at a lower temperature, but they find almost no isotopic fractionation effects from the low temperature combustion. We tried to combust the anthracite at lower temperatures (550° C) in Pyrex tubes, and did not achieve quantitative yields. However, the total system background using Pyrex tubes for combustion was a factor of two less than that using Vycor:  $1.1\mu g vs 2.2\mu g$  modern carbon, as shown in Figure 2.

## CONCLUSION

Table 2 summarizes the identifiable sources of contamination along with the contributions of each to the total system background. Contamination levels are shown as micrograms of modern equivalent carbon added to the sample. Clearly, the most serious contribution was from combustion. Memory effects in the graphitization and the <sup>14</sup>C in the iron catalyst were lesser problems. Storage, handling, and ion source cross talk were much less serious.

From these data, we could determine the sample size required to obtain a desired final measurement uncertainty with the present system. The final or total measurement uncertainty was calculated as the quadratic combination of the background uncertainty shown in Figure 2 and the sam-



Fig 4. The total measurement uncertainty *vs* Holocene material age for different sample sizes with an assumed measurement precision of 2%. The background was assumed to have the form shown in Fig 2.

ple measurement precision. The sample measurement precision is calculated by our analysis system to be the larger of the two possibilities: the precision found from the counting statistics of the sample and the associated standard measurements, or the standard deviation of the several measurements carried out on that sample. As shown in Figure 4,  $200\mu$ g of carbon were sufficient for the measurement of Holocene materials to a final uncertainty of 200 years, assuming a 2% ( $\pm 160$  yr) precision in the measurement. For most of the Holocene, 100 and even  $50\mu$ g carbon samples yield useful age determinations when the sample is limited to these amounts. As an example, the smallest unknown sample that we have dated was a charcoal smudge on a rock that produced only  $32\mu$ g of carbon. The measured age was  $11,000 \pm 1200$  yr BP, in good agreement with larger bone and charcoal samples from the site.

Figure 5 indicates the final age ranges that would be assigned to late Pleistocene materials having different sample sizes using our present sys-



Fig 5. The final measured age range for samples of various sizes assuming a concentration measurement precision of 3% with the background shown in Figure 2. The background uncertainty dominates throughout the late Pleistocene portion of the plot. For example,  $200\mu$ g of 35 kyr carbon would yield an age range of 32.5 to 39.5 kyr.

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tem. A measurement precision of 3% and the background levels from Figure 2 were assumed for all cases. Again, the uncertainty in the background dominates the final uncertainty of the measurement for very small and very old samples. The 20 to  $50\mu g$  samples could yield only a limit on the age of Pleistocene materials, but a  $500\mu g$  sample is clearly sufficient for age determinations through 40,000 years. For many applications,  $200\mu g$  was enough.

Small sample <sup>14</sup>C dating using accelerators is already measuring sample sizes considerably smaller than the optimistic projections of ten years ago. With the identification of the sources of much of our total system contamination, we hope to make  $100\mu$ g an easily dated sample size throughout much of the range of accelerator <sup>14</sup>C dating.

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# AN ASSESSMENT OF LABORATORY CONTAMINATION AT THE ISOTRACE RADIOCARBON FACILITY

# D M GURFINKEL

# Collegium Archaeometricum, c/o Department of Metallurgy and Materials Science, University of Toronto, Toronto, Ontario Canada, M5S 1A4

ABSTRACT. An assessment of the contamination contribution of various sample preparation procedures used at the Isotrace Radiocarbon Facility, University of Toronto, is described. Samples of geologic material, millions of years old, or samples derived therefrom, were tested because these would presumably contain only dead carbon. Results showed, however, that <sup>14</sup>C contamination could be detected in several samples, complicating the contamination assessment. Best estimates of the contamination contribution from sample preparation were reported as: cracking: <0.17% modern, acetylene synthesis: <0.25% modern, combustion: <0.39% modern, and handling: <0.54% modern. These estimates were reported as upper limits because they likely represented <sup>14</sup>C derived from two sources: sample preparation and the sample itself.

#### INTRODUCTION

Contamination introduced during sample preparation is believed to be a major contributor to the background measured in accelerator mass spectrometry (AMS). Thus, it is important to evaluate each step in the procedure as a possible source of contamination. At the Isotrace Facility these steps include an initial chemical pretreatment such as acid-base extraction for organic samples (eg, charcoal, wood, bone collagen) or an acid leach for inorganic carbonates (eg, shell). The pretreated residues are then combusted (organic material) or hydrolyzed in acid (carbonates). The resultant carbon dioxide is next converted to acetylene which is decomposed by means of a "cracking" process to form solid carbon targets. These targets are placed in a cesium ion source from which a carbon beam is generated and analyzed by AMS. Operation of the cesium ion source and accelerator has been described by Kieser *et al* (1986).

This study describes efforts made in 1984 and early 1985, and briefly summarized by Beukens, Gurfinkel and Lee (1986), to quantitatively determine the extent of contamination introduced during the combustion, acetylene synthesis, and cracking processes. Chemical pretreatment while recognized as a potential source of contamination was not investigated directly in this study. There is also no discussion of the contamination contribution from the ion source and accelerator system itself, *ie*, "machine background," as this is described in detail elsewhere (Beukens, Lee & Litherland, ms in preparation). In this study, the machine background is assumed constant and extremely small. The major difficulty encountered was the apparent presence of <sup>14</sup>C contamination in the samples that were expected to be dead. As a result, the contamination levels measured likely represented a combination of <sup>14</sup>C originating from the sample itself and <sup>14</sup>C introduced during sample preparation.

# SAMPLE PREPARATION PROCEDURES

*Combustion.* Combustion was achieved using a sealed combustion tube method (H Schwarcz, pers commun, 1981). Such a tube is illustrated in Fig-



Fig 1. Sealed Vycor combustion tube

ure 1. An organic residue, typically containing 5mg carbon, was placed in the Vycor inner tube shown, which was then transferred to the larger Vycor combustion tube containing cupric oxide wire (1g, Baker Analyzed Reagent). This larger tube was evacuated to 0.001 torr and sealed at the tube sealing manifold shown in Figure 2. The tube contents were mixed to ensure good contact between sample and reagents and the tube was heated at 850°C for two hours, then cooled down to room temperature overnight. Reduced cupric oxide in the form of cuprous oxide or copper metal was visible in the cooled tube as a pink residue. At elevated temperatures this reduced material converted any nitrogen oxides present to nitrogen which later was separated from the desired carbon dioxide gas. Silver wire (26 gauge, obtained from Sargent Welch) acted as a scrubber for sulphur and halogen compounds.

The vacuum line shown in Figure 2 was used to break the combustion



Fig 2. Carbon dioxide recovery line

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tubes and recover the carbon dioxide gas. The tube was inserted into the arm shown, which was then rotated so as to drop a weight on the tube tip, breaking it. The released carbon dioxide gas was dried over two dry ice/ alcohol traps and frozen out in a liquid nitrogen-cooled trap, while any nitrogen gas present was pumped away. The carbon dioxide was then expanded from the trap, the quantity present determined using the mercury manometer shown in the figure, and the gas then transferred to a storage vessel for subsequent acetylene synthesis. Tests with organic material of known carbon content indicated a conversion efficiency of at least 95%.

*Carbonate Hydrolysis.* For the preparation of carbonate-containing samples, carbon dioxide was generated by acid hydrolysis in 85% H<sub>3</sub>PO<sub>4</sub> rather than from combustion (Lowdon, Wilmeth & Blake, Jr, 1969). The gas was then dried and recovered in the line described above.

Acetylene Synthesis. The procedure described below was adapted from Polach, Gower and Fraser (1973) and was based on a two-step process for



Fig 3. Lithium carbide reaction apparatus

acetylene synthesis. Carbon dioxide was first reacted with hot lithium metal to form lithium carbide which was next reacted with water to generate acetylene.

Figure 3 shows the lithium carbide reaction apparatus. The reaction vessel was made from 304L stainless steel containing 0.03% carbon. Ca 40 to 60mg of lithium metal (obtained from the Lithium Corp of America) was added to this vessel, a quantity of metal representing a three to four-fold excess over stoichiometric requirements. The lithium was heated in a vacuum for 20 minutes at 600°C and then carbon dioxide was added. This resulted in an initial pressure rise which dropped off quickly as conversion to lithium carbide proceeded. Five minutes after addition of the gas, the reaction temperature was raised to 800°C for another 20 minutes to ensure complete carbide conversion. After the heating was completed, the vessel was cooled by immersion in cold water, distilled water was added to the lithium carbide and the generated acetylene was dried and collected in the line shown in Figure 4. Conversion efficiency of carbon dioxide to acetylene was found to be 80% (RP Beukens, pers commun, 1986).

*Cracking*. The acetylene was converted to solid carbon targets by a "cracking" process described by Beukens and Lee (1981), with one major modification. The acetylene to carbon conversion was performed in a 1 kv AC discharge rather than in an RF discharge from a Tesla coil as originally described. Beukens and Lee also designed a more functional cracking chamber, shown in Figure 5. The carbon material was deposited simultaneously on two aluminum substrates (shown in Figure 5), the surfaces of



Fig 4. Acetylene recovery and cracking line



Fig 5. Cracking chamber (not shown: inlet and outlet stopcocks perpendicular to page. See Fig 4).

which were prepared by scoring with silicon carbide paper (3M #360 or #400) followed by ultrasonic cleaning in absolute alcohol. This roughening of the substrate surface was essential to ensure good carbon-to-aluminum adhesion under bombardment from the cesium beam in the ion source.

The cracking process proceeded as follows. Enough acetylene was added to the evacuated chamber to bring the initial pressure to 11 torr. The starting current was 0.4 mA and the cracking process was maintained for 12 minutes during which time the current and acetylene pressure slowly dropped. A blue-colored discharge was initially observed in the 2 to 3mm gap between the aluminum surfaces but this changed to a purple color as the acetylene gas was exhausted. After 12 minutes the cracking chamber was evacuated, a second load of acetylene gas was added, and the above process was repeated. When the cracking of the second load of acetylene was complete, the carbon targets were removed from the chamber and stored in a vacuum desiccator. When enough acetylene was available, as was generally the case, a second pair of targets was produced.

Each target prepared was examined under a stereo microscope. Finegrained carbon material with good adherence to the aluminum surface was present over which a layer of carbon having a frothy, bubbly texture was usually visible. This frothy material did not perform well in the cesium ion source. For this reason it was routinely removed from the target surface by gentle scraping with a clean scalpel blade. This exposed the fine-grained carbon, ca 200 to  $300\mu$ g were present, from which good carbon beams could be generated in the ion source.

*Contamination Control.* Several procedures were used to minimize and monitor contamination; for example, all samples were stored in polyethylene bags or glass vials. During operations, such as weighing and transfer, samples were handled in such a manner that only glass, metal, or dead carbon material such as plastic surfaces were contacted.

In the combustion procedure the Vycor tubes, cupric oxide, and silver wire were heated in the atmosphere at 850°C prior to use to ensure that any residual carbon in these materials was oxidized. Blank combustion tubes (*ie*, tubes containing cupric oxide and silver wire, but no sample) were run regularly and the amount of carbon dioxide generated was  $0.07 \pm 0.01\%$  of average sample size (5mg carbon).

In the acetylene synthesis process, special precautions were taken in the cleaning of the stainless steel reaction vessel. As they were shop made, the reaction vessels were quite dirty when received, having been exposed to grease and lubricants during machining. An industrial strength ultrasonic detergent (obtained from Bransonic) was used to remove these greases and lubricants. Several hot-water washes then followed to remove any traces of detergent. Next the vessels were subjected to the "pickling" process shown in Table 1 (ASM, 1964). All cleaning steps were conducted with ultrasonic agitation. The vessels were then oven-dried and stored in a vacuum desiccator. Each reaction vessel underwent a blank run (lithium only, no carbon dioxide) before being used for a sample. Acetylene was generated in these blank runs, probably originating from carbon in the stainless steel of the reaction vessel and/or from contaminants in the lithium. Acetylene blanks averaged 0.20  $\pm$  0.03% of typical sample size (ca 4mg carbon), but a vessel was considered acceptable for use if the blank was up to 0.5% of the average sample. An acceptable blank was usually obtained on the first run although occasionally a vessel would have to be run twice. Because cross-contamination effects have been reported in these vessels (Radnell & Muller, 1980) the standard procedure was to use a reaction vessel for only one sample after which a new metal surface was exposed by reaming out the inside of the vessel and the cleaning process and blank runs were repeated.

Lithium metal was found to be very reactive. On exposure to air the metal rapidly lost its metallic sheen, changing first to a dull black (believed to be lithium nitrides and hydroxides) then to white, indicative of lithium oxides and carbonates (Mausteller, Tepper & Rodgers, 1967). For this rea-

Pickling procedure for lithium reaction vessel Wash Time (min) 1 90% U SO 10

TABLE 1

1. $20\% \Pi_2 SO_4$	10
2. $20\%$ H <sub>2</sub> SO <sub>4</sub>	10
3. Warm $H_2O$	2
4. 8% HNO <sub>3</sub> – 3% HF	5
5. Warm H <sub>2</sub> O	2
6. 20% NaÕH – 6% KMnO₄	10
7. Warm H₀O	2
8. Warm H <sub>0</sub> O	9

2

2

5

2

9. 20% H<sub>3</sub>SO

10. Warm H<sub>2</sub>O

11. 20% HNO3

12. Warm H<sub>2</sub>O

son the lithium, when not in use, was stored in a vacuum desiccator and when required was handled in an argon-filled glove bag. With adequately dried argon, the lithium would retain its metallic sheen while being weighed and transferred to reaction vessels.

### SAMPLES

In order to study contamination effects dead samples, *ie*, samples that contained no detectable <sup>14</sup>C, had to be selected. It was assumed that this could be achieved by using samples of, or derived from, geologic material millions of years old. They include:

1) *Anthracite coal.* This sample was obtained from the Geological Survey of Canada in the form of small black chunks no larger than a 0.4cm cube. Three pretreatment procedures were applied to this sample.

a) *No chemical extraction.* Small portions of anthracite were broken off from randomly selected chunks and combusted directly without any pre-treatment.

b) *Acid-base extraction*. Several grams of material were finely ground using a mortar and pestle and extracted first in base (hot 0.25N NaOH, 1 hr) then acid (hot 2N HCl, 1 hr).

c) *Prebaking.* Several grams of material were finely ground using a mortar and pestle, heated at 600°C in atmosphere for 2 hr, and then stored in a glass vial.

2) *Calcite*. This was Precambrian (Grenville Province) crystal material collected at the Madawaska Mines in Bancroft, Ontario. The calcite crystal was initially washed in 0.1N HCl (10 min) and then acid leached (*ie*, left overnight in a sufficient quantity of 0.2N HCl to hydrolyze ca 20% of the carbonate). In one treatment the calcite was coarsely ground, confining the leaching activity to outside surfaces, and in the second the calcite was finely ground, so that the leaching activity was more uniformly distributed throughout the sample.

3) *Limestone*. This was collected from a Paleozoic, fossiliferous limestone deposit in Prince Edward County, Ontario. It was in the form of large gray chunks which were crushed and given a routine 20% acid leach.

4) *High purity graphite*. This was a synthetic, zone-refined, reactor-grade graphite in rod form obtained from the Chalk River Nuclear Laboratories, Atomic Energy of Canada, Ltd, in Chalk River, Ontario. The exact origin of the carbon used in the manufacture of this graphite was unknown but was believed to be dead carbon as no appreciable difference was observed in results between this sample and natural graphite. In the laboratory the graphite was used in two forms.

a) Small cores of graphite, 3mm in diameter, were drilled out of the larger rod, set in small aluminum cylinders and placed directly in the ion source.

b) A portion of the larger rod was finely ground using a mortar and pestle and then prebaked and stored in the same manner as the anthracite coal.

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5) Calcium carbonate reagent. This reagent had been stored in the laboratory for several years and the chemical supplier was unknown. It was selected for use because reagent  $CaCO_3$  is normally manufactured from limestone (Lepley, 1978). This sample was given no pretreatment.

6) Calcium carbide (technical grade (80% obtained from BDH) was selected for use because it was prepared by the heating of calcium oxide and coal or coke (Shine, 1978).

7) Cylinder carbon dioxide gas (obtained from Canox of Canada Ltd, Toronto, Ontario) was selected because the manufacturer indicated that it was prepared from natural gas.

# RESULTS AND DISCUSSION

One of the major problems encountered in this study was the apparent presence of <sup>14</sup>C contamination in samples that were assumed dead. This was clearly indicated by the variations in results obtained in Tables 3 and 4 between different samples and for the same samples after different pre-treatments. If no sample contamination were present then all similarly processed samples would have similar ages. Because of this indication of contamination, it could not be assumed that even the oldest samples were necessarily <sup>14</sup>C free. The contamination assessments for the cracking (Table 2), acetylene synthesis (Table 3), and combustion (Table 4) procedures were thus reported as upper limits.

Table 2, eg, reports the contamination level for the cracking procedure as <0.17% modern. If it could be assumed that both the calcium carbide and high purity graphite placed directly in the ion source were dead, then the contamination from the cracking process would have been considered negligible (Beukens, Gurfinkel & Lee, 1986). If however, one or both the samples were contaminated then the similarity between their ages would have been merely coincidental. By reporting the results as an upper limit, this possibility as well as the possibility that both samples were indeed dead have been encompassed.

Similarly in Table 3, the contamination level for acetylene synthesis was reported as <0.25% modern based on results for finely ground calcite and in Table 4, the contamination level for the combustion procedure was reported as <0.39% modern based on prebaked anthracite.

Material	Preparation processes used	% modern	Eqv age (vr BP)	No. of targets measured
High-purity graphite	None, directly in ion source	$0.130 \pm 0.009$	$53,600 \pm 600$	5
Calcium carbide	Hydrolysis and cracking	$0.142 \pm 0.028$	$52,700 \pm 1600$	6

 TABLE 2

 Contamination contribution of cracking process

Contamination contribution of cracking process: <0.17% modern (based on results from calcium carbide sample plus 1 standard deviation)

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Material	Pretreat- ment	Preparation processes used	% modern	Eqv age (yr BP)	No. of targets measured
Calcite	20% acid leach finely- ground sample	Acid hydroly- sis, acetylene synthesis, and cracking	0.237 ± 0.015	48,600 ± 500	13
Calcite	20% acid leach, coarsely- ground sample	"	$0.59 \pm 0.12$	41,200 ± 1600	5
Lime- stone	20% acid leach	"	$0.68~\pm~0.07$	$40,100 \pm 800$	1
Calcium carbon- ate re- agent	None	"	$1.25 \pm 0.06$	$35,200 \pm 400$	1
Cyclinder CO <sub>2</sub>	"	Acetylene syn- thesis and cracking	$0.556 \pm 0.047$	41,700 ± 700	6

 TABLE 3

 Contamination contribution of acetylene synthesis

Contamination contribution of acetylene synthesis:  $<\!0.25\%$  modern (based on results from finely ground calcite sample plus 1 standard deviation)

The differences in ages observed for the two pretreatment procedures performed on the calcite indicated the presence of a widely-distributed contaminant, which was more efficiently removed in the finely ground material because of improved acid accessibility. The origin of the contamination was unknown but may have occurred naturally, the result of penetration of modern material via a microfissure system present in the calcite crystal. That such systems exist in geologic material has been documented (RP Beukens, pers commun, 1986).

				1	
Material	Pretreatment	Preparation processes used	% modern	Eqv age (yr вр)	No. of targets measured
Anthracite	None	Combus- tion, acet- ylene syn- thesis, and cracking	0.94 ± 0.19	37,490 ± 1620	8
	Acid-base extraction	"	$0.62 \pm 0.04$	$40,830 \pm 510$	3
	Prebaking at 600°C	"	$0.358 \pm 0.033$	$45,200 \pm 700$	2
High-purity graphite	"	"	$0.513 \pm 0.034$	$42,400 \pm 500$	17

 TABLE 4

 Contamination contribution of combustion process

Contamination contribution of combustion process: <0.39% modern (based on results of prebaked anthracite plus 1 standard deviation)
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The comparatively young and variable average age  $(37,490 \pm 1620 \text{ yr BP})$  obtained for the untreated anthracite material was suggestive of a heterogeneously distributed contaminant. The method of sampling used for this untreated material, randomly breaking of small portions from larger-sized chunks, made the results particularly susceptible to variability from such a contaminant. When the material was homogenized by grinding, and treated with acid and base, the average age was older and less variable than the untreated sample. The most successful treatment, however, was prebaking at 600°C in which presumably the contaminant was preferentially oxidized relative to the anthracite. The fact that this treatment was considerably more successful than the extractions suggested a very tightly bound contaminant.

The presence of handling contamination, *ie*, contamination introduced not in the processes of combustion, acetylene synthesis, or cracking specifically, but during other manipulations of the sample, was apparent in the graphite sample. The difference between the results of graphite in the ion source (0.130  $\pm$  0.009% modern, Table 2) and after processing (0.513  $\pm$  0.034% modern, Table 4) indicated that laboratory-introduced contamination was present. Up to 0.39% modern (Table 4) could have originated from the combustion, acetylene synthesis, and cracking procedures itself. However, this leaves a minimum of ca 0.1% modern contamination to an upper limit of 0.54% which must have originated from other sources. As this was not <sup>14</sup>C inherently present, it must have been handling contamination.

As described in the samples section, combusted graphite underwent considerably more manipulation than the sample placed directly in the ion source. For example, combusted graphite was finely ground, a process that Gillespie and Hedges (1984) noted appears to introduce contamination. The prebaking process might have been expected to remove these contaminants, however depending on the chemical nature and binding capacity of the contaminant, removal may have been incomplete or recontamination may have occurred during subsequent storage and/or weighing and transfer of the graphite powder to combustion tubes. That contaminants can be tightly bound was illustrated with the anthracite sample. Given the highly adsorptive nature of carbon material 0.54% modern handling contamination is likely to represent a true upper limit. Less adsorptive material would presumably be less susceptible to this phenomenon.

#### CONCLUSIONS

Based on the above results the following conclusions can be made:

1) It cannot be assumed that any sample is "dead." If this is not recognized, misinterpretation of contamination levels could result. Note, eg, that if only the results of cylinder  $CO_2$  (0.556 ± 0.047% modern) and combusted graphite (0.513 ± 0.034% modern) had been available and had been assumed dead, then this study might have concluded there was no significant contamination from the combustion procedure and ca 0.4% contamination occurred during acetylene synthesis. The use of old samples of known finite ages in the 60,000 to 70,000 years BP range to assess laboratory contamination would alleviate this problem. With such samples it would be possible to determine the relative contribution of sample preparation vs the sample itself in the data reported here.

2) There appears to be handling contamination which is likely to vary with sample composition. Thus, it may become necessary to determine the contamination levels for each of the material classes dated, *ie*, wood, shell, bone, charcoal, etc, as well as investigating more rigorous handling methods to minimize such contamination.

3) Based on the above data, the best estimates for the contamination contribution during sample preparation at the Isotrace Facility are:

- a) cracking < 0.17% modern
- b) acetylene synthesis < 0.25% modern
- c) combustion <0.39% modern
- d) handling < 0.54% modern

These estimates were reported as limits because they represent contamination not just from sample preparation but possibly from the sample itself.

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## MEASUREMENT OF SMALL VOLUME OCEANIC <sup>14</sup>C SAMPLES BY ACCELERATOR MASS SPECTROMETRY

## PETER SCHLOSSER, CHRISTOPH PFLEIDERER, BERND KROMER, INGEBORG LEVIN, K O MÜNNICH

Institut für Umweltphysik der Universität Heidelberg, Im Neuenheimer Feld 366, D-69 Heidelberg, FRG

## GEORGES BONANI, MARTIN SUTER, and WILLY WÖLFLI

## Institut für Mittelenergiephysik, ETH-Hönggerberg, CH-8093 Zürich Switzerland

ABSTRACT. A technique for <sup>14</sup>C measurement of small volume (0.5L) oceanic water samples by Accelerator Mass Spectrometry (AMS) is described. Samples were taken from a CTD/ rosette system used for standard hydrographic work. After CO<sub>2</sub> extraction and target preparation, the samples were measured at the Zürich tandem accelerator facility. On the basis of <sup>14</sup>C data from samples collected on a station in the northern Weddell Sea, the precision of the measurements is estimated to ca ±8‰. The error in the present AMS results is dominated by the statistical error in <sup>14</sup>C detection. From results of duplicate targets, it is concluded that a precision of ±5‰ can be reached. The <sup>14</sup>C data are discussed in relation to the Weddell Sea hydrography.

#### INTRODUCTION

During the last decades, <sup>14</sup>C measurements have progressed to an important tool in physical oceanography, allowing estimates of large-scale oceanic transport and mixing processes (Stuiver, Quay & Östlund, 1983; Broecker *et al*, 1985; Schlitzer *et al*, 1985). A limiting factor in present oceanographic <sup>14</sup>C studies is the fact that the low-level counting technique used so far for <sup>14</sup>C measurement requires sampling and processing of 250L of water to obtain a precision of  $\leq 5\%$  which is needed in many oceanographic applications to resolve the structures of the <sup>14</sup>C distribution. The large volume Gerard bottles used for water sampling requires extra casts for <sup>14</sup>C stations and the operation of the CO<sub>2</sub> extraction devices needs additional manpower. Therefore, <sup>14</sup>C sampling mainly was restricted to cruises with dedicated geochemical sampling programs as, eg, GEOSECS or TTO.

Recent developments in Accelerator Mass Spectrometry (AMS) allow <sup>14</sup>C measurement on samples much smaller than needed for low-level counting. The main question in the application of AMS <sup>14</sup>C measurements in oceanographic studies, however, is the precision that can be achieved. A critical limit for oceanographic applications is a precision of  $\approx 10\%$ , which is sufficient for the treatment of the entry of bomb <sup>14</sup>C into the interior of the ocean. The purpose of this paper is to present AMS <sup>14</sup>C measurements of small volume water samples collected on a station in the northern Weddell Sea which demonstrate that it is possible to obtain <sup>14</sup>C data from samples taken from CTD/rosette systems used for standard hydrographic work with a precision well below 10‰.

#### SAMPLE COLLECTION AND MEASUREMENT

The first samples were collected during the third cruise of the German Polar Research Vessel *Polarstern* to Antarctica (ANT III, January to March 1985) on station 243 in the northern Weddell Sea. As this station was rather shallow, additional samples of Weddell Sea Bottom Water (WSBW) were taken on station 244 in the central Weddell Sea. (For geographical position of the stations, see Fig 1.)

The samples were drawn from a CTD/rosette system equipped with 12 Niskin bottles (volume: 12L) into pre-evacuated glass bulbs (volume: 1L) sealed with PTFE valves. The glass bulbs had been cleaned with concentrated HCl before they were evacuated. To avoid changes in the CO<sub>2</sub> concentration of the water by microbial activity the water samples were poisoned with HgCl<sub>2</sub>. In the laboratory the water was acidified with phosphoric acid and the CO<sub>2</sub> was extracted using a technique described by Dörr and Münnich (1980). The AMS targets were prepared by catalytic reduction of the CO<sub>2</sub> to carbon. The experimental setup for the target preparation is similar to that described by Vogel *et al* (1984). Measurement was done at the Zürich AMS facility. The technical details of the measurement are given by Suter *et al* (1984) and Bonani *et al* (1986). The <sup>14</sup>C data are reported as  $\Delta^{14}$ C, *ie*, as the per mil deviations from the 1950 decaycorrected NBS oxalic acid standard (Stuiver & Polach, 1977).

The present  $1\sigma$  precision of  $\pm 8\%_0$  is dominated by the statistical (counting) error of the accelerator sample respective to the standard measurement (5–6‰ each). The corresponding systematic errors are on the



Fig 1. Geographical positions of stations 243 and 244 in the northern Weddell Sea

$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Press (dbar)	<i>θ</i> (°С)	S (‰)	$\Delta^{14}C^{**}_{(\%_0)}$	δ <sup>13</sup> C† (‰)	$\Sigma CO_2$ ( $\mu mol/l$ )	Water mass
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Station 24 (62° 28.6′ 150185	43 S, 34° 38.1′ W	v')				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	10	0.028	33.618	-83.3 -94.1	1.53	2068	SW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	79	-1.739	34.401	-123.5 -120.2	0.73	2228	WW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	300	0.096	34.666	-158.8	0.14	2275	WDW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	599	0.042	34.669	$-146.6 \\ -148.8$	0.14	2318	WDW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	901	-0.042	34.667	$-154.0 \\ -150.3$	0.02	2301	DW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1200	-0.170	34.663	$-155.1 \\ -149.8*$	$\begin{array}{c} 0.30 \\ 0.34 \end{array}$	$\begin{array}{c} 2271 \\ 2270 \end{array}$	DW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1800	-0.327	34.658	-168.1 - 165.0	0.30	2268	DW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2701	-0.481	34.656	-155.6	0.51	2241	DW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	3300	-0.625	34.650	$-157.2 \\ -171.8$	0.52	2247	DW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$				-148.8*	0.49	2267	
$\begin{array}{c} \text{Station 244} \\ (64^{\circ} \ 33.4' \ \text{S}, \ 27^{\circ} \ 03.3' \ \text{W}) \\ 160185 \\ 4798 & -0.937 & 34.634 & -133.8 & 0.64 & 2233 & \text{WSBW} \\ 4925 & -0.948 & 34.634 & -141.8 & 0.53 & 2246 & \text{WSBW} \\ & & -138.1 & & \\ & & & -132.7^{*} & 0.41 & 2245 \end{array}$	3526	-0.680	34.647	$-157.2 \\ -138.1^{*}$	$\begin{array}{c} 0.70 \\ 0.50 \end{array}$	$\begin{array}{c} 2229 \\ 2242 \end{array}$	DW
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Station 24 (64° 33.4′ 160185	14 S, 27° 03.3' W	v)				
4925 -0.948 34.634 -141.8 0.53 2246 WSBW -138.1 -132.7* 0.41 2245	4798	-0.937	34 634	-133.8	0.64	9933	WSBW
-132.7* 0.41 2245	4925	-0.948	34.634	-141.8 -138.1	0.53	2246	WSBW
				-132.7*	0.41	2245	

TABLE	1
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<sup>14</sup>C measurements of water samples taken in the Weddell Sea. Duplicate  $\Delta^{14}$ C

\* Numbers are from duplicate samples taken from the same Niskin bottle, and storage, water processing, target preparation and measurement steps were completely independent. \*\*  $1\sigma$  error =  $\pm 8\%$ 

 $\pm^{13}$ C was measured using conventional mass spectrometry;  $1\sigma \text{ error} = \pm 0.04\%$ .

order of 2-3% only. The observed overall precision derived from the results of duplicate samples (see Table 1) is consistent with the error of the accelerator measurement. Thus, additional errors through sampling, storage, and target preparation seem to be negligible on this level of accuracy. This gives us confidence that by increasing counting time, a  $\pm 5\%$  precision can be reached.<sup>1</sup> In the discussion of the present data, we assume a total error of  $\pm 8\%_0$  for the single measurement, and a  $\sigma = 8\%_0/N^{1/2}$  for each mean value derived from N single measurements.

#### **RESULTS AND DISCUSSION**

The hydrography of station 243 (extended by station 244) is typical for the northern Weddell Sea. The potential temperature respective to salinity

<sup>1</sup>Note added in proof: This precision has been reached meanwhile; see B Kromer *et al* (in press) to appear in the AMS-4 1987 Proceedings volume of Nuclear Instruments & Methods.





Fig 2B. <sup>14</sup>C profile for station 243/244. The data points marked by open signs are from samples that were run completely independently (see also Table 1).

profiles (Fig 2A) show a thin ( $\approx 20$ m thick) cold layer of Winter Water (WW) directly below the fresher and warmed-up surface layer (SW). The Warm Deep Water (WDW) underlying the WW is relatively cold at this station with a maximum temperature of 0.1°C in its core at ca 300m depth. Below the WDW, the potential temperature decreases steadily with depth to reach a value of -0.94°C in the Weddell Sea Bottom Water (WSBW) found at station 244 at 4930m depth. The salinity increases from the surface to the core of the WDW where a maximum of 34.669‰ is found and slowly decreases again below the center of the WDW to a value of 34.634% in the WSBW at station 244. The water mass between the WDW ( $\theta \ge 0$ °C) and the WSBW ( $\theta \ge -0.8$ °C) is called the Deep Water (DW).

The <sup>14</sup>C data are plotted in Fig 2B and listed in Table 1. The depth profile shows  $\Delta^{14}$ C values between -83 and  $-94\%_0$  in the Surface Water decreasing to  $-122\%_0$  in the WW (79m). Below the WW the  $\Delta^{14}$ C values further decrease to  $-151 \pm 6\%_0$  in the WDW (depth range at station 243: 300-600m;  $\Delta^{14}$ C range: -147 to  $-159\%_0$ ). In the depth range between 900 and 3500m the mean  $\Delta^{14}$ C value is  $-156 \pm 3\%_0$  (range: -138 to  $-172\%_0$ ), not significantly different from the WDW value of  $-151\%_0$ . The mean  $\Delta^{14}$ C value of the WSBW (4 samples) amounts to  $-137 \pm 4\%_0$ , a value significantly higher than the <sup>14</sup>C concentration of the overlying water.

Our AMS data can be compared with the existing <sup>14</sup>C measurements from the Weddell Sea published by Weiss, Östlund and Craig (1979). These data were obtained by conventional low-level counting with an accuracy of  $\pm 4\%$ . Within the errors the mean surface  $\Delta^{14}$ C value of -92% given by

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Weiss *et al* agrees with our value of -90% observed at station 243. The same holds for our WDW <sup>14</sup>C concentration (-151%) in comparison to -155% given by Weiss *et al*). As the data from Weiss *et al* are from 1973 it can be concluded that the influence of bomb <sup>14</sup>C on the <sup>14</sup>C content of the WDW is only of minor importance. The fact that we find a surface concentration not really different from the one in 1973 although the atmospheric <sup>14</sup>C concentration has decreased (430\%) in 1973 (Levin *et al*, 1985); 200% in 1985 (Levin *et al*, 1987)) may well be due to the different locations of the stations, varying extent of the ice cover, or different gas exchange rates with the atmosphere. In the following, the data are discussed in the context of the Weddell Sea oceanography.

The <sup>14</sup>C distribution of the Weddell Sea is controlled by circulation and gas exchange with the atmosphere in this region. The relatively warm and salty WDW is a key water mass transporting heat and salt from the Circumpolar Flow into the Weddell Sea. The fresher and slightly warmed SW, found during summer in the upper 50m of the water column, is formed by atmospheric exchange and water/ice interaction. The WW is the remnant of the winter mixed layer which forms under the sea ice cover with temperatures near the surface freezing point of sea water with a core depth of ca 100m (Gordon & Huber, 1984). The WSBW is a mixture of WDW and shelf water masses.

The low <sup>14</sup>C concentrations of the WDW and of the intermediate waters reflect the high ages of the deep Pacific and Atlantic Oceans from which these waters are derived. The higher <sup>14</sup>C concentrations in the SW are caused by partial CO<sub>2</sub> re-equilibration of the upper water layers mainly during southern summer (atmospheric  $\Delta^{14}$ C values at the time of sampling: 200% (Levin et al, 1987)). The WW is a mixture between WDW and SW and consequently has a <sup>14</sup>C concentration between those of WDW respective to SW. The waters below the WDW core are of the deep Atlantic and deep Pacific origin and show low <sup>14</sup>C concentrations comparable to those of the WDW. The WSBW is a mixture of deep waters with low  $^{14}C$ concentrations and shelf-water masses which are partially re-equilibrated with the atmosphere. Under the assumption that WSBW is a mixture of 40% WDW, 19% WW, and 41% Western Shelf Water (WSW), Weiss, Östlund and Craig (1979) calculated a <sup>14</sup>C value of -119% for this water mass. Our measured value of  $(-137 \pm 4)\%$  is slightly lower which means that the WSBW is less influenced by atmospheric exchange than assumed so far. It might be that this difference is caused by improper assumptions for the mixing ratios of the water masses involved in the WSBW formation process. The calculation of Weiss et al does not take into account that the Ice Shelf Water (ISW)<sup>2</sup> plays an important role in the formation process of WSBW as has been shown in recent work by Foldvik, Gammelsröd and Törresen (1985a,b). For a more detailed understanding of the <sup>14</sup>C distribution of the Weddell Sea further work is needed.

<sup>&</sup>lt;sup>2</sup> ISW is a water mass formed by cooling and admixture of melt water under the Filchner/ Ronne Ice Shelves.

#### Peter Schlosser et al

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#### UNIVERSITY OF LUND RADIOCARBON DATES XX

## SÖREN HÅKANSSON

## Radiocarbon Dating Laboratory, Department of Quaternary Geology University of Lund, Sweden

#### INTRODUCTION

Most of the <sup>14</sup>C measurements reported here were made between October 1985 and October 1986. Equipment, measurement, and treatment of samples are as reported previously (R, 1968, v 10, p 36–37; 1976, v 18, p 290; 1980, v 22, p 1045; 1986, v 28, no. 3, p 1111).

Age calculations are based on a contemporary value equal to 95% of the activity of NBS oxalic acid standard (No. 4990A) and on the conventional half-life for <sup>14</sup>C of 5568 yr. Results are reported in years before 1950 (years BP). Errors quoted with the dates are based on counting statistics alone and are equivalent to  $\pm 1$  standard deviation ( $\pm \sigma$ ).

Corrections for deviations from  $\delta^{13}C = -25.0\%_{00}$  in the PDB scale are applied for all samples; also for marine shells. The apparent age for marine material due to the reservoir effect must be subtracted from our dates on such samples.

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

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

#### ACKNOWLEDGMENTS

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#### GEOLOGIC SAMPLES

Sweden

### Långören series

Wood of *Pinus* coll by scuba diving outside Långören I., Torhamn archipelago, SE Blekinge, S Sweden (56° 04' N, 15° 50' E). Coll Aug 1984 (Lu-2485) and Aug 1985 by P Berglund; subm by B Berglund, Dept Quaternary Geol, Univ Lund. Pretreated with HCl and NaOH.

		$9380 \pm 90$
Lu-2485.	Långören, Pine Stump 1	$\delta^{I3}C = -27.4\%{00}$

Wood from ca 25 tree rings of pine stump exposed at ca 3m water

depth after dredging away ca 1m sediment. *Comment:* previous date for pine stump from same area is  $9300 \pm 130$  BP (St-806; R, 1963, v 5, p 204).

## **70 ± 40** Lu-2484. Långören, Ship Wreck 1 $\delta^{13}C = -24.7\%_0$

Wood from ship board coll at 2.5m depth. Wreck partly exposed above sand. *Comment:* possible calibrated  $1\sigma$  intervals (Stuiver, 1982, p 8) are: cal AD 1690–1725, 1815–1840, 1880–1915.

Lu-2492. Ljunghusen  $\delta^{I3}C = -26.2\%$ 

Wood (*Quercus* sp) id by T Bartholin, from ca 4.8m below surface at Höllviken, near Ljunghusen Train Stop (55° 24′ 30″ N, 13° 55′ 30″ E), SW Scania. Coll Aug 1985 and subm by G Söderlund, Vellinge Local Authority, Vellinge. *Comment:* pretreated with HCl and NaOH.

## Southern Småland series

Sediment and water mosses from lakes Spjällsjön (56° 41′ N, 14° 35′ 40″ E), Hälsegyl (56° 32′ 40″ N, 14° 37′ E), and Kalven (56° 32′ N, 14° 33′ 40″ E), S Småland. Coll 1985 and subm by S Björck, Dept Quaternary Geol, Univ Lund. Dating is part of study of Late Weichselian stratigraphy and chronology of lake sediments in S Sweden. Depths (m) refer to sediment surface. All samples pretreated with HCl. Lu-2511 and -2514 received additional treatment with NaOH, and soluble fractions were dated separately.

## Spjällsjön

Samples were taken with 5 and 10cm Russian-type corer. Water depth 1.65m at coring point.

Lu-2511. Spjällsjön 1, insoluble  $\delta^{I3}C = -20.5\%$ 

Insoluble fraction of muddy clay, depth 3.975 to 4.025m. *Comment:* insoluble fraction contained ca 40% of total organic carbon in pretreated sample. Total organic carbon content: ca 1.2%. Sample undersized; diluted; 78% sample. Expected age ca 12,300 BP.

		$12,240 \pm 110$
Lu-2511A.	Spjällsjön 1, soluble	$\delta^{13}C = -20.4\%0$

Acid-precipitated part of NaOH-soluble fraction, depth 3.975 to 4.025m. *Comment:* this fraction contained ca 60% of total organic carbon in pretreated sample. Two 24-hour extractions with 4% NaOH at 80°C.

## Lu-2512. Spjällsjön 2

 $\frac{11,760 \pm 220}{\delta^{I3}C = -25.7\%_{00}}$ 

Water mosses, depth 4.04 to 4.06m. Lithostratigraphy indicates Bølling pollen zone. *Comment:* very small sample; diluted; 26% sample. (4 1-day counts.)

 $\frac{11,710 \pm 140}{\delta^{I3}C = -20.6\%}$ 

### Lu-2514. Spjällsjön 3, insoluble

Insoluble fraction of clay gyttja, depth 3.88 to 3.91m. *Comment:* this fraction contained ca 45% of total organic carbon in pretreated sample. Total organic carbon content: ca 1.8%. Sample undersized; diluted; 70% sample. Expected age ca 11,700 BP.

## Lu-2514A. Spjällsjön 3, soluble $\delta^{I3}C = -20.6\%$

Acid-precipitated part of NaOH-soluble fraction, depth 3.88 to 3.91m. *Comment:* this fraction contained ca 55% of total organic carbon in pretreated sample. Sample undersized; diluted; 88% sample.

		$10,420 \pm 180$
Lu-2515.	Spjällsjön 4	$\delta^{13}C = -25.6\%$

Water mosses, depth 3.63 to 3.67m. Lithostratigraphy indicates Early Younger Dryas pollen zone. *Comment:* very small sample; diluted: 28% sample. (4 1-day counts.)

### Hälsegyl

Samples were taken with 5 and 10cm Russian-type corer. Water depth 1.55m at coring point.

		$11,860 \pm 110$
Lu-2513.	Hälsegyl, 4.355–4.405m	$\delta^{13}C = -18.4\%$

Clay gyttja. *Betula-Pinus* zone of Allerød chronozone. *Comment:* organic carbon content: ca 5%.

		$11,500 \pm 110$
Lu-2516.	Hälsegyl, 4.30–4.355m	$\delta^{I3}C = -20.0\%$

Clay gyttja. End of *Betula-Pinus* and beginning of *Betula-Pinus-Empetrum* zone of Allerød chronozone. *Comment:* organic carbon content: ca 7%.

## Kalven

Samples taken with 10cm Russian-type corer. Water depth ca 0.75m at coring point.

		$11,460 \pm 150$
Lu-2517.	Kalven, 3.59–3.63m	$\delta^{13}C = -18.8\%0$

Clay gyttja. At very end of *Betula-Pinus* zone of Allerød chronozone. *Comment:* sample undersized; diluted; 58% sample. Organic carbon content: ca 6%.

# 10,480 ± 150Lu-2518. Kalven, 3.38–3.41m $\delta^{l3}C = -22.6\%_0$

Clay gyttja. At very end of *Artemisia* zone of Younger Dryas chronozone. *Comment:* sample undersized; diluted; 44% sample. (3 1-day counts.) Organic carbon content: ca 5%.

#### Hanö Bay series

Peat from submarine bog ca 8 to 11m below present sea level in Hanö Bay E of Scania (55° 43.5′ N, 14° 12.3′ E). Coll June 1985 by L Hansen; subm by S Björck. Pollen analysis by T Persson, Lab Quaternary Biol, Univ Lund. Dating is part of study of shore displacement and paleogeography of Hanö Bay region during Late Weichselian-Early Holocene. Samples taken with Russian-type corer. Bog surface ca 8m below sea level at coring point (Hansen, 1985, p 13–14). Depths (cm) refer to bog surface. Samples pretreated with HCl.

		$8120 \pm 80$
Lu-2594.	Hanöbukten 2C, 80–85cm	$\delta^{I3}C = -29.3\%_{00}$

Sandy, highly humified peat. Just above beginning of *Tilia* pollen curve (T°).

		$8070 \pm 80$
Lu-2595A.	Hanöbukten 2C, 7–12cm	$\delta^{13}C = -29.5\%$

Acid-precipitated part of NaOH-soluble fraction from highly humified peat.

#### Hammarmossen series

Peat and gyttja from Hammarmossen, 1km W of Hällefors, Västmanland, central Sweden (59° 45' N, 14° 30' E). Coll July 1985 and subm by D R Foster, Harvard Univ. Dated as complement to Kräckelbäcken series (R, 1986, v 28, no. 3, p 1115–1117). Results of previous study of patterned fen in Canada pub by Foster *et al* (1983), and Foster and King (1984). All samples taken with 5cm Russian-type peat corer. Pretreated with HCl. All samples except Lu-2526 charred in nitrogen atmosphere before burning. Depths (cm) refer to bog or sediment surface.

Lu-2526. Hammarmossen 1, Core I1, 25–30cm  $\delta^{13}C = -27.2\%$ 

Basal, slightly humified *Sphagnum* peat from S end of mire. *Comment:* peat apparently contaminated by recent plant material influenced by <sup>14</sup>C from nuclear bomb testing.

 $920 \pm 45$ 

## Lu-2527. Hammarmossen 2, Core I2, 105–110cm $\delta^{I3}C = -27.4\%$

Basal *Sphagnum* peat, slightly more humified than Lu-2526, above. Core taken 25m from S boundary of nature preserve.

 $\mathbf{2320}~\pm~\mathbf{50}$ 

#### Lu-2528. Hammarmossen 3, Core I3, 215–220cm $\delta^{13}C = -26.4\%$

Basal *Sphagnum* peat, moderately humified, taken ca 200m from S edge of mire.

 $\mathbf{3140} \pm \mathbf{50}$ 

## Lu-2529. Hammarmossen 4, Core I4, 300–305cm $\delta^{13}C = -25.8\%_0$

Basal *Sphagnum* peat, moderately humified, taken ca 300m from S edge of mire.

 $3950 \pm 60$ 

Lu-2530. Hammarmossen 5, Core I5, 300–309cm  $\delta^{I3}C = -24.8\%$ Basal *Sphagnum* peat, highly humified, taken ca 350m from S edge of mire. Core from largest drained pool.

 $5190~\pm~60$ 

**Lu-2531.** Hammarmossen 6, Core I6, 375–385cm  $\delta^{13}C = -25.0\%$ Basal *Sphagnum* peat, highly humified, from approx center of mire.

 $5240 \pm 60$ 

**Lu-2532.** Hammarmossen 7, Core 18, 365–375cm  $\delta^{13}C = -25.9\%$ Basal *Sphagnum* peat, highly humified, from approx crest of N lobe of mire.

 $2130~\pm~50$ 

Lu-2533. Hammarmossen 8, Core I9, 170–180cm  $\delta^{13}C = -27.4\%$ 

Basal *Sphagnum* peat, highly humified, taken ca 100m from N margin of mire.

		$5820~\pm~60$
Lu-2534.	Hammarmossen 9, Core II b,	$\delta^{I3}C = -26.6\%0$
	335-345cm	

Basal Sphagnum peat, highly humified.

		$2390~\pm~50$
Lu-2535.	Hammarmossen 10, Core II c,	$\delta^{13}C = -26.4\%0$
	235–245cm	

Basal *Sphagnum* peat, moderately humified, taken ca 200m from E margin of mire along transect II.

		$1450 \pm 45$
Lu-2536.	Hammarmossen 11, Core II d,	$\delta^{13}C = -26.6\%0$
	130–140cm	

Basal *Sphagnum* peat, moderately humified, taken at E margin of mire at forest border.

		$1300 \pm 45$
Lu-2537.	Hammarmossen 12, Core DP 1b,	$\delta^{13}C = -25.2\%$
	90–100cm	

Algal gyttja from drained pool.

		$1940~\pm~50$
Lu-2538.	Hammarmossen 13, Core DP 1b,	$\delta^{I3}C = -25.9\%$
	110–120cm	

Sphagnum peat from drained pool.

Lu-2539. Hammarmossen 14, Core DP E, 210–220cm  $2040 \pm 50$  $\delta^{13}C = -26.7\%$ 

Algal gyttja from E drained pool.

		$2390 \pm 50$
Lu-2540.	Hammarmossen 15, Core DP E,	$\delta^{13}C = -26.1\%$
	225-230cm	,

Sphagnum peat from E drained pool.

 $\mathbf{3770} \pm \mathbf{60}$ 

**Lu-2541.** Hammarmossen 16, Pool 2, 305–310cm  $\delta^{13}C = -26.7\%$ Algal gyttja from pool. Water depth 1.9m at coring point. *Comment:* sample undersized; diluted; 88% sample.

**4200**  $\pm$  **60 Lu-2542.** Hammarmossen 17, Pool 2, 315–320cm  $\delta^{13}C = -26.9\%$ *Sphagnum* peat from same pool as Lu-2541, above.

**2580** ± 50 **Lu-2543.** Hammarmossen 18, Pool 1, 285–290cm  $\delta^{13}C = -27.3\%$ Algal gyttja from pool. Water depth 1.9m at coring point.

**4010**  $\pm$  **60 Lu-2544.** Hammarmossen 19, Pool 1, 300–310cm  $\delta^{13}C = -25.9\%$ *Sphagnum* peat from same pool as Lu-2543, above.

**4130** ± **60 Lu-2545.** Hammarmossen 20, Pool 1, 310–315cm  $\delta^{13}C = -26.7\%$ *Sphagnum* peat from same pool as Lu-2543, above.

### Bjäresjö series (II)

Peat from lake S of Bjäresjö village, 5km NW of Ystad, S Scania (55° 27.5' N, 13° 45.3' E). Coll 1985 and subm by M-J Gaillard, Dept Quaternary Geol, Univ Lund. Dated as complement to Bjäresjö series (R, 1986, v 28, no. 3, p 1119–1120). Samples are from Cores C1 and C3, taken with 5cm Russian-type corer. Depths (m) refer to sediment surface. Pretreated with HCl.

**Lu-2561.** Bjäresjö 7:85, 5.05–5.11m
  $\delta^{13}C = -28.4\%$  

 Carr peat with remains of *Carex* and wood. Core C1. Water depth

1.75m at coring point. Pollen zone AT 1 or AT 2 (Nilsson, 1961).

					$9690 \pm 90$
	Lu-2562.	Bjäresjö	8:85, 8.93–9	).03m	$\delta^{I3}C = -29.7\%$
	0	• •			 

Carr peat with remains of *Carex* and wood (*Pinus*). Core C3. Water depth 1.7m at coring point. Pollen zone PB (Nilsson, 1961).

## **Subfossil Pine Series II**

Subfossil wood (*Pinus silvestris*) from lakes Tjåutjanjarka (68° 20.3' N, 19° 8.2' E) and Pulsojärvi (68° 25' N, 21° 07' E), N Lappland. Coll 1985 and subm by T Bartholin, Lab Wood Anatomy and Dendrochronol, Dept Qua-

ternary Geol, Univ Lund. Dated as complement to Subfossil Pine Series I (R, 1986, v 28, no. 3, p 1111–1113). All samples pretreated with HCl and NaOH. Lu-2577 and -2578 were charred in nitrogen atmosphere before burning.

		5440 ± 60
Lu-2576.	Tjåutjanjarka, Sample 25075	$\delta^{13}C = -27.8\%00$

Wood from tree rings No. 1 to 60 (from center).

		$4750 \pm 70$
Lu-2577.	Pulsojärvi, Sample 19006	$\delta^{13}C = -28.0\%$

Wood from tree rings No. 1 to 60 (from center). *Comment:* sample undersized; diluted; 85% sample.

		$4400 \pm 60$
Lu-2578.	Pulsojärvi, Sample 19007	$\delta^{13}C = -26.3\%00$

Wood from tree rings No. 1 to 45 (from center). *Comment:* sample undersized; diluted; 89% sample.

### **Årshultsmyren series**

Peat from raised bog, SW Småland (56° 47' N, 13° 25.5' E), alt ca 155m. Coll 1985 and subm by M Thelaus, Dept Quaternary Geol, Univ Lund. Dated as part of study of palaeohydrol changes in raised bogs and lake basins in S and central Småland. Samples taken with 10cm Russiantype corer. Depths (m) refer to bog surface. Humification is given in H1– 10 scale (Magnusson, Lundqvist & Regnell, 1963, p 567). All samples pretreated with HCl and charred in nitrogen atmosphere before burning.

		$4860~\pm~60$
Lu-2582.	Årshultsmyren 1, 4.79–4.83m	$\delta^{13}C = -24.0\%0$
Sphagnum	peat, H8, Coring Point BP 5, Sec D.	

		$4770 \pm 60$
Lu-2583.	Årshultsmyren 2, 4.71–4.76m.	$\delta^{13}C = -25.8\%$
Sphagnum	peat, H3, Coring Point BP 5, Sec D.	

		$5020~\pm~60$
Lu-2584.	Årshultsmyren 3, 4.42–4.46m	$\delta^{I3}C = -26.8\%$
		DD 10 C D

Sphagnum-Eriophorum peat, H8, Coring Point BP 12, Sec D.

		$4860 \pm 60$
Lu-2585.	Årshultsmyren 4, 4.37–4.42m	$\delta^{13}C = -27.4\%00$
0.1	114 Carrier Daint PD 19 Sec D	

Sphagnum peat, H4, Coring Point BP 12, Sec D.

### **Björkeröds Mosse series**

Coarse organic matter, mainly brown mosses, washed from sediment from fen basin (ca 400x40m) on hill ridge Kullaberg at Björkeröd, NW Scania (56° 17' N, 12° 30' E), alt 70 to 80m. Coll 1985 and subm by G Lem-

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### Sören Håkansson

dahl, Dept Quaternary Geol, Univ Lund. For other dates from area, see Mt Kullen biostratigraphy series (R, 1971, v 13, p 346–347) and Håkulls Mosse series (I–IV) (R, 1978, v 20, p 416–417; 1980, v 22, p 1049–1050; 1984, v 26, p 394–395; 1986, v 28, no. 3, p 1113). Samples taken with 10cm piston corer. Depths (m) refer to fen surface. No pretreatment. All samples undersized; diluted. Amount of  $CO_2$  from sample is given in *Comments* below as "% sample."

## Lu-2589. Björkeröds Mosse A6:1, 3.94–4.15m $3^{13}C = -28.5^{0}/_{10}$

Coarse organic matter, mainly brown mosses, from gray calcareous clay with thin silt layers. Pollen zone DR 1 (Berglund, 1971). *Comment:* 19% sample. (3 1-day counts.)

## Lu-2590. Björkeröds Mosse A6:2, 3.74–3.94m $b^{13}C = -29.8\%$

Coarse organic matter, mainly brown mosses, from gray calcareous silty clay. Pollen zone DR 1. *Comment:* 57% sample. (4 1-day counts.)

# Lu-2591. Björkeröds Mosse A6:4, 3.30–3.42m $\delta^{13}C = -26.8\%$

Coarse organic matter, mainly brown mosses, from gray calcareous clay with thin silt layers. Pollen zone DR 1. *Comment:* 28% sample. (3 1-day counts.)

*General Comment:* hard-water error possible because of carbonate content in sediment due to calcareous till in catchment.

## Lu-2651. Håkulls Mosse B8:9, 3.80–3.88m $11,220 \pm 100$ $\delta^{13}C = -27.4\%$

Wood fragments from small fen on hill ridge Kullaberg, NW Scania (56° 17' N, 12° 31' E), alt ca 125m. Coll 1983 and subm by G Lemdahl. Wood washed from sediment sample (j-k) taken with 10cm Livingstone piston corer. Allerød pollen zone. Depth refers to fen surface. For previous dates from Håkulls Mosse, see Björkeröds Mosse series, above, for refs. *Comment:* no pretreatment; sample undersized; diluted; 79% sample. (3 1-day counts.)

## Stensjön series

Sediment from Stensjön, Kalmar län, E Småland (57° 12' N, 16° 17' E). Coll March 1983 and subm by N-O Svensson, Dept Quaternary Geol, Univ Lund. Dated as part of study of Late Weichselian and Early Holocene shore displacement on Gotland and in E Småland, mainly based on bio- and lithostratigraphic studies of lake sediments (Svensson, 1985). For other dates from area, see Eastern Småland series (R, 1986, v 28, p 141–143). Samples taken with 10cm and 7cm (Lu-2634) Russian-type corer. Depths (cm) refer to sediment surface. Water depth ca 2.2m at coring point. All samples pretreated with HCl. Lu-2632 received additional treatment with NaOH and soluble fraction was precipitated with HCl and dated separately.

 $9720 \pm 150$ 

Lu-2632. Stensjön 4, insoluble, 524.25–529.75cm  $\delta^{13}C = -31.4\%$ 

Insoluble fraction of gyttja. Pollen zone boundary Preboreal/Boreal. Estimated age 9700 BP, based on pollen stratigraphy. *Comment:* sample undersized; diluted; 38% sample. (3 1-day counts.)

 $9450~\pm~100$ 

Lu-2632A. Stensjön 4, soluble, 524.25–529.75cm  $\delta^{13}C = -31.1\%$ 

Acid-precipitated part of NaOH-soluble fraction. *Comment:* sample undersized; diluted; 77% sample.

		$9500 \pm 90$
Lu-2633.	Stensjön 5, 505.5–511.5cm	$\delta^{13}C = -30.6\%0$

Gyttja. Boreal pollen zone. Estimated age 9500 BP, based on pollen stratigraphy.

		$8740~\pm~80$
Lu-2634.	Stensiön 6, 467.25–479.75cm	$\delta^{13}C = -31.3\%$

Gyttja. Pollen zone boundary BO 1/BO 2. Estimated age 8900, based on pollen stratigraphy.

#### Iceland

$11,520 \pm$	100
$\delta^{I3} \dot{C} = -1.$	3‰

 $6300 \pm 120$ 

## Lu-2524. Urridaá

Marine bivalve shells (*Chlamys islandica*), *in situ* at contact between lodgement till (below) and glacial-marine silt (above) at Leirárvogur, Borgarfjördur, W Iceland (64° 22.5' N, 21° 52' W). Coll Sept 1985 and subm by Ó Ingólfsson, Dept Quaternary Geol, Univ Lund.

#### Akranes series (II)

Humic acid fraction of sandy peat from 295 to 320cm below present high-tide marks at Höfdavik, just N of Akranes (64° 20' N, 22° 04' W). Coll 1983 and subm by Ó Ingólfsson. Dated to gain information about peat growth rate. For date on insoluble fraction, see R, 1986, v 28, no. 3, p 1121–1122.

## Lu-2395AI. Akranes 1, 310–320cm $\delta^{13}C = -27.7\%$

Acid-precipitated part of NaOH-soluble fraction of peat from 310 to 320cm below present high-tide marks. *Comment:* sample undersized: diluted; 42% sample.

# 6060 ± 80Lu-2395AII. Akranes 1, 295–310cm $\delta^{I3}C = -27.9\%$

Acid-precipitated part of NaOH-soluble fraction of peat from 295 to 310cm below present high-tide marks. *Comments:* sample undersized; diluted; 78% sample.

## **Southern Iceland Series II**

Marine mollusk and balanid shells and charcoal from S Iceland. Coll 1983–1985 and subm by A Hjartarson, Natl Energy Authority, Reykjavík. Dated as complement to Southern Iceland Series I (R, 1986, v 28, no. 3, p 1122–1123). Mollusks and charcoal id by submitter.

		$10,440 \pm 90$
Lu-2596.	Oddgeirshólar, Árnessysla	$\delta^{13}C = +1.0\%0$

Shells (*Pecten islandicus, Spisula solida, Mya truncata, Zirphaea crispata*) from silt and sand layers (basal sediments) 18km S of Budi end moraines at bank of Hvitá R (64° 00' N, 20° 48' W), alt 25m. *Comment:* outer 39% removed by acid leaching.

## Lu-2597. Vatnsendi, Árnessysla $9840 \pm 90$ $\delta^{13}C = +0.9\%$

Unid. thin shells of bivalves, balanids, and one gastropod from southernmost fossil-bearing site, Árnessysla, at Villingaholtshreppur gravel pit (63° 53' N, 20° 47' W), alt 30m. *Comment:* outer 9% removed by acid leaching.

## Lu-2598. Syđri-Rauđalaekur, Rangarvallasysla $\delta^{I3}C = -0.4\%$

Unid. fragments of gastropods, balanids, and bivalves from silt and sand layers in lower part of raised delta of Rangarvellir at Holtahreppur (63° 51' N, 20° 28' W), alt 10m. *Comment:* outer 8% removed by acid leaching. Sample undersized; diluted; 92% sample.

		$11,530 \pm 100$
Lu-2599.	Nauthólsvík, Reykjavík	$\delta^{13}C = +3.7\%$

Large shell fragments (*Mya truncata*) from Fossvogur fossil-bearing layers (Einarsson, 1968) at Nauthólsvík, W of harbor (64° 07' N, 21° 56' W). *Comment:* outer parts of shell fragments could not be completely removed by acid leaching since they were partly covered by lava remains. Lava showed no reaction for 10% HCl.

### Lu-2600. Hròarsholtslaekur

 $\frac{10,060 \pm 70}{\delta^{13}C = +1.5\%_{00}}$ 

Thick fragments (Arctica islandica) from loose sand beds at Hròarsholtslaekur, Laekur, Árnessysla (63° 53' N, 20° 53' W), alt 35m. Comment: outer 54% removed by acid leaching. (3 1-day counts.)

## Lu-2601. Buđi, Árnes, Árnessysla $7800 \pm 60$ $\delta^{I3}C = -25.6\%$

Charcoal of Salix or Cytisus from top of subfossil soil just below Thjórsá lava near Buði waterfall (64° 01' N, 20° 17' W), alt 70m. Comment: pretreated with HCl. (3 1-day counts.)

*General Comment:* corrections for deviations from  $\delta^{13}C = -25\%$  PDB are applied. No corrections are made for reservoir age of living marine mollusks. Reservoir age for waters of Iceland pub by Håkansson (1983).

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#### Greenland

#### **Kilen series**

Marine bivalves and terrestrial moss from Kilen, N Greenland (ca 81° 10' N, 14° 00' W). Coll Aug 1985 and subm by C Hjort, Dept Quaternary Geol, Univ Lund. Dated as part of study of glacial and interglacial chronology and paleoclimatology and occurrence of biological refuges in NE and N Greenland. Bivalves id by submitter.

		$11,350 \pm 100$
Lu-2569.	Kilen CHT 1	$\delta^{I3}C = +0.9\%$

Shells and fragments (*Hiatella arctica, Mya truncata*) from silt in frostboils from +15 to +22m. *Comment:* outer 36% removed by acid leaching.

**8870** ± 80 Lu-2570. Kilen CHT 2a  $\delta^{I3}C = +0.9\%$ 

Shell fragments (*Hiatella arctica, Mya truncata*) from free-melted area at +22m within glacier. Sample supposed to give max age of readvance. *Comment:* outer 28% removed by acid leaching.

		$270 \pm 50$
Lu-2571.	Kilen CHT 4a	$\delta^{I3}C = -31.4\%$

Terrestrial moss exposed by melting of glacier. Sample supposed to give max age of readvance. *Comment:* pretreated with HCl and NaOH. Sample undersized; diluted; 68% sample.

		$8890~\pm~80$
Lu-2572.	Kilen CHT 12	$\delta^{13}C = +1.1\%$

Shells and fragments (*Hiatella arctica*, *Mya truncata*) from free-melted area at ca +15m within glacier. Sample supposed to give max age of readvance. *Comment:* outer 33% removed by acid leaching.

		$0300 \pm 00$
Lu-2605.	Kilen CHT 15	$\delta^{13}C = +0.8\%$

Shells (*Mya truncata*) from top till in "Ymer-sequence." *Comment:* outer 53% removed by acid leaching.

		>41,000
Lu-2573.	Kilen CHT 23	$\delta^{I3}C = +0.8\%$

Shells (*Hiatella arctica, Mya truncata*) from highest marine sediments on Kilen (sand and gravel) overlying till at ca +70m. *Comment:* outer 33% removed by acid leaching. (3 1-day counts.)

		$10,100 \pm 90$
Lu-2574.	Kilen CHT 24a	$\delta^{13}C = +0.5\%$

Shells (*Hiatella arctica*, *Mya truncata*) from sand at ca + 34m overlain by gravel beds. Date of importance for shore-line displacement curve. *Comment:* outer 39% removed by acid leaching.

8380 + 80

		>39,000
Lu-2575.	Kilen CHT 25	$\delta^{I3}C = +1.0\%$

Dislocated shell fragments (*Hiatella arctica*) from ca + 60m. Comment: outer 32% removed by acid leaching.

General Comment: corrections for deviations from  $\delta^{13}C = -25\%_0$  PDB are applied. No corrections are made for reservoir age of living marine mollusks. Revised reservoir age for E Greenland based on 4 dates on 3 shell samples coll 1899 and 1900 (Hjort, 1973; Olsson, 1980) is 515 ± 25 yr. No recent dates available for N Greenland coast.

Crete

#### Lu-2525. Tylisos

 $2230 \pm 70$  $\delta^{13}C = -9.8\%$ 

Small calcareous concretions from 2m below surface in loess deposits at Tylisos, Crete (35° 18' N, 25° 01' E), alt ca 200m. Coll June 1985 and subm by T Nihlén, Dept Phys Geog, Univ Lund. Dated as part of study of eolian deposits in N Africa and Mediterranean (Nihlén, 1985; Rapp & Nihlén, 1986).

United States

#### Minnesota

#### Northern Minnesota series

Sediment from Heikkilla Lake (47° 39' 16" N, 92° 10' 24" W), S Lempia Lake I (47° 43' 22" N, 92° 15' W), S Lempia Lake II (47° 43' 24" N, 92° 15' 07" W), Swamp Lake (47° 37' 52" N, 92° 18' W), Sabin Lake I (47° 35' 23" N, 92° 18' 05" W), and Sabin Lake II (47° 34' 40" N, 92° 17' 30" W), Iron Range, N Minnesota. Coll Sept 1984 and subm by S Björck. Dated to gain information about chronology of deglaciation and revegetation during Laurentide ice retreat in N Minnesota, as complement to previous study in NW Ontario (Björck, 1985). Samples taken with 5cm Livingstone corer. Depths (m) refer to sediment surface or peat surface (Swamp Lake). All samples pretreated with HCl. All samples except Lu-2500, -2504, and -2505 undersized; diluted. Amount of CO<sub>2</sub> from sample is given in Comments as "% sample." Organic carbon content given in Comments is calculated from final yield of CO2 and based on amount of material remaining after pretreatment. Loss of organic carbon during processing of sample and non-proportional loss during pretreatment may result in somewhat lower values than original ones.

#### Heikkilla Lake

Alt 442m. Water depth 1m at coring point.

		$12,100 \pm 150$
Lu-2556.	Heikkilla Lake, 1.68–1.72m	$\delta^{13}C = -22.8\%00$

Silty organic clay. *Comment:* 50% sample. Organic carbon content: ca 0.8%. (3 1-day counts.)

 $12,070 \pm 170$ 

Lu-2496. Heikkilla Lake, 1.53–1.57m  $\delta^{13}C = -23.7\%$ 

Silty organic clay. *Comment:* 55% sample. Organic carbon content: ca 1%.

11,320 
$$\pm$$
 130Lu-2497. Heikkilla Lake, 1.38–1.42m $\delta^{I3}C = -22.8\%$ 

Silty organic clay. *Comment:* 72% sample. Organic carbon content: ca 1.5%.

		$10,690 \pm 120$
Lu-2498.	Heikkilla Lake, 1.235–1.27m	$\delta^{13}C = -19.8\%0$

Clayey algal gyttja. *Comment:* 56% sample. Organic carbon content: ca 11%. (3 1-day counts.)

		$10,110 \pm 150$
Lu-2499.	Heikkilla Lake, 1.15–1.19m	$\delta^{I3}C = -16.2\%$

Algal gyttja. Comment: 62% sample. Organic carbon content: ca 19%.

### S Lempia Lake

Alt 446.5m. Lake has 2 separate basins. Water depth at coring points: 3m in Basin I and 7m in Basin II.

## Lu-2555. S Lempia Lake I, 6.46–6.51m $12,050 \pm 240$ $\delta^{13}C = -25.4\%$

Silty organic clay. *Comment:* 25% sample. Organic carbon content: ca 0.7%. (4 1-day counts.)

		$11,380 \pm 100$
Lu-2500.	S Lempia Lake I, 6.32–6.42m	$\delta^{13}C = -26.7\%$

Sandy, gravelly, organic clay with mosses. *Comment:* organic carbon content: ca 2%.

## $10,660 \pm 160$

## Lu-2501. S Lempia Lake I, 6.18–6.23m $\delta^{I3}C = -22.7\%$

Clay gyttja. *Comment:* 38% sample. Organic carbon content: ca 1.5%. (3 1-day counts.)

## Lu-2502.S Lempia Lake II, 2.90–2.96m $11,500 \pm 550$ $\delta^{I3}C = -25.3\%_0$

Slightly organic clay. *Comment:* 17% sample. Organic carbon content: ca 0.5%. (4 1-day counts.)

**7580** ± 90Lu-2503. S Lempia Lake II, 2.70–2.75m $\delta^{13}C = -29.2\%$ 

Clayey algal gyttja. *Comment:* 79% sample. Organic carbon content: ca 15%.

#### Swamp Lake

Alt 438m. Coring made in peat at lake shore.

		$9510~\pm~90$
Lu-2504.	Swamp Lake, 5.12–5.19m	$\delta^{13}C = -24.3\%00$
0	ad Commente arrania carbon contente ca 9	50%

Organic sand. *Comment:* organic carbon content: ca 2.5%.

		$8890~\pm~80$
Lu-2505.	Swamp Lake, 5.0-5.05m	$\delta^{I3}C = -26.8\%00$

 $450 \pm 45$ 

 $420 \pm 45$ 

Sandy, muddy, peat. *Comment:* organic carbon content: ca 15%.

#### Sabin Lake

Alt 416m. Lake has 2 separate basins. Water depth at coring points: 5.2m in Basin I and 5.3m in Basin II.

		$10,230 \pm 120$
Lu-2506.	Sabin Lake I, 3.97–4.05m	$\delta^{13}C = -28.4\%$

Clayey, silty, gyttja. Comment: 70% sample. Organic carbon content: ca 4%.

		$10,320 \pm 170$
Lu-2507.	Sabin Lake II, 3.25–3.31m	$\delta^{13}C = -29.1\%$

Clay gyttja. *Comment*: 65% sample. Organic carbon content: ca 5%.

#### **RESERVOIR AGE SAMPLES**

#### Kristineberg series

Shells and soft organic parts of bivalves coll alive in 1946 by A Hillefors in Gunnarsfjärden, outside Kristineberg (58° 15' N, 11° 26' E), Swedish W coast. Subm 1976 by collector. Dated to gain more information about reservoir effects in coastal waters of W Sweden.  $\delta^{13}$ C value of bivalve meat is of special interest for research on influence of marine food on <sup>14</sup>C age of humans who lived in coastal areas (see eg, Tauber, 1981a,b; Chisholm, Nelson & Schwarz, 1982).

#### $\delta^{13}C = +2.3\%$ Lu-1782. Kristineberg, shells

Shells (Cyprina islandica) from one comparatively young specimen. Comment: expected <sup>14</sup>C age of mollusks living in 1946 is 110  $\pm$  20 BP, corrected for reservoir effects (see Olsson, 1980, p 670). Thus, reservoir age is  $340 \pm 50$  yr.

#### $\delta^{13}C = -20.1\%$ Lu-1781. Kristineberg, organic parts

Organic parts of 2 bivalves (Cyprina islandica); one used for Lu-1782, above, and one larger specimen. Comment: expected reservoir-corrected <sup>14</sup>C age:  $110 \pm 20$  BP. Reservoir age:  $310 \pm 50$  yr.

General Comment: mean value for reservoir age for Swedish W coast based on previous measurements of 4 samples in this lab is  $340 \pm 30$  yr (Olsson,

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1980, fig 6, p 673). Corrections for deviations from  $\delta^{13}C = -25\%$  PDB are applied also for these samples.

#### Långören series

Seaweed and terrestrial moss coll ca AD 1900 for insulation in house built on Långören I., Torhamn archipelago, SE Blekinge, S Sweden (56° 04' N, 15° 50' E). Subm by B Berglund. Dated to gain more information about reservoir effects in S Baltic Sea. Moss was intended as ref sample for atmospheric <sup>14</sup>C level in area at time of colln. Material pretreated with HCl.

		010 1 10
Lu-1867.	Långören 1900, Zostera	$\delta^{13}C = -9.5\%$

Seaweed (*Zostera marina*). Comment: expected <sup>14</sup>C age of marine plants living in AD 1900 is 110  $\pm$  20 BP corrected for reservoir effects (Olsson, 1980, fig 4, p 670 and table 3, p 671). Thus, reservoir age is 230  $\pm$  45 yr. Previous measurements on marine plants from S Baltic Sea (St-1468, -1469, -1474, -1517) yielded values between 210  $\pm$  75 and 250  $\pm$  65 yr for reservoir age (Olsson, 1980, p 671), in good agreement with our value. (3 1-day counts.)

		$160 \pm 40$
Lu-1868I.	Långören 1900. Hvlocomium 1	$\delta^{13}C = -27.0\%$

Terrestrial moss (*Hylocomium splendens*). Comment: expected <sup>14</sup>C age of terrestrial plants living in AD 1900 is  $85 \pm 15$  BP (see Stuiver, 1982, p 8). Thus, reservoir age is  $75 \pm 45$  yr. (3 1-day counts.)

# 140 $\pm$ 45Lu-1868II.Långören 1900, Hylocomium 2 $\delta^{13}C = -27.5\%$

Other portion of same moss as used for Lu-1868I, above. *Comment:* dated to try to confirm reservoir age of terrestrial moss. Reservoir age:  $55 \pm 50$  yr. Olsson (1980, p 668) found reservoir age of  $115 \pm 95$  yr for terrestrial animal (*Alces alces*) from SE Sweden.

*General Comment:* corrections for deviations from  $\delta^{13}C = -25\%$  PDB are applied also for these samples.

#### **RECENT PLANT SAMPLES**

Results are given as difference,  $\Delta$ , from our <sup>14</sup>C standard (95% activity of NBS oxalic acid standard No. 4990A, age corrected to 1950):

$$\Delta = \delta^{14} C - (2\delta^{13} C + 50) \left( 1 + \frac{\delta^{14} C}{1000} \right)$$

where  $\delta^{14}$ C is observed deviation from <sup>14</sup>C standard in per mil and  $\delta^{13}$ C deviation from PDB standard in per mil.

#### **Terrestrial plant series (II)**

Various plant materials coll to determine atmospheric <sup>14</sup>C activity. Measured as complement to previous series (R, 1977, v 19, p 439). All samples coll by S Håkansson.

340 + 40

 $\Delta = 356 \pm 6.0\%$  $\delta^{I3}C = -23.2\%$ 

## Lu-1783. Skrylle 1977, Picea

Wood from outermost tree ring from stump of *Picea abies* cut down Dec 1977, ca 400m E of Recreation Center Skryllegården (55° 41′ 40″ N, 13° 22′ E). *Comment:* pretreated with HCl and NaOH. Clean air ref value for German Federal Republic is  $\Delta = 338 \pm 3\%$  for growing season of 1977 (Levin, Münnich & Weiss, 1980, p 386; Segl *et al*, 1983, p 583, footnote 1).

	_	$\Delta = 352 \pm 5.9\%$
Lu-1784.	Åmossen 1977, <i>Carex</i>	$\delta^{I3}C = -25.7^{\prime}/600$

Sedge (*Carex* sp) coll Oct 23, 1977 at shore of lake at Åmossen, S Scania (55° 27' 10" N, 13° 15' 30" E). *Comment:* pretreated with HCl.

		$\Delta = 305 \pm 6.0\%$
Lu-1978.	Måryd 1978, <i>Juncus</i>	$\delta^{I3}C = -27.2^{0}/00$

Juncus sp coll July 7, 1978 at shore of pond at Måryd, S Scania (55° 42' 05" N, 13° 22' 25" E). Comment: no pretreatment.

		$\Delta = 284 \pm 4.9\%$
Lu-1889.	Mästermyr 1980, Sesleria	$\delta^{13}C = -25.0\%$

Grass (*Sesleria caerulea*) growing on marl from newly dried wet area on calcareous bedrock at Mästermyr, SW Gotland (57° 13′ 45″ N, 18° 18′ 15″ E). Coll May 20, 1980. *Comment:* pretreated with HCl. (3 1-day counts.) No indication of carbon uptake from marl (*cf* Lu-1938, below).

		$\Delta = 287 \pm 4.8\%_{00}$
Lu-1938.	Skrylle 1980, Luzula	$\delta^{I3}C = -28.2^{0}/_{00}$

Rush (*Luzula pilosa*) growing on noncalcareous soil on quartzite bedrock, 600m E of Recreation Center Skryllegården (55° 41′ 40″ N, 13° 22′ 25″ E). Coll May 31, 1980. Measured as ref for atmospheric <sup>14</sup>C activity close to ground during spring of 1980 for comparison with Lu-1889, above. *Comment:* pretreated with HCl. (3 1-day counts.)

		$\Delta = 286 \pm 6.2\%$
Lu-1946.	Måryd 1980, Juncus	$\delta^{13}C = -27.0^{0}$

*Juncus* sp coll Sept 14, 1980 at same loc as Lu-1978, above. *Comment:* no pretreatment.

		$\Delta = 269 \pm 5.9\%$
Lu-1980.	Måryd 1981, Juncus	$\delta^{I3}C = -27.6^{'0}/_{00}$

*Juncus* sp coll Oct 4, 1981 at same loc as Lu-1978 and -1946, above. *Comment:* no pretreatment.

## Submerged plant series (II)

Recent submerged plants from 2 Scanian lakes; coll by S Håkansson. Measured as complement to previous series (R, 1977, v 19, p 437). Lu-2016. Bysjön 1976, Enteromorpha  $\Delta = 321 \pm 6.0\%$  $\delta^{13}C = -12.7\%$ 

Green tubeformed algae (*Enteromorpha intestinalis*) from Lake Bysjön, S Scania (55° 40′ 30″ N, 13° 33′ E). Coll Sept 29, 1976. *Comment:* pretreated with HCl.

Lu-1844. Odensjön 1979, algae 
$$\Delta = 71 \pm 5.2\%_{00}$$
  
 $\delta^{13}C = -27.8\%_{00}$ 

Various algae washed from *Myriophyllum* coll Sept 30, 1979 in Lake Odensjön, NW Scania (56° 00' 15" N, 13° 16' 45" E). *Comment:* no pretreatment.

Lu-1986	Odensiön 1980. Myriophyllum	$\Delta = 73 \pm 5.4\%_{00}$ $\delta^{13}C = -19 3\%_{00}$
Lu-1980.	Odensjon 1980, <i>Myriopnyllum</i>	0 C = -19.5%00

Myriophyllum alterniflorum from Lake Odensjön. Coll Oct 5, 1980. Comment: pretreated with HCl.

#### ARCHAEOLOGIC SAMPLES

#### Sweden

## Ängdala series (III)

Charcoal and wood from flint mines (Olausson, Rudebeck & Säfvestad, 1980; Ringberg & Rudebeck, 1982) at Ängdala, S Sallerup parish, S Scania. Coll 1981 and 1983 and subm by E Rudebeck, Inst Archaeol, Univ Lund. For other dates from area, see R, 1980, v 22, p 1058; 1981, v 23, p 398; 1984, v 26, p 408. Lu-2508 and -2509 pretreated with HCl and NaOH. Lu-2510 with HCl only.

Lu-2508.Ängdala 1981, MHM 6434 $2800 \pm 50$  $\delta^{13}C = -26.5\%$ 

Charcoal from fill layer in flint mine, depth ca 1.6m, Structure 62 (55° 35' 30" N, 13° 07' 30" E), alt 27.5m. Assoc with flint waste, bone, antler, and pottery indicating Early Neolithic culture. *Comment:* no explanation for too late  $^{14}$ C date.

		$4990 \pm 60$
Lu-2510.	Ängdala 1983:2	$\delta^{13}C = -26.5\%00$

Charcoal from fill layer in flint mine (No. 24, Area C), depth ca 3.1m, alt ca 24m. Close to site for Lu-2508, above. Assoc with flint waste. Estimated to be of Early Neolithic Age since wood from nearby flint mine (No. 25) was dated at  $4960 \pm 70$  BP (Lu-2212: R, 1984, v 26, p 408).

## Lu-2509. Ängdala 1983, MHM 6655 $\delta^{13}C = -27.6\%$

Wood (No. 6) from Structure 220, Tr 4, in Neolithic flint mine (55° 35′ 25″ N, 13° 07′ 10″ E), depth ca 2m, alt ca 21.5m. Assoc with flint waste.

## **Fosie Series II**

Charcoal from settlement area (Settlement I) with traces (*eg*, posthole marks) of houses with assoc artifacts indicating Late Bronze Age (Björhem & Säfvestad, 1983; Björhem, ms, 1983) at Fosie, Lockarp parish, S Scania (55° 33' 15" N, 13° 03' 20" E). Coll 1979 and subm by N Björhem, Inst Archaeol, Univ Lund. For other dates from area, see Fosie Series I (R, 1984, v 26, p 408).

		$2870 \pm 50$
Lu-2519.	Fosie IV, MHM 6185:331a	$\delta^{13}C = -25.6\%$

Charcoal from Pit A, Level IV, depth 0.6 to 0.8m. Assoc with pottery, flint, bone, and crucible. *Comment:* normal pretreatment with HCl and NaOH.

		2520 ± 70
Lu-2520.	Fosie IV, MHM 6185:84	$\delta^{I3}C = -25.7\%$

Charcoal from basal layer in large pit, Sq 52/63, Level V. Assoc with bronze object, pottery, flint, and bone. *Comment:* mild pretreatment with HCl and NaOH. Sample undersized; diluted; 54% sample.

		$2560 \pm 70$
Lu-2521.	Fosie IV, MHM 6185:80	$\delta^{13}C = -26.7\%$

Charcoal from Pit E, Level IV, depth ca 0.5 to 0.7m. Assoc with pottery, flint, and bone. *Comment:* mild pretreatment with HCl and NaOH. Sample undersized; diluted; 62% sample.

## Lu-2522. Fosie IV, MHM 6185:109 $\delta^{l3}C = -25.5\%_0$

Charcoal from pit, Sq D, Level III, depth ca 0.3m. Assoc with bronze object, pottery, flint, and bone. *Comment:* mild pretreatment with HCl and NaOH. Sample undersized; diluted; 55% sample.

		$2620 \pm 50$
Lu-2523.	Fosie IV, MHM 6185:180	$\delta^{I3}C = -25.4\%$

Charcoal from Pit I, Sq C, Level IV, depth ca 0.5 to 0.7m. Assoc with pottery, flint, and bone. *Comment:* normal pretreatment with HCl and NaOH.

## Jonstorp series

Charcoal from Middle Neolithic settlement area (Pitted Ware culture?) at Jonstorp, NW Scania (56° 13' N, 12° 40' E). Coll by A Wihlborg; subm by A Carlie, Inst Archaeol, Univ Lund. Dated as part of study of cultural characteristics and chronologic relations between different sites in area.

Lu-2592.Jonstorp M3, x = 10, y = 12 $4120 \pm 60$  $\delta^{13}C = -24.3\%$ 

Charcoal from x = 10, y = 12, Layer 4. *Comment:* mild HCl pretreatment.

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3850 + 60

4130  $\pm$  70Lu-2593. Jonstorp M3, x = 15.4, y = 10 $\delta^{13}C = -25.3\%_0$ 

Charcoal from x = 15.4, y = 10, Layer 4. *Comment:* no pretreatment; sample undersized; diluted; 66% sample.

#### **Battle Axe culture series**

Charcoal and hazelnut hulls from settlement areas (Battle Axe culture) at Kabusa (55° 25′ N, 13° 57′ E) and Ullstorp (55° 31.5′ N, 13° 58′ E), S Scania. Coll 1960 by R Petré (Lu-2554) and 1986 by M Larsson; subm by L Larsson, Inst Archaeol, Univ Lund. Human bone collagen from Battle Axe culture grave at St Beddinge dated at 3740  $\pm$  60 BP (Lu-2464: R, 1986, v 28, no. 3, p 1128). Lu-2630 received mild pretreatment with NaOH and HCl; normal pretreatment with HCl and NaOH for other samples.

			$000 \pm 00$
Lu-2554.	Ullstorp	$\delta^{I3}C =$	-25.8%

Charcoal from post hole, Grave 1, Ullstorp 11, Ullstorp parish. Assoc with pottery and flint tools.

		$3960~\pm~70$
Lu-2630.	Kabusa, Anl 21	$\delta^{13}C = -28.1\%$

Charcoal and few hazelnut hull fragments from Structure 21 at Kabusa, St Köpinge parish. *Comment:* sample undersized; diluted; 74% sample.

		$3920 \pm 60$
Lu-2631.	Kabusa, Anl 22	$\delta^{I3}C = -25.5\%$

Hazelnut hulls and few charcoal fragments from Structure 22 at Kabusa. Assoc with pottery.

#### **Fairyhill series**

Charcoal from settlement area with artifacts indicating Late Mesolithic to Late Neolithic culture at Fairyhill 12:3, Stehag parish, central Scania (55° 55′ N, 13° 26′ E). Coll 1985 by L Carlie; subm by L Larsson. Lu-2628 received mild pretreatment with NaOH and HCl. Normal pretreatment with HCl and NaOH for other samples.

		$4810 \pm 60$
Lu-2546.	Fairyhill 12:3, Anl 117A	$\delta^{I3}C = -27.0\%$

Charcoal from Structure 117A. Assoc with pottery and flint tools.

		$2190~\pm~50$
Lu-2547.	Fairyhill 12:3	$\delta^{I3}C = -25.9\%$

Charcoal from x = 96, y = 136. Assoc with flint tools. *Comment:* Mesolithic date expected, but flint tools or charcoal apparently reworked. Lu-2627. Fairyhill 12:3, Anl 3  $\delta^{13}C = -26.6\%$ 

 $5920 \pm 90 \\ \delta^{13}C = -26.2\%$ 

Charcoal from Structure 3, x = 95, y = 197. Assoc with pottery and flint artifacts. *Comment:* somewhat earlier than expected but reasonable.

		$5900~\pm~100$
Lu-2628.	Fairyhill 12:3, Anl 10A	$\delta^{13}C = -27.1\%$

Charcoal from Structure 10A, Sect VI. Assoc with flint tools. *Comment:* sample undersized; diluted; 51% sample.

		$5710 \pm 70$
Lu-2629.	Fairyhill 12:3, Anl 61	$\delta^{I3}C = -25.9\%_{00}$

Charcoal from Structure 61, Sect III:E. Assoc with flint tools and pottery.

#### Lu-2553. Skateholm IX

Charcoal from x = 906, y = 904 to 905, Layer 2, at Ö Vemmenhög 1:11, S Scania (55° 23′ 20″ N, 13° 29′ 30″ E). Skateholm IX is Ertebølle culture settlement in E part of Skateholm settlement area (R, 1986, v 28, p 155). Assoc with flint tools. *Comment:* mild pretreatment with NaOH and HCl. Sample undersized; diluted; 66% sample.

#### **Ystad project series**

Charcoal from various sites in area around Ystad. Archaeol study is part of interdisciplinary proj on dynamics of human influence on landscape in Ystad area, S Scania (Larsson, 1986; Olausson, 1986). Coll 1985 by M Larsson and M Regnell; subm by M Larsson, Inst Archaeol, Univ Lund.

**Lu-2548.** St Herrestad  $\delta^{13}C = -25.3\%_0$ 

Charcoal from hearth (Structure 7) at St Herrestad 68:103, St Herrestad parish (55° 27′ 30″ N, 13° 52′ 40″ E). Assoc with flint and pottery indicating Middle Neolithic Age. *Comment:* normal pretreatment with HCl and NaOH. Date unexpectedly late for unknown reason.

		$680 \pm 45$
Lu-2549.	Trunnerup	$\delta^{I3}C = -27.2\%$

Charcoal from hearth at Trunnerup 4:3, Villie parish (55° 30' N, 13° 38' E). Assoc with flint and pottery indicating Early Neolithic Age. *Comment:* normal pretreatment with HCl and NaOH. Apparently no connection between charcoal and artifact assemblage.

		$1210 \pm 60$
Lu-2550.	Mossby 27:1, Anl 131	$\delta^{13}C = -25.7\%$

Charcoal from Structure 131 near clay wall of Early Neolithic Age at Mossby 27:1, W Nöbbelöv parish (55° 25′ N, 13° 37′ E). Assoc with flint and pottery from older part of Early Neolithic Age. *Comment:* no pretreatment; sample undersized; diluted; 72% sample. Date unexpectedly late for unknown reason. In nearby part of Mossby area Iron Age settlement was excavated in Aug 1985 (D Olausson, pers commun, 1986).

#### Lu-2552. Mossby 27:1, Anl 84 and 85

 $6480 \pm 70 \\ \delta^{13}C = -25.7\%0$ 

Charcoal from 2 pits (Structures 84 and 85) at same site as Lu-2550, above. Same artifact assemblage as Lu-2550. *Comment:* mild pretreatment with NaOH and HCl. Somewhat earlier than expected, but reasonable.

#### Lu-2551. Gånarp

 $\frac{2940 \pm 60}{\delta^{13}C = -25.6\%}$ 

Charcoal from fill in remainder of kiln, depth ca 0.4m, at Gånarp 6:1, Tostarp parish, NW Scania (56° 17' 10" N, 12° 56' 20" E). Coll Oct 1985 and subm by A Löfgren, Riksantikvarieämbetet, UV-Syd, Lund. Assoc with slag indicating Early Iron Age. *Comment:* mild pretreatment with NaOH and HCl.

### Hässlehult series

Charcoal from settlement area (Ertebølle culture) at Hässlehult 1:1, Ryssby parish, W Småland (56° 49.5′ N, 16° 22′ E). Coll 1984 by E Westergren and M Rasch; subm by E Westergren, Inst Archaeol, Univ Lund.

# 7040 ± 70 Lu-2563. Hässlehult, Sample 1 $\delta^{I3}C = -25.8\%_0$

Charcoal from soot-mixed sand, Sq 113/110, depth 0.4m. Assoc with flint waste. *Comment:* normal pretreatment with HCl and NaOH.

Lu-2564. Hässlehult, Sample 2  $\delta^{I3}C = -26.0\%$ 

Charcoal particles from soot-mixed sand layer below ploughed surface layer. Assoc with micro-chips and flint waste. *Comment:* mild HCl pretreatment. Sample undersized; diluted; 62% sample.

#### Nymölla series (IV)

Charcoal from coastal settlement area (Middle Neolithic—Pitted Ware culture and Battle Axe culture) at Nymölla, Gualöv parish, NE Scania (56° 02' N, 14° 28' E). Coll May 1985 and subm by B Wyszomirska, Inst Archaeol, Univ Lund. For previous dates from area, see R, 1982, v 24, p 210; 1984, v 26, p 407; 1986, v 28, no. 3, p 1130. Normal pretreatment with HCl and NaOH.

## Lu-2557. Nymölla III, XIV/14 $\delta^{13}C = -25.1\%$

Charcoal from occupation layer, Sq XIV/14, +7.5 to 7.62m. Assoc with pottery and flint implements.

		$3300 \pm 60$
•	Nymölla III, XV/15	$\delta^{13}C = -25.8\%$

Charcoal from occupation layer, Sq XV/15, +7.34m. Assoc with pottery and flint implements.

## Lu-2559. Nymölla III, XVI/15 $3470 \pm 60$ $\delta^{13}C = -25.5\%$

Charcoal from occupation layer, Sq XVI/15, +7.6m. Assoc with pottery, flint implements, and animal bones.

*General Comment:* estimated date ca 4600 to 4000 BP, based on artifact assemblage. No explanation for deviating dates.

## Lu-2567. Jägershill, MHM 6206 $\delta^{13}C = -21.9\%$

Collagen from animal bone (*Bos*) from occupation layer, Structure 1, Sq 15/10, at Jägershill, S Malmö, SW Scania (55° 34' N, 13° 03' E). Coll 1979 and subm by M Svensson, Inst Archaeol, Univ Lund. Assoc with flint implements and Middle Neolithic Funnelbeaker pottery of early type. *Comment:* organic carbon content: 1.6%. Collagen extracted as described previously (R, 1976, v 18, p 290), without NaOH treatment. Sample undersized; diluted; 69% sample.

## Lu-2568. Hindbymosse, MHM 1505

 $\frac{4430 \pm 70}{\delta^{13}C = -22.8\%_{00}}$ 

 $4440 \pm 70$ 

Collagen from animal bone (*Bos*) from occupation layer, x-39, y-6, at Hindbymosse, S Malmö, S Scania (55° 34' N, 13° 02' E). Coll 1968 by unknown; subm by M Svensson. Assoc with flint implements and Funnelbeaker pottery from middle part of Middle Neolithic Age. *Comment:* collagen extracted as for Lu-2567, above. Organic carbon content: 1.4%. Sample undersized; diluted; 74% sample.

## Skanör—Falsterbo series

Charcoal from settlement areas at Skanör and Falsterbo, SW Scania. Coll Aug 1985 and subm by L Ersgård, Inst Archaeol, Univ Lund. Dating is part of study of chronology and structural changes of settlement in area during Early and High Medieval time. Normal pretreatment with HCl and NaOH.

**Lu-2579.** Skanör 1985:1 $930 \pm 50$ Charcoal from Layer 4, Tr D, Strandvallen, Skanör (55° 23' 05" N, 12°50' E).

		$1030 \pm 45$
Lu-2580.	Skanör 1985:2	$\delta^{I3}C = -25.9\%_{00}$

Charcoal from Layer 11, Tr D. Same site as Lu-2579, above.

Lu-2558

		550 ± 45
Lu-2581.	Falsterbo 1985	$\delta^{I3}C = -26.7\%$

Charcoal from Layer E, Tr A, Grumbodarna, Falsterbo (55° 23' 21" N, 12° 49' 11" E). *Comment:* date somewhat later than expected.

### **Käglinge Gravel Pit series**

Charcoal from settlement area (Late Neolithic to Bronze Age) at Glostorp 10:7, ca 1.5km WNW of Käglinge, SW Scania (55° 32.2' N, 13° 3.5' E). Excavation of area necessitated by industrial exploitation. Subm by R Thörn and B Nielsen, Malmö Mus, Malmö.

		$2630 \pm 50$
Lu-2606.	Käglinge Grustäkt 1	$\delta^{13}C = -22.7\%0$

Finely disseminated powdery charcoal in sand and silt from hearth (Structure 25), +33.45 to +33.85m. Coll Aug 1982 by G Persson. *Comment:* pretreated with HCl.

		2840 ± 50
Lu-2607.	Käglinge Grustäkt 2	$\delta^{13}C = -21.4\%00$

Charcoal and soot in sand from hearth (Structure 27), +33.15 to +33.40m. Coll Aug 1982 by B Nielsen. Assoc with bone. *Comment:* pre-treated with HCl and NaOH.

		2900 ± 50
Lu-2608.	Käglinge Grustäkt 3	$\delta^{13}C = -26.0\%$

Charcoal from cooking pit (Structure 69), +33.14 to +34.05m. Coll Sept 1982 by B Nielsen. Assoc with flint. *Comment:* pretreated with HCl.

		$2820 \pm 50$
Lu-2609.	Käglinge Grustäkt 4	$\delta^{I3}C = -26.1\%0$

Charcoal from long hearth (Structure 128) in E part of settlement, +35.01 to +35.32m. Coll July 1982 by E Jonsson. Assoc with pottery. *Comment:* pretreated with HCl and NaOH.

		$2970 \pm 60$
Lu-2611.	Käglinge Grustäkt 5	$\delta^{I3}C = -26.2\%$

Charcoal from cooking pit (Structure 323), +33.13 to +33.83m. Coll Aug 1982 by B Nielsen. Assoc with flint. *Comment:* pretreated with HCl. Sample undersized; diluted; 85% sample.

		$2850 \pm 50$
Lu-2612.	Käglinge Grustäkt 6	$\delta^{I3}C = -25.8\%$

Charcoal from cooking pit (Structure 352), +33.36 to +33.96m. Assoc with flint. *Comment:* pretreated with HCl and NaOH.

					2940 ± 50
Lu-2613.	Käglinge Grus	täkt 7			$\delta^{13}C = -27.0\%$
<u></u>		10	a = 13	00.00	

Charcoal from cooking pit (Structure 374), +33.83 to +34.75m. Coll

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Sept 1982 by B Lindahl. Assoc with pottery and flint. *Comment:* pretreated with HCl and NaOH.

		$1590~\pm~50$
Lu-2614.	Käglinge Grustäkt 8	$\delta^{13}C = -24.4\%$

Charcoal from long hearth (Structure 558) at NW boundary of used area, +34.48 to +34.66m. Coll Dec 1983 by R Thörn. *Comment:* pretreated with HCl and NaOH.

		2930 ± 50
Lu-2615.	Käglinge Grustäkt 9	$\delta^{I3}C = -26.5\%$

Charcoal from cooking pit (Structure 643), +35.20 to +36.26m. Coll July 1982 by S Siech. Assoc with flint. *Comment:* mild pretreatment with HCl and NaOH.

		$2260 \pm 60$
Lu-2616.	Käglinge Grustäkt 10	$\delta^{I3}C = -26.4\%$

Charcoal from pit (Structure 661), +32.87 to +33.29m. Coll Aug 1982 by G Persson. Assoc with flint and bone. *Comment:* pretreated with HCl and NaOH. Sample undersized; diluted; 83% sample.

## 2090 $\pm$ 80Lu-2610. Fosie, RAÄ No. 93, MHM 6688 $\delta^{13}C = -26.3\%$

Small fragments and powder of charcoal from post holes (Long-House I) at Lot No. 4, Block Bronsdolken, Fosie parish, SW Scania (55° 33.4′ N, 13° 2.4′ E). Coll Oct 1983 and subm by B-Å Samuelsson, Malmö Mus, Malmö. House type indicates Early Iron Age. *Comment:* pretreated with HCl. Sample undersized; diluted; 34% sample. (3 1-day counts.)

# 940 $\pm$ 50Lu-2617. Tygelsjö, MHM 6718 $\delta^{13}C = -21.7\%$

Collagen from ill-preserved bone fragments of domestic animals from Structure 5, Tygelsjö, S Scania (55° 31' N, 13° 0.3' E). Coll April 1984 and subm by J Kling, Malmö Mus, Malmö. Assoc with posthole marks of long house indicating Late Iron Age. *Comment:* organic carbon content: 1.8%. Collagen extracted as described previously (R, 1976, v 18, p 290) without NaOH treatment. Sample undersized; diluted; 84% sample.

## **Elisedal series**

Charcoal from Viking Age settlement area at Block Tränsbettet and Stångbettet, Elisedal industrial area, S Scania (55° 34.1' N, 13° 4.6' E). Coll April 1983 and subm by J Kling. Pretreated with HCl and NaOH.

						$1610 \pm 45$
Lu-2618.	Eliseda	al, MHM	6553,	Sample 1		$\delta^{13}C = -26.2\%$
	c 1		C 1 11	(6	10.7	

Charcoal from basal layer of kiln (Structure 10:I).

## $1960 \pm 50$

 $\delta^{13}C = -26.7\%$ 

## Lu-2619. Elisedal, MHM 6553, Sample 2

Charcoal from Structure 10:IV. *Comment:* sample undersized; diluted; 91% sample.

*General Comment:* both dates earlier than expected from artifact assemblage on site.

## Verkeån series

Wood (*Fagus silvatica*), id by A Bråthen, Lab Dendrochronol, Trollhättan, from series of posts visible at low water N of mouth of Verkeån, Ravlunda parish, E Scania (55° 43.4′ N, 14° 12′ E). Coll March 1984 and May 1986 and subm by L Hansen, Malmö. Dating is part of interdisciplinary proj dealing with archaeol and Quaternary geol of Hanö Bay region (Hansen, 1986). Pretreated with HCl and NaOH, and charred in nitrogen atmosphere before burning.

Lu-2586.	Verkeån 3	$410 \pm 45 \\ \delta^{I3}C = -27.5\%$
Lu-2622.	Verkeån 6	$\frac{320 \pm 45}{\delta^{13}C = -26.5\%_{00}}$
Lu-2623.	Verkeån 29	$350 \pm 45$ $\delta^{13}C = -26.6\%$
Lu-2624.	Verkeån 58	$330 \pm 45$ $\delta^{13}C = -28.8\%00$
Lu-2625.	Verkeån 114	$310 \pm 60$ $\delta^{I3}C = -28.2\%$

*Comment:* sample undersized; diluted; 68% sample.

		$350 \pm 45$
Lu-2626.	Verkeån, kasun, södra	$\delta^{13}C = -26.6\%0$
Ca 2.8m b	elow sea level.	

### Åland

#### Otterböte series (II)

Peat from Tellmossen, ca 200m from Otterböte settlement area, Kökar I., Åland (59° 56' N, 20° 52' E). Coll Nov 1985 by I Påhlsson; subm by B Hulthén, Lab Ceramic & Clay Mineralogy, Dept Quaternary Geol, Univ Lund. For previous dates from Otterböte, see R, 1984, v 26, p 409. Assoc pottery indicates Bronze Age. Pretreated with HCl and charred in nitrogen atmosphere before burning. Depths (cm) refer to bog surface.

Lu-2602.	Otterböte, 165 to 175cm	$\frac{2570 \pm 50}{\delta^{13}C} = -24.5\%$
Lu-2603.	Otterböte, 155 to 165cm	$\frac{2430 \pm 50}{\delta^{13}C} = -24.7\%$
Lu-2604.	Otterböte, 145 to 155cm	$\frac{2330 \pm 50}{\delta^{I3}C = -27.7\%_0}$

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#### UNIVERSITY OF GRANADA RADIOCARBON DATES IV

# CECILIO GONZALEZ-GOMEZ, PURIFICACION SANCHEZ-SANCHEZ, and ELENA VILLAFRANCA-SANCHEZ

# Laboratorio de Datación por Carbono-14 and Instituto Andaluz de Geología Mediterránea del CSIC Facultad de Ciencias, Universidad de Granada, 18071 Granada, Spain

This date list contains the results of <sup>14</sup>C determinations of archaeologic samples from Spain and Portugal obtained at the Laboratory mostly from 1983 to July 1986. Preparation and measurements were made in the same manner as previously reported (R, 1982, v 24, no. 2, p 217–221; R, 1985, v 27, no. 3, p 610–615; R, v 28, no. 3, p 1200–1205).

The published intervals of corrected data for samples younger than 7250 BP are derived from Klein *et al* (1982) and appear as "cal" ages. Sample descriptions are based on information provided by submitters. Age determinations and research were done with the help of Research Project 0925/81, CAICYT, Spain.

#### ARCHAEOLOGIC SAMPLES

#### Spain

#### **Castillo de Escobedo series**

Charcoal from Castillo de Escobedo (43° 24' 12" N, 4° 10' 02" W), Camargo, Cantabria prov. Samples coll and subm 1983 by R Bohigas-Roldán, Mus Reg Prehist y Arqueol Santander, to date a humic level of dense ocupation.

UGRA-180.	No. 2	$930 \pm 110$

Cal AD 890-1265.

### UGRA-182. H-0 N1 SE $1190 \pm 110$

20cm depth; cal AD 610–1030.

General Comment: dates agree with expected ages.

#### UGRA-184. No. 1

 $860~\pm~130$ 

Wood from Torrejón-Las Henestrosas (42° 52′ 30″ N, 4° 12′ 05″ W), Las Henestrosas, Cantabria prov. Sample coll 1984 by A Sobremazas-Salcines and subm 1984 by R Bohigas-Roldán, to date occupation level of deposit. *Comment:* date agrees with expected age; cal AD 905–1325.

#### **Cova Santa series**

Charcoal from Cova Santa (38° 48' 20" N, 0° 53' 30" W), Fuente La Higuera, Valencia prov. Samples coll 1978 and subm 1983 by J Aparicio-Pérez, Dept Hist Antigua, Fac Geog & Hist, Univ Valencia, to date Eneolithic and Neolithic periods.

UGRA-188. LL3.C-5	
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 $5060~\pm~110$ 

Cal 4110–3650 вс.

UGRA-192. LL4.C-2	$2640 \pm 120$
90cm depth; cal 1105–520 вс.	
<b>UGRA-193. LL4.C-3</b> 90cm depth; cal 2890–400 BC.	$3260~\pm~900$
UGRA-196. LL4.C-6	$14{,}600~\pm~300$
20cm depth.	

General Comment: age for LL4.C-6 is probably too old.

# **Cueva del Toro series**

Charcoal from Cueva del Toro (37° 01' N, 4° 25' W), Sierra del Torcal, Málaga prov. Samples coll and subm 1983 by D Martín-Socas, Dept Arqueol & Prehist, Fac Geog & Hist, Univ La Laguna, Tenerife, Canary Islands, to date Neolithic and Eneolithic periods in Málaga prov.

UGRA-189.	No. 1

93cm depth; cal 1670-990 BC.

UGRA-194. No. 6

 $6400 \pm 280$ 

 $3090 \pm 130$ 

2.51m depth; cal 5775–4800 вс.

General Comment: dates agree with expected ages.

# **Piedrafita series**

Charcoal from Piedrafita (43° 26' 32" N, 5° 59' 07" W), Las Regueras, Oviedo prov, Asturias. Samples coll 1980 by M A Blas-Cortina and subm 1983 by J Fortea-Pérez, Dept Prehist, Fac Geog & Hist, Univ Oviedo, to date Megalithic chronology in Asturias.

UGRA-191.	No. 3-PFV.1	2610 + 110

35cm depth; cal 1035-430 BC.

UGRA-195.	No. 4—PFI.2	$2560 \pm 1$	10
UGRA-195.	No. 4—PFI.2	$2560 \pm 1$	1

80cm depth; cal 905–410 BC.

General Comment: expected age was ca 4500 BP for both samples.

# UGRA-197. M-1. Villar 1

 $\mathbf{2590} \pm \mathbf{100}$ 

Charcoal from Cerro de los Encaños (40° 03' 20" N, 2° 26' 40" W), Villar del Horno, Cuenca prov. Sample coll 1983 by A Gómez-Ruíz and subm 1984 by M Sierra-Delage, Mus Nac Etnolog, Madrid. Sample from 80cm depth. *Comment:* date agrees with expected age; cal 1010–425 BC.

# Fuente de la Mota series

Wood from Fuente de la Mota (39° 39′ 18″ N, 2° 03′ W), Barchín Hoyo, Cuenca prov. Samples coll 1981 and subm 1984 by M Sierra-Delage.

UGRA-199.	4F (81)	$2070 \pm 410$
55cm depth	; cal 770 bc–ad 425.	

UGRA-202.	3H (81)	$2360 \pm 90$
95 and denths	-1770,905 pc	

35cm depth; cal 770–205 BC. General Comment: dates agree with expected ages.

# **Cova Matutano series**

Charcoal from Cova Matutano (40° 06' 50" N, 0° 02' E), Villafamés, Castellón de la Plana prov. Samples coll 1984 and subm 1985 by F Gusi-Jener, Research Service Archaeol & Prehist County Council, Castellón de la Plana, to date Upper Paleolithic in Castellón de la Plana prov.

UGRA-201.	Mat.84.2.N-IC7	$12,460 \pm 180$
<b>UGRA-208.</b> 2.6m depth.	8bis-N.1C5.P.260	13,220 ± 270
<b>UGRA-225.</b> 3.2m depth.	9-10-N.1C8	13,370 ± 260
<b>UGRA-241.</b> 2.19m depth.	3-N.1C.P.219	11,590 ± 150
<b>UGRA-242.</b> 2.35 to 2.44m	<b>6-N.1C3.P.235–244</b> a depth.	11,570 ± 210
<b>UGRA-243.</b> 2.2m depth.	4-N.1C1.P.220	11,410 ± 610
<b>UGRA-244.</b> 2.35 to 2.44m	<b>7-N.1C4.P.235–244</b> n depth.	$12,520 \pm 350$

General Comment: dates agree with expected ages.

# Sierra Plana de la Borbolla series

Charcoal from Sierra Plana de la Borbolla (43° 23' 24" N, 4° 37' 41" W), Buelna, Llanes, Oviedo prov, Asturias. Samples coll and subm 1983 by P Arias-Cabal, Dept Prehist, Univ Santander, to date Chalcolithic and Megalithic periods in N Iberian peninsula.

UGRA-205. SV 83D 0–7 N 2	$580~\pm~80$
15cm depth; cal AD 1265–1425.	
UGRA-206. SV 83 D N 6-7 N 2	$600~\pm~90$
15cm depth; cal AD 1250–1420.	

UGRA-209. SV 82 C E2/3 N 1C 7550	±	1	9	)(
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General Comment: expected ages were ca 4000 BP.

# Hoya Quemada series

Charcoal from Hoya Quemada (40° 14′ 55″ N, 0° 44′ 01″ W), Mora de Rubielos, Teruel prov. Samples coll and subm 1983 by F Burillo-Mozota, Colegio Univ Teruel, to date Bronze Age in Aragon.

UGRA-207. No. 1 C.5I-13 2.19m depth; cal 2990–2325 BC.	$4070~\pm~190$
<b>UGRA-211.</b> No. 2 C.5I-5 2.23m depth; cal 1770–1370 BC.	$3260~\pm~100$
<b>UGRA-212.</b> No. 2 C.11 I 0.70m depth; cal 2055–1595 BC.	$3450~\pm~90$
<b>UGRA-213.</b> No. 4 C.11 H 1.61m depth; cal 1980–1555 bC.	$3420\pm100$

General Comment: expected age for UGRA-207 was 3400 BP.

UGRA-214.	MBI/II/1	

Charcoal from El Jardinero (39° 23' N, 7° 10' W), Valencia de Alcántara, Cáceres prov. Sample coll and subm 1983 by P Bueno-Ramírez, Dept Prehist, Univ Alcalá de Henares, Madrid, from 2.67m depth. *Comment:* date agrees with expected age; cal 570–5 BC.

 $\mathbf{2210}\,\pm\,\mathbf{110}$ 

# Cerro de la Mora series

Charcoal from Cerro de la Mora (37° 13' 31" N, 3° 59' 07" W), Moraleda, Granada prov. Samples coll and subm 1985–1986 by J Carrasco-Rús and M Pastor-Muñoz, Dept Prehist, Univ Granada, to date end of Bronze Age in Granada prov.

<b>UGRA-217. TABLA 12</b> 2.20m depth; cal 2470–1870 вс.	$3690~\pm~90$
<b>UGRA-218. CAPA 10</b> 2m depth; cal 1385–855 BC.	$2920~\pm~90$
<b>UGRA-231. TABLA 3</b> 1m depth; cal 1085–610 вс.	$2670~\pm~100$
<b>UGRA-232. CAPA 9</b> 1.60m depth; cal 1070–615 вс.	$2670~\pm~90$
<b>UGRA-235. САРА 42</b> 7m depth; cal 1200–675 вс.	$2740~\pm~90$

UGRA-262. Fortificación	$3710~\pm~90$
From 2.40 to 3m depth; cal 2475–1885 BC.	
UGRA-263. CM/86/CV-B	$2990~\pm~90$
3m depth; cal 1495–905 вс.	
UGRA-264. CM/V-869 (Botón)	$2850~\pm~90$

2.90m depth; cal 1320-810 BC.

General Comment: dates agree with expected ages.

# Los Castillejos de Sanchorreja series

Charcoal from Los Castillejos de Sanchorreja (40° 39' 40" N, 4° 52' 20" W), Sanchorreja, Avila prov. Samples coll 1981 and subm 1984 by F J González-Tablas-Sastre, Dept Prehist & Arqueol, Univ Salamanca, to date end of Bronze Age in N Meseta.

UGRA-237. C-1.VI $3670 \pm 10$	00
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1.60m depth; cal 2390–1774 BC.

#### UGRA-238. C-1.V $\mathbf{3770} \pm \mathbf{90}$

1.20m depth; cal 2530–1945 BC.

*General Comment:* ages probably a little older than expected.

# UGRA-254. SCH-80/D-12

Charcoal from Cueva Chica de Santiago (38° 00' 48" N, 5° 55' 07" W), Cazalla de la Sierra, Sevilla prov. Sample coll 1980 and subm 1983 by P Acosta-Martínez, Dept Prehist & Arqueol, Univ Sevilla, to date start of Neolithic period in Sierra Morena. Sample from 2.70m depth. Comment: expected age was ca 7000 BP; cal 5325-4910 BC.

# Cueva de Nerja series

Seeds and charcoal from Cueva de Nerja (36° 45′ 45″ N, 3° 50′ 55″ W), Maro, Nerja, Málaga prov. Samples coll 1980–1982 and subm 1983 by M Pellicer-Catalán, Dept Prehist & Arqueol, Univ Sevilla, to date Chalcolithic and start of Neolithic periods in Andalusian coast.

# UGRA-255. NM-80/B/2

 $5190 \pm 90$ 

0.70m depth; cal 4295–3780 BC.

# UGRA-261. NT-82/9

1.40m depth; cal 5360–4925 BC.

General Comment: expected age for UGRA-261 was ca 7000 BP.

# UGRA-259. DE-81/13-NW

 $6260 \pm 100$ 

Charcoal from Cueva de la Dehesilla (36° 39' 45" N, 5° 38' 40" W), Algar, Cádiz prov. Sample coll 1981 and subm 1983 by P Acosta-Martínez, to date start of Neolithic period in S Iberian peninsula. Sample from 3.60m depth. Comment: expected age was ca 7500 BP; cal 5455–4960 BC.

 $6200 \pm 100$ 

 $6160 \pm 100$ 

#### UGRA-260. C.T.I/1

Bones from Sepulcro 1 Cortijo del Tardón (37° 01' N, 4° 33' W), Antequera, Málaga prov. Sample coll and subm 1986 by J E Ferrer-Palma, Dept Prehist & Arqueol, Fac Filosof & Letras, Univ Málaga, to date Megalithic culture in Málaga prov. *Comment:* expected age was ca 4000 BP; cal 2140– 1690 BC.

#### UGRA-233. 6-C.10E-S.6

 $\mathbf{3760} \pm \mathbf{100}$ 

Charcoal from Cueva del Coscojar (40° 17' 00" N, 0° 41' 10" W), Mora de Rubielos, Teruel prov. Sample coll 1982 and subm 1983 by F Burillo-Mozota, Colegio Univ Teruel, to date Middle Bronze Age and Eneolithic period in Levante and Ebro valley. *Comment:* expected age was ca 2600 BP; cal 2530–1910 BC.

#### Portugal

#### **Castelo de Aguiar series**

Charcoal from Castelo de Aguiar (41° 28′ 07″ N, 7° 38′ 17″ W), Teloes, Vila Pouça de Aguiar, Tras os Montes prov. Samples coll and subm 1983 by S M Soares-Oliveira, Inst Arqueol, Fac Letras, Univ Porto, to date recent prehist in N Portugal.

UGRA-179. CST AGR 83-2	$4700 \pm 100$
2m depth; cal 3775–3170 вс.	
UGRA-181. CST AGR 83-4	$2730 \pm 140$
1.10m depth; cal 1245–610 BC.	
UGRA-185. CST AGR 83-3	$3930\pm180$

1.10m depth; cal 2900–2015 BC.

General Comment: age for CST AGR 83-4 is probably a little younger.

# UGRA-203. No. 7

 $\mathbf{2550} \pm \mathbf{100}$ 

Seeds from Castro de Romariz (41° 51′ 52″ N, 8° 37′ 37″ W), Romariz, Vila da Feira, Aveiro prov. Sample coll 1982 by R M Sobral-Centeno and subm 1984 by A Coelho-Ferreira-da-Silva, Fac Letras, Univ Porto. *Comment:* date agrees with expected age; cal 865–415 BC.

#### UGRA-221. 1/CU-84/5.V/G2

 $\mathbf{2340} \, \pm \, \mathbf{100}$ 

Charcoal from Corno do Cunho (41° 17′ 02″ N, 6° 31′ 55″ W), Peredo da Bemposta, Modagorico, Tras os Montes prov. Sample coll by P J Soares-Felix and subm 1984 by M De-Jesus-Sanches, Grup Est Arqueol do Porto, from 60cm depth. *Comment:* expected age was ca 3200 BP; cal 770–180 BC.

# UGRA-222. No. 9

#### $1440 \pm 100$

Charcoal from Citania de Sanfins (41° 19′ 22″ N, 8° 22′ 52″ W), Sanfins

# $3530~\pm~70$

de Ferreira, Paços de Ferreira, Porto prov. Sample coll 1979 and subm 1984 by A Coelho-Ferreira-da-Silva, from 60cm depth. *Comment:* expected age was 1850 BP; cal AD 415–770.

# Monte da Tumba series

Charcoal from Monte da Tumba (38° 16′ 54″ N, 8° 13′ 12″ W), Torrão, Alcacer do Sal, Baixo Alemtejo prov. Samples coll 1982 and subm 1983 by M J Coelho-Soares, Univ Evora and Mus Arqueol Setúbal, to date Chalcolithic period in SW Iberian peninsula.

UGRA-234.	M.T./Cv.1	$4280~\pm~100$
Cal 3350-26	50 вс.	

#### UGRA-236. M.T./Cv.3

Саl 3655-2915 вс.

General Comment: dates agree with expected ages.

#### GEOLOGIC SAMPLES

Spain

#### UGRA-210. ZL-860 B

Charcoal from Lanjarón (36° 55′ 20″ N, 3° 28′ 50″ W), Granada prov. Sample coll and subm 1983 by L García-Rossell, Inst Andaluz Geol Mediterranean CSIC, Fac Cien, Univ Granada, to date Quaternary fm. Sample from 7m depth.

# UGRA-253. Moucide-2

Charcoal from Moucide (43° 35′ 30″ N, 7° 23′ 25″ W), Burela, Lugo prov. Sample coll and subm 1985 by F Díaz-Fierros-Viqueira, Dept Edafol, Fac Farm, Univ Santiago de Compostela. Sample from 1.05m depth. *Comment:* date much younger than expected; cal AD 300–620.

## Saldropo series

Peat from Saldropo (43° 03' 10" N, 2° 43' 36" W), Ceanuri, Vizcaya prov. Samples coll and subm 1985 by F M Ugarte-Elorza, Soc Cien Aranzadi, Mus S Telmo, San Sebastián, to date Vasco-Cantabric country.

UGRA-256. No. 1	$4510\pm110$
2.70m depth; cal 3545–2925 вс.	
UGRA-257. No. 3	$920~\pm~100$
0.30m depth; cal AD 900–1260.	
UGRA-258. No. 2	$2460~\pm~100$
1.30m depth; cal 805–390 BC.	

General Comment: dates agree with expected ages.

>20,000

 $1530 \pm 80$ 

 $4550 \pm 150$ 

#### References

- González-Gómez, C, López-González, J D and Domingo-García, M, 1982, University of Granada radiocarbon dates I: Radiocarbon, v 24, no. 2, p 217–221.
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  González-Gómez, C, Sánchez-Sánchez, P and Villafranca-Sánchez, E, 1986, University of Granada radiocarbon dates III: Radiocarbon, v 28, no. 3, p 1200–1205.
  Klein, S, Lerman, J C, Damon, P E and Ralph, E K, 1982, Calibration of radiocarbon dates: Tables based on the consensus data of the Workshop on Calibrating the Radiocarbon Time Scale: Radiocarbon v 29, no. 120. Time Scale: Radiocarbon, v 24, no. 2, p 103–150.

#### VIENNA RADIUM INSTITUTE RADIOCARBON DATES XVI

# HEINZ FELBER

# Institut für Radiumforschung und Kernphysik der Osterreich Akademie der Wissenschaften, Vienna, Austria

Measurements have continued with the same proportional counter system, pretreatment procedure, methane preparation and measurement, and calculation, as described previously (R, 1970, v 12, no. 1, p 298–318). Uncertainties quoted are single standard deviations. No <sup>13</sup>C/<sup>12</sup>C ratios were measured. Sample descriptions have been prepared in cooperation with submitters. Some dates have been calibrated using the correction tables of Klein *et al* (1982) and are reported as "cal" ages in the comment.

#### ACKNOWLEDGMENTS

I express my thanks to Ing L Stein for excellent work in sample preparation and for careful operation of the dating equipment.

#### GEOLOGIC, GEOGRAPHIC, AND BOTANIC SAMPLES

#### Austria

#### VRI-899. Wöllatal, Kärnten 12,080 ± 150

Wood at -13m in fossil soil, -50cm thick, above strongly compressed ground moraine. Fossil soil is overlain by washed down coarse clastic material followed by younger moraine overlain again by redeposited coarse detritus. Sample from Wöllatal (46° 52′ 13″ N, 13° 04′ 21″ E), Kreuzeckgruppe, Carinthia, at 1210.8m asl. Coll 1983 by S Jacobs; subm by A Fritz, Naturwiss Verein f Kärnten, Klagenfurt. *Comment* (HF): date contradicts assumption of Würm interstadial. No NaOH pretreatment.

#### Nieselach series, Kärnten

Wood and slate coal (lignite) of seam in late Würm glacial succession, at ca -10m, from Nieselach (13° 30′ 30″ N, 46° 36′ 30″ E), Carinthia. Coll 1984 and subm by Dirk van Husen, Tech Univ Vienna.

*General Comment* (DvH): establishes sedimentation chronology and dates embedment of wood.

VRI-988.	Nieselach 1	$30,400 \pm 1300$
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Slate coal.

VRI-987. Nieselach 2 3	61,600 +	1	1800 1500
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Root-wood embedded in slate coal seam.

VRI-989. Nieselach 3 > 35,800

Wood (root?) embedded in coarse sandy gravel overlying slate coal seam.

# Schafberg area series, O Ö

Peat from dried out part of Halleswiessee (47° 46′ N, 13° 22′ E), Schafberg area, Upper Austria, at 781m asl. Coll 1984 by boring and subm by Roland Schmidt, Inst Limnol, Österr Akad Wiss, Gaisberg, Salzburg.

*General Comment* (RS): dates both drying out of lake and level oscillations (Schmidt, 1981). (HF): HCl pretreatment only.

Radicella peat from depth 210 to 220cm.

## VRI-907. 230-240

 $\mathbf{2280}~\pm~\mathbf{70}$ 

Radicella peat from depth 230 to 240cm.

## Zellhof series, Salzburg

Samples from Zellhofer Moor bog (47° 59' N, 13° 06' E) near Zellhof, Salzburg. Coll 1983 by boring and subm by Roland Schmidt.

General Comment (RS): dates pollen diagram. (HF): HCl pretreatment only.

# VRI-903. 450–455

Radicella peat at -450 to -455 cm. Comment (RS): dates crossing of Quercetrum mixtum and Corylus curves.

#### VRI-904. 505-510

#### $\mathbf{8720} \pm \mathbf{120}$

 $7240 \pm 150$ 

Detritus gyttja at -505 to -510 cm. Comment (RS): dates Corylus increase.

#### VRI-905. 547–552

 $12,020 \pm 160$ 

Gyttja at -547 to -552 cm. *Comment* (RS): dates beginning of organic sedimentation at Bölling/Oldest Dryas boundary. Age is too young, perhaps caused by unsuitable range of depth.

# Tamsweg series, Salzburg

Peat from bogs near Tamsweg (47° 08' N, 13° 48' E), Salzburg. Coll 1984 and subm by Robert Krisai, Univ Salzburg.

General Comment (RK): dates beginning of peat growth. (HF): HCl pretreatment only.

# VRI-974. Schwefelbrunnmoos $7920 \pm 100$

Peat from Schwefelbrunnmoos bog (47° 07' 25" N, 13° 54' 20" E) at ca3.6m depth.

# VRI-975. Dürreneggsee 8760 ± 160

Peat from W lake Dürrenbergsee bog (47° 10' 25" N, 13° 52' 30" E) at ca 7.6m depth.

# VRI-976. Überlingmoos 9160 ± 160

Peat from Überlingmoos bog (47° 10′ 25″ N, 13° 54′ 15″ E) at ca 6m depth.

390

# VRI-985. Lofer, Salzburg

# $10,340 \pm 190$

391

Wood, B72/84, in undisturbed ground moraine underlying "Loferer Bergsturz" landslide from cut at left side of R Saalach (47° 36' N, 12° 42' E), NNE Lofer, Salzburg. Coll 1984 by Johanna Brückl, subm by Josef-Michael Schramm, Univ Salzburg. *Comment* (J-M S): yields max age of landslide. (HF): HCl pretreatment only.

# Schwemm series, Tirol

Lacustrine sediments of former lake (47° 39' 30" N, 12° 18' E), Schwemm, Tyrol. Coll 1984 and subm by K Oeggl, Bot Inst, Univ Innsbruck.

*General Comment* (KO): absolute dating of pollen-analytically determined events. (HF): HCl pretreatment only.

# VRI-846. Schwemm B5/768 10,370 ± 80

Gyttja on clay at -758 to -768 cm. Comment (KO): dates first organic sedimentation.

# VRI-847. Schwemm B5/740 8650 ± 130

Gyttja immediately above lake marl at -730 to -740 cm. Comment (KO): dates second organic sedimentation.

# VRI-848. Schwemm B5/650 6450 ± 90

Gyttja at -640 to -650 cm. Comment (KO): dates first appearance of cereal pollen.

# VRI-849. Schwemm B5/490 5240 ± 90

Gyttja at -485 to -490 cm. Comment (KO): dates first appearance of Abies.

# VRI-850. Schwemm B5/395 3990 ± 80

Gyttja at -390 to -395 cm. Comment (KO): dates first appearance of Fagus.

# VRI-851. Schwemm B5/130 1090 ± 60

Sphagnum-Radicella peat at -125 to -130 cm. Comment (KO): dates human influence.

# St Jakob i Def series, Osttirol

Soil samples from different profiles at Oberhauser Zirbenwald; St Jakob im Defereggen (46° 57′ N, 12° 13′ E), 186cm asl, East-Tyrol. Coll 1983 by Hubert Kammerlander; subm by Friedrich Kral, Univ Bodenkultur, Vienna.

*General Comment* (HK, HF): dates for pollen diagram. Humic acid fraction was dated to eliminate contamination by younger rootlets.

### VRI-912. OZI-1/12–15

 $\mathbf{270} \pm \mathbf{60}$ 

Sandy raw humus at -12 to -15cm, profile 1. Comment (HK): dates

raw humus following extended human influence. Presently oldest trees aged 200 a.

#### VRI-913. OZI-1A/20-25

# Modern

Sand with humus at -20 to -25 cm, profile 1A. *Comment* (HK): should date natural wood regeneration after extended human influence.

## VRI-978. Wattens, Tirol

 $7470 \pm 120$ 

Charcoal from charcoal layer ca 1m below surface embedded in loam sediment of R Inn at Wattens (47° 17′ 46″ N, 11° 36′ 00″ E) Tyrol, at 552m asl. Coll 1984 and subm by Gernot Patzelt, Univ Innsbruck. *Comment* (GP, HF): assoc with VRI-882 (R, v 27, no. 3, 1985) dated at 9730  $\pm$  120, coll -4m below this sample, dating interval of 2260  $\pm$  170 yr for this deposition.

## **Obergurgl series**, Tirol

Peat with sand of small bog at "Kleinalbl," Gurgler Alm, near former end of tongue of Gurgler Ferner Glacier, Obergurgl (46° 50′ 22″ N, 11° 00′ 11″ E), Tyrol, at 2160m asl. Coll 1984 and subm by Gernot Patzelt.

*General Comment* (GP): absolute dating of bog development (HF): HCl pretreatment only.

# VRI-979. Gurgler Ferner 1 3920 ± 80

Peat at -108 to -110 cm above coarse stony solifluction material. Comment (GP): dates end of solifluction period.

# VRI-980. Gurgler Ferner 2 4270 ± 80

Peat at -135 to -138cm below stony solifluction material. *Comment* (GP): together with VRI-979, limits solifluction period related to postglacial climate oscillation.

# VRI-981. Gurgler Ferner 3 4850 ± 90

Peat at -157 to -160 cm, base. *Comment* (GP): dates beginning of bog development and min age for ice retreat in this area.

#### Kaunertal series, Tirol

Wood (*Pinus cembra*) formerly buried under moraine material, now visible at different levels on inner slope of AD 1850 moraine; from margin of Gepatschferner Glacier (46° 52′ 33″ N, 10° 45′ 06″ E), Kaunertal, Ötztaler Alpen, Tyrol. Coll 1984 and subm by Gernot Patzelt.

*General Comment* (GP): together with sample Gepatschferner 2, Hv-11412, dated at  $2205 \pm 55$ , at 2285m asl, series fixes chronology of moraine development. (HF): HCl pretreatment only.

# **VRI-982.** Gepatschferner 3 2020 ± 70

Wood at 2255m asl. Comment (GP): dates glacial advance.

#### VRI-983. Gepatschferner 5

 $1660 \pm 70$ 

Wood at 2260m asl. Comment (GP): dates glacial advance.

Europe

### VRI-915. Stuttgart, FRG

Copal of unknown origin identified by dealer as "real natural amber," from colln of Staatl Mus Nat Sci, Stuttgart, FRG. Subm by Dieter Schlee, Mus Naturkunde Stuttgart. *Comment* (DS): color and lacquer coating removed. (HF): no pretreatment. Clearly discernible nuclear weapons influence.

# VRI-852. Kasbegi, USSR

Cyperaceae-*Radicella* peat of floating horizon, 40cm thick, in wide valley flooded and cut by nameless rivulet with repeatedly changed bed near Kasbegi (42° 40' N, 44° 50' E), Caucasus, USSR. Coll 1984 by K Oeggl. *Comment* (KO): dates floating horizon.

#### **Other Countries**

#### VRI-954. Algeria

Calcareous quartz sand encrustation in Algerian Sahara. Coll at surface by Eckhard Klenkler, Ettenheim, FRG. *Comment* (HF): homogeneity of sample suggests continuous growth phase. Tentatively assumed recent concentration, 85% modern (Münnich & Vogel, 1959; Geyh & Schillat, 1966) yields model age, 29,700  $\pm$  1200. Recent concentration, 100% modern yields max age, 31,000  $\pm$  1200.

#### VRI-999. Moa, Tanzania

# $115~\pm~0.8\%~modern$

2.11 ± 0.3% modern

Copal, identified by dealer as Tanzania amber from Pliocene, coll at Moa, Tanzania. Subm by Dieter Schlee. *Comment* (DS): color and lacquer ground off. (HF): no pretreatment. Clearly discernible nuclear weapons influence indicates very young age of resin.

#### **Dominican Republic series, Central America**

Amber-copal of unknown site, Dominican Republic, from colln of Staatl Mus Naturkunde, Stuttgart; subm by Dieter Schlee.

*General Comment* (DS): classified as intermediate between copal and amber. Authenticity is expected by dating. (HF): no pretreatment.

#### VRI-916.

# 31,500 + 1700 - 1400

Non-adhesive copal, intermediate between typical fresh copal and typical amber. *Comment* (DS): date proves sample to be copal.

#### **VRI-998.**

# > 35,000

"Young amber," according to dealer; no further specification. *Comment* (DS): date does not refute sample classification of amber several million yr old.

#### Thimi series, Nepal

Samples from clay pit near Thimi (27° 39′ 44″ N, 85° 23′ 27″ E), Kathmandu Valley, Nepal, coll 1984 and subm by Gernot Patzelt.

#### 393

#### $\mathbf{240} \pm \mathbf{60}$

119 ± 0.8% modern

General Comment (GP): Kathmandu Valley filled with lake sediments recently exposed in terrace by river cutting. Dates provide time frame of last lake development. (HF): no pretreatment.

# VRI-1001. Thimi 1

Gyttja from 1m layer in lake sediment, ca -180 to -185 cm below terrace surface, at 1323m asl.

## VRI-1002. Thimi 2

Wood and plant detritus in layer 19m below terrace surface, ca 17m below Thimi 1, at 1306m asl.

#### VRI-917. New Zealand

Copal identified by dealer as "amber from New Zealand," from colln of Staatl Mus Nat Sci, Stuttgart; subm by Dieter Schlee. Comment (HF): clearly discernible nuclear weapons influence.

#### ARCHAEOLOGIC AND HISTORIC SAMPLES

#### Austria

# VRI-1003. Globasnitz, Kärnten

Charred wood from floor in kitchen of pilgrims' house, near early Christian church complex, above coarsely leveled rock surface; from Hemmaberg excavation (46° 33' 08" N, 16° 40' E), Globasnitz, Carinthia. Coll 1981 at -0.7m and subm by Franz Glaser, Landesmus f Kärnten, Klagenfurt. Comment (FG): pilgrims' house is Late Antique, older than early Christian church at Hemmaberg. Age range cannot be delimited by ceramic fragments. Date fits expectation. (HF): cal AD  $400 \pm 610$ .

#### VRI-908. See am Mondsee, O Ö

Wood in lake marl below Neolithic cultural layer at Sta See am Mondsee (47° 33' N, 13° 27' E), Upper Austria, at 481m asl. Coll 1983 at depth 77 to 83cm by Johann Offenberger; subm by Roland Schmidt. *Comment* (RS): dates chronologic boundaries of stratigraphic gap between Neolithic cultural layer and Atlanticum (Offenberger *et al*, 1981). (HF): HCl pretreatment only.

#### VRI-955. Dachstein, O Ö

Charcoal and ceramic fragments at -20 cm, E part of Mt Dachstein plateau near Lackenofen ( $47^{\circ} 28'$  N,  $13^{\circ} 42'$  E), at 2000m asl. Coll 1984 by Franz Mandl; subm by Fritz-Eckart Barth, Naturhist Mus, Vienna. Comment (FM): date confirms expectation (Mandl, 1984). (HF): cal 1545 to 1125 BC.

# VRI-984. Auffang, O Ö

Wood from fill (loamy soil and bricks) at archaeol site at Auffang (48° 12' 17" N, 13° 13' 13" E) near Schalchen, Upper Austria, at depth 1.8 to 1.9m. Coll 1984 and subm by Christine Schwanzar, O O Landesmus,

#### > 35,000

119 ± 0.7% modern

> 31.000

 $1520~\pm~60$ 

#### $7180 \pm 100$

# $3080 \pm 70$

 $310 \pm 70$ 

395

Linz. *Comment* (ChS): dates fill. (HF): cal AD 1425–1660. HCl pretreament only.

#### VRI-892. Trieben, Steiermark 4990 ± 90

Charcoal from excavation Grünanger LG/no. 16, Cutl, LF21E, Trieben (47° 29' 35" N, 14° 26' 48" E), Styria, at -20cm. Coll 1980 by Clemens Eibner and Hubert Presslinger; subm by H Presslinger, Montanuniv Leoben. *Comment* (HP): ceramic finds do not yield chronologic assoc. Dates Neolithic settlement.

#### **Bärndorf series**, Steiermark

Charcoal and wood from excavations at Bärndorf near Rottenmann (47° 31′ 38″ N, 14° 11′ 35″ E), Styria. Coll 1983 by Clemens Eibner and Hubert Presslinger.

*General Comment* (HP): this area has been mined from primitive times to present; without <sup>14</sup>C dating, chronology is impossible.

VRI-893. Prenterwinkel no. 1	$400 \pm 60$
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Charcoal (47° 31′ 31″ N, 14° 25′ 55″ E), 20cm behind slope of dump opened by road construction.

#### VRI-894. Prenterwinkel no. 2 370 ± 60

Charcoal in same stratum as VRI-893.

#### VRI-895. Pretscherer no. 39 $180 \pm 60$

Wood (47° 31′ 26″ N, 14° 26′ 39″ E), -70 cm, from well-preserved wood structure.

VRI-927.	Pretscherer no. 92	$280 \pm 60$

Wood from cut of dump, basal layer, 15.6m run, planum, -3.20 to -3.30m.

# VRI-928. Pretscherer no. 93 210 ± 60

Wood from cut of dump, basal layer, 15m run, planum, -3.20 to -3.30m.

# VRI-929. Pretscherer no. 94 260 ± 80

Wood from cut of dump, basal layer, 13m run, planum, -3.20 to -3.30m.

# VRI-931. Kaiserköpperl no. 36 1390 ± 60

Charcoal (47° 31' 05" N, 14° 26' 14" E) cut 1, planum, -20cm. Excavation of miners' settlement; occupied from end of Neolithic to Celtic period.

# VRI-932. Kaiserköpperl no. 51 $870 \pm 60$

Charcoal, cut 2, 2 to 4m run, -65cm. Same occupation as VRI-931.

VRI-933. Kaiserköpperl no. 59

 $\mathbf{2350}~\pm~\mathbf{70}$ 

Charcoal, cut 2, 1.20m run, -80cm. Same occupation as VRI-931.

### Admont series, Steiermark

Charcoal from excavations at Mt Dürrenschöberl near Aigen bei Admont (47° 34′ 10″ N, 14° 21′ 49″ E), Styria. Coll 1983 by Clemens Eibner and Hubert Presslinger; subm by Hubert Presslinger.

*General Comment* (HP): excavations of iron smelting site yielded ceramics of several epochs.

VRI-934. Dürrenschöberl no. 51 2280	±	7	0
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Charcoal in furnace area, cut 2.

# VRI-935. Dürrenschöberl no. 21 $640 \pm 60$

Charcoal from basal layer with ceramic fragments, cut 2, depth 80cm.

# VRI-977. Lech am Arlberg, Vorarlberg $350 \pm 60$

Wood from beam in wall of Roman church at Lech am Arlberg ( $47^{\circ} 13'$  N,  $10^{\circ} 09'$  E), Vorarlberg. Coll 1984; subm by Josef Fastl, Vienna. *Comment* (JF): dates subsequently installed beam. (HF): cal AD 1420–1650. HCl pretreatment only.

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#### UNIVERSITY OF WISCONSIN RADIOCARBON DATES XXIV

# RAYMOND L STEVENTON and JOHN E KUTZBACH

# Center for Climatic Research, Institute for Environmental Studies University of Wisconsin-Madison, 1225 West Dayton Street Madison, Wisconsin 57306

Procedures and equipment used in the University of Wisconsin laboratory have been described in previous date lists. Except as otherwise indicated, wood, charcoal, and peat samples are pretreated with dilute NaOH—NA<sub>4</sub>P<sub>2</sub>O<sub>7</sub> and dilute H<sub>3</sub>PO<sub>4</sub> before conversion to the counting gas methane; when noted, marls and lake cores are treated with acid only. Very calcareous materials are treated with HCL instead of H<sub>3</sub>PO<sub>4</sub>. Pretreatment of bone varies with the condition of the bone sample; solid bone with little deterioration is first cleaned manually and ultrasonically. The bone is treated with 8% HCL for 15 minutes, then dilute NaOH—Na<sub>4</sub>P<sub>2</sub>O<sub>7</sub> for 3 hours at room temperature, washed until neutral, and the collagen extracted according to Longin (1971). Charred bone is treated with dilute HCL, NaOH—Na<sub>4</sub>P<sub>2</sub>O<sub>7</sub>, and then dilute HCL again.

The dates reported have been calculated using 5568 yr as the half-life of <sup>14</sup>C. The standard deviation quoted includes only  $1\sigma$  of the counting statistics of background, sample, and standard counts. Background methane is prepared from anthracite, standard methane from NBS oxalic acid. The activities of the dated samples for which  $\delta^{13}$ C values are listed have been corrected to correspond to a  $\delta^{13}$ C value of -25%; the activity of the standard methane has been corrected to -19%.

Sample descriptions are based on information supplied by those who submitted samples.

#### ACKNOWLEDGMENTS

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#### ARCHAEOLOGIC SAMPLES

#### United States

#### Indiana

# Jennison Guard site (12D29S) series

Samples coll from Jennison Guard site (12D29S), Dearborn Co (39° 06' 03" N, 84° 50' 15" W) by J K Blosser and subm by K D Vickery, Univ

Cincinnati, Ohio. Site is single-component Middle Woodland habitation containing Steuben and Snyders-like projectile points, limestone and grit/ limestone tempered Twin Mounds Plain and Cordmarked pottery types with some decorated ceramics, bladelets of Flint Ridge and Harrison Co flint, and mica cutouts and debris, including one Snyders-like projectile point effigy.

	$1800 \pm 70$
WIS-1744.	$\delta^{I3}C = -24.9\%$

Wood charcoal from Unit F2, Level 3.

	$1660 \pm 70$
WIS-1745.	$\delta^{13}C = -25.5\%$

Wood charcoal from Unit F2, Level 2.

	$1810 \pm 70$
WIS-1746.	$\delta^{I3}C = -27.0\%$

Wood charcoal from Feature 3, Levels 3 and 4.

*General Comment:* dates are acceptable for Middle Woodland occupation of site, estimated between AD 1 and 300. Earlier date of WIS-1745 corresponds with underlying stratigraphy and upper portion of midden deposit (Zone II), respectively, in same excavation Unit F2. (WIS-1744 was taken from lower 5cm of third 10cm cut below plow zone, in (sub-midden) Zone III. WIS-1745 was taken from upper 5cm of second 10cm cut below plow zone, Zone III, which was midden portion of site).

# Nebraska

# **Bill Packer site (25Sm9) series**

WIS-1764.

Sample coll 1980–81 from Bill Packer site (25Sm9), Sherman Co (41° 23' N, 98° 46' W) by G F McKenzie and subm by J Ludwickson, Nebraska State Hist Soc, Lincoln. Three dates from Great Oasis storage pit, 1 date from later Central Plains tradition (Itskari [Loup River] phase) lodge (McKenzie & Holen, 1983).

WIS-1762.	$900 \pm 70 \\ \delta^{13}C = -25.6\%$
Wood charcoal from Great Oasis storage pit.	,
WIS-1763.	$970 \pm 70$ $\delta^{13}C = -25.7\%$

Wood charcoal from Great Oasis storage pit.

 $940 \pm 70$  $\delta^{13}C = -25.1\%$ 

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Wood charcoal from Great Oasis storage pit.

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WIS-1765.

 $\frac{670 \pm 70}{\delta^{13}C} = -25.2\%$ 

Wood charcoal from storage pit in floor of Itskari (Loup River) phase lodge.

*General Comment:* dates for Great Oasis occupation are similar to those from other Great Oasis sites despite being 100 miles beyond known range. Its-kari phase data is consistent with context, confirming 200 yr lapse in occupations.

		$970 \pm 70$
WIS-1795.	Archaeologic site (25Mo86)	$\delta^{13}C = -22.0\%$

Wood charcoal from hearth at site 25Mo86, Morrill Co (41° 29' N, 102° 50' 30" W) coll by R Cape and subm by R Bozell, Nebraska State Hist Soc. Sample from single-component Woodland camp assoc with Ash Hollow Cord Roughened pottery (Kivett, 1952; Champe, 1946).

*General Comment:* date is generally consistent with other Central Plains subarea Woodland dates, ranging from  $1150 \pm 150$  to  $750 \pm 90$  BP. Date lends further support to notion that Woodland culture in this portion of subarea persisted relatively late.

## Shipman site (25Wt7) series

Wood charcoal coll 1941 from Shipman site (25Wt7) Webster Co (40° 05' N, 98° 23' W) by M F Kivett and G S Metcalf; subm by J Ludwickson. Samples are from two Upper Republican phase house ruins (Ludwickson, 1979).

WIS-1796.	$810 \pm 70 \\ \delta^{13}C = -24.3\%00$
Sample from Lodge 1.	
<b>WIS-1797.</b> Sample from post hole in Lodge 4.	$660 \pm 70 \\ \delta^{I3}C = -26.8\%$
<b>WIS-1798.</b> Sample from post hole in Lodge 4.	$690 \pm 70 \\ \delta^{I3}C = -26.6\%$
<b>WIS-1799.</b> Sample from post hole in Lodge 4.	$430 \pm 70 \\ \delta^{13}C = -26.6\%$
<b>WIS-1800.</b> Sample from post hole in Lodge 4.	$\frac{620 \pm 70}{\delta^{13}C} = -26.2\%$

	$530 \pm 70$
WIS-1801.	$\delta^{13}C = -26.9\%00$

Sample from post hole in Lodge 4.

	$670 \pm 70$
$\delta^{I3}C$ =	= -26.1%

Sample from wall post hole in Lodge 4.

*General Comment:* Shipman site is basis for three-subphase model of Upper Republican phase development. Dates are consistent with interpretation, confirming 14th century subphase III.

Ohio

WIS-1814.

# Sand Ridge site (33Ha17) series

Samples coll 1974–75 from Sand Ridge site (33Ha17), Hamilton Co (39° 06' 05" N, 84° 23' 45" W) by R E Riggs *et al* and subm by R E Riggs, Univ Wisconsin-Madison (Starr, 1960). *Comment:* dates fall within expected ranges.

	$1230 \pm 70$
WIS-1747.	$\delta^{13}C = -26.2\%$

Wood charcoal from Level 10, thick Late Woodland-Newtown phase midden.

	$1080 \pm 70$
WIS-1748.	$\delta^{I3}C = -26.0\%$

Wood charcoal from Level 6, upper portion of Late Woodland-New-town phase midden.

	$820 \pm 70$
WIS-1793.	$\delta^{13}C = -24.8\%$

Wood charcoal from Level 4, Fort Ancient tradition midden.

# Turpin site (33Ha19) series

Samples coll summer 1981 from Turpin site (33Ha19) Hamilton Co (39° 06′ 52″ N, 84° 23′ 39″ W) and subm by R E Riggs (Starr, 1960; Oehler, 1973). *Comment:* all dates fall within expected ranges and in proper stratigraphic order.

# WIS-1749.

# $1140 \pm 70 \\ \delta^{13}C = -26.2\%$

Wood charcoal from Feature 4, Late Woodland-Newtown phase deposit containing Newtown phase ceramics and lithics.

 $\frac{1320 \pm 70}{\delta^{13}C = -25.7\%}$ 

#### WIS-1750.

Wood charcoal from Feature 8, pit containing Newtown phase pottery and Late Woodland corner-side-notched variety projectile point.

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 $300 \pm 70$ 

#### WIS-1751.

 $\frac{1460 \pm 70}{\delta^{13}C} = -26.0\%$ 

Wood charcoal from Level 6, late Woodland-Newtown phase midden containing Newtown phase artifacts and some intermixed Fort Ancient materials.

**WIS-1792.** 
$$\delta^{13}C = -25.2\%$$

Wood charcoal from Level 11, Late Woodland-Newtown phase midden.

South Dakota

# WIS-1794. Angostura Reservoir site (39Fa69) $\delta^{13}C = -26.3\%$

Wood charcoal coll Sept 1985 from Angostura reservoir site, Fall River Co (43° 17' N, 103° 30' W) by T Church and subm by R A Alex, South Dakota Archaeol Research Center, Ft Meade. Hearth charcoal was recovered when reservoir water receded. Hearth was flooded for 40 years.

# WIS-1815. Angostura Reservoir site (39Fa23) $720 \pm 70$ $\delta^{I3}C = -24.5\%$

Wood charcoal from Angostura Reservoir site, Fall River Co (43° 17' N, 103° 22' W) coll and subm by R A Alex. Part of previously undescribed cultural complex in W South Dakota with ceramic affiliation to Initial Variant of Middle Missouri tradition (Wheeler, 1957).

#### Wisconsin

# **Double site (47Pi81) series**

Charcoal from Double site (47Pi81), Pierce Co (44° 39' N, 92° 38' W). Subm by J T Penman, State Hist Soc Wisconsin-Madison. Samples from village and mound complex (Penman, 1984). Previously dated (R, 1978, v 20, p 163; 1986, v 28, p 1210). *Comment:* Features 1, 3, and 4 were dated. These features produced oak (*Quercus* sp) id by L A Zalucha, also id was *Polygonum, Chenopodium*, and corn in Feature 3. Dates for Double site fall into range of dates for Diamond Bluff site (47Pi2) 3km S of Double. Date on burned bone from Mound "K" is first <sup>14</sup>C date for Oneota conical mound.

#### WIS-1775.

# $890 \pm 70 \\ \delta^{I3}C = -25.5\%$

Sample coll by C Rohrbaugh and R Saft in Aug 1984 from Oneota mound. Most of sample was charcoal mixed with charred bone from Mound K.

#### WIS-1776.

#### $930 \pm 70$

Oak and willow charcoal coll June 1984 by J T Penman from Feature 3.

# WIS-1861. Bachmann site (47Sb202)

# $2080 \pm 70$ $\delta^{13}C = -26.0\%$

Wood charcoal coll June 1986 from Bachmann site, Sheboygan Co (43° 43' N, 87° 48' W) by L A Rusch and subm by J T Penman. Comment: dates from test excavations (Rusch & Penman, 1985) did not contain diagnostic artifacts (R, 1986, v 28, p 1211). This sample from Feature 16 contains Early Woodland ceramics and is only Early Woodland site in Wisconsin within Lake Michigan Basin.

# Gottschall Site (47Ia80) series

Wood charcoal coll from Gottschall Rockshelter (47Ia80), Iowa Co (43° 06' 19" N, 90° 21' 01" W) by R J Salzer et al and subm by R J Salzer, Beloit College.

	$1670 \pm 70$
WIS-1816.	$\delta^{13}C = -26.2\%$

Charcoal from Feature 16, sample nos. 84C15 and 84C16 combined, Millville phase hearth.

# WIS-1817.

Charcoal from Feature 1, sample nos. 84C2, 84C3A, and 84C3B combined, Effigy Mound hearth.

### $1610 \pm 70$

 $970 \pm 70$  $\delta^{13}C = -26.7\%$ 

#### WIS-1818.

# $\delta^{13}C = -26.1\%$

Charcoal from Feature 19, sample no. 84C12, Millville phase hearth.

# WIS-1819.

#### $1620 \pm 70$

 $1070 \pm 70$  $\delta^{13}C = -27.3\%$ 

 $1630 \pm 70$ 

Charcoal from Feature 19, sample no. 84C19, Millville phase hearth.

# WIS-1833.

Charcoal from Feature 1, sample nos. 84C6 and 84C8 combined, Effigy Mound hearth.

#### WIS-1834.

 $\delta^{13}C = -26.1\%$ Charcoal from Feature 16, sample no. 84C18, Millville phase hearth. General Comment: WIS-1816 and -1834: AD 280 and 320 respectively, were coll from Feature 16, Millville phase hearth. Feature is stratigraphically ear-

lier than Feature 19, WIS-1818 and -1819: AD 340 and 330. Dates agree with accepted range of Millville phase dates at other sites in area.

Two remaining samples, WIS-1817 and -1833, AD 980 and 880, date Feature 1, hearth that can be stratigraphically assoc with Effigy Mound culture that occupied S Wisconsin from AD 700-1200. Feature 1 has origins above stratum that produced "splash" of blue-black pigment used to paint >40 paintings on wall of rock shelter.

Direct dating of prehistoric rock art has only been rarely achieved. Gottschall dates minimal chronologic estimate for at least some of rock art at site. Some motifs of human and animal figures have counterparts in shell engraving at Spiro site (Oklahoma) and Cahokia site (Illinois) at later times (ca AD 1100–1300).

#### Fred Edwards site (47Gt377) series

Wood charcoal coll Aug 1985 from Fred Edwards site (47Gt377), Grant Co (42° 43' 30" N, 90° 50' 58" W) by K Karstens and subm by J B Stoltman, Dept Anthropol, Univ Wisconsin-Madison. Samples date Middle Mississippian contacts in SW Wisconsin (R, 1986, v 28, no. 3, p 1211). *Comment:* all dates within range for site except WIS-1854, which is much too young and cannot be explained.

**990**  $\pm$  **70** WIS-1773.  $\delta^{13}C = -26.6\%$ 

Sample from Feature 63, basin-shaped pit containing Late Woodland and Middle Mississippian ceramics.

	810 ± 70
WIS-1774.	$\delta^{I3}C = -27.0\%$

Sample from Feature 67, basin-shaped pit containing Late Woodland (Hartley Cross-Hatched, Hartley Tool Impressed) and Middle Mississippian ceramics.

	$920~\pm~70$
WIS-1853.	$\delta^{I3}C = -26.5\%0$

Sample from Feature 63, same as WIS-1773, above.

	$650 \pm 70$
WIS-1854.	$\delta^{13}C = -26.3\%$

Sample from Feature 50, deep basin-shaped pit.

 $980 \pm 70 \\ \delta^{13}C = -26.5\%$ 

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WIS-1864.

Sample from Feature 47, basin-shaped pit.

#### GEOLOGIC SAMPLES

United States

#### Delaware

#### Walters Puddle series

Core coll June 1985 from Walters Puddle, New Castle Co (39° 24' N, 75° 41' 30" W) by R Thompson *et al* and subm by P Newby, Brown Univ, Providence, Rhode Island. All depths from water/sediment interface, water depth 1m.

404	R L Steventon and J E Kutzbach	
	WIS-1802.	$5820~\pm~80$
	Organic mud from 52 to 61cm.	
	WIS-1803.	$11,880 \pm 160$
	Organic clay from 63 to 69cm.	
	WIS-1804.	$14,400 \pm 150$

Organic clay from 109 to 116cm.

Florida

# Lake Tulane series

Core coll 1984 from Lake Tulane, Highlands Co (27° 35' N, 81° 30' W) and subm by H E Wright, Jr, Univ Minnesota, Minneapolis. All measurements from datum 36cm above lake water surface, water depth 22.3m. Dated to provide sedimentation rate. All samples were organic silty lake sediment (Watts, 1980; R, 1986, v 28, no. 3, p 1216).

WIS-1752.	$4650~\pm~70$
2592 to 2602cm depth.	
WIS-1753.	$9810~\pm~90$
2798 to 2808cm depth.	
WIS-1754.	$17,170 \pm 210$
3152 to 3162cm depth (one 4-day count).	
WIS-1755.	$24,210 \pm 400$
3352 to 3362cm depth (one 5-day count).	
WIS-1756. Lake Verona	>33,000
Core coll April 1985 from Lake Verona, Highlands	Co (27° 36' N, 81°

30' W) and subm by H E Wright, Jr. Gyttja from 2964 to 2974cm below water surface, water depth 2235cm (Watts, 1975).

# **Sheelar Lake series**

WIS-1810.

Core coll 1980 from Sheelar Lake, Gold Head Branch State Park, Clay Co (29° 50' N, 81° 57' 30" W) and subm by H E Wright, Jr. Dates provide chronology for vegetation history of region. All measurements from water surface, water depth 18.5m (Watts & Stuiver, 1980). Date previously reported, WIS-965 (R, 1979, v 21, p 126).

Gyttja from 2010 to 2018cm depth.

 $11,170 \pm 100$ 

Gyttja from 2192 to 2200cm depth.

WIS-1811. Gyttia from 2263 to 2279cm depth	$12,760 \pm 130$
<b>WIS-1812.</b>	$14,360 \pm 140$
WIS-1813.	17,690 ± 220
Gyttja from 2462 to 2472cm depth.	

# Maine

# **Caribou Bog series**

Livingstone core, 5cm diam, coll Aug 1975 from Caribou Bog, Penobscot Co (45° 56' N, 68° 46' W) by K Gajewski *et al* and subm by K Gajewski, Univ Wisconsin-Madison. Dated to provide Holocene history. All depths from bog surface (Gajewski, 1979).

<b>WIS-1757.</b> <i>Sphagnum</i> peat from 145 to 150cm depth.	$1880~\pm~70$
WIS-1758. Sphagnum peat from 275 to 280cm depth.	$3820 \pm 80$
WIS-1759. Fibrous peat from 501 to 510cm depth.	$6470~\pm~70$
WIS-1760. Lake sediment from 600 to 605cm depth.	$7840~\pm~80$
WIS-1761.	$9390 \pm 90$

Inorganic lake sediment from 741 to 751cm depth. Dates transition from glacio-marine to freshwater sediment.

# Massachusetts

# **Houghton Pond series**

Livingstone core, 2" diam, coll from Houghton Pond, Norfolk Co (42° 12' 22" N, 71° 05' 35" W) and subm by R S Webb, Brown Univ. All depths from water/sediment interface, water depth 11.8m.

WIS-1771.	$3790~\pm~80$
Gyttja from 297 to 306cm.	
WIS-1772.	$8930 \pm 90$
Gyttja from 556 to 566cm.	

## **No Bottom Pond series**

Core coll Feb 1986 from No Bottom Pond, Barnstable Co (41° 45' N, 70° 03' 30" W) by R Webb *et al* and subm by P Newby and R Webb. All depths from water/sediment interface, water depth 10.0m.

WIS-1829.	$3710~\pm~70$
Dark organic lake mud from 149.5 to 155.5cm.	
WIS-1830.	$4560 \pm 70$
Dark organic lake mud from 396.5 to 403.5cm.	
WIS-1831.	$6040~\pm~80$
Dark organic lake mud from 563.5 to 567.5cm.	

WIS-1832. Walden Pond 530 ± 70

Frozen core coll Aug 1979 from Walden Pond, Middlesex Co (42° 26' N, 71° 20' W) by R L Steventon *et al* and subm by M J Winkler, Univ Wisconsin-Madison. Gyttja from 78 to 81cm below water/sediment interface, water depth 28.8m.

## **Owl Pond series**

Livingstone core, 5cm diam, coll July 1985 from Owl Pond, Brewster Co (41° 46′ 11″, 70° 01′ 02″ W) by R S Webb *et al* and subm by P Tzedakis, Brown Univ. Dated to calculate sedimentation rate for paleo-climatic interpretation. All measurements from water/sediment interface, water depth 9.13m.

#### WIS-1865.

#### $10,270 \pm 140$

Gyttja with fibrous plant fragments and spruce pollen from 892 to 904cm, basal date.

#### WIS-1866.

# $6810\ \pm\ 80$

Gytta from 589.5 to 597.5cm depth. Dates oak pollen peak and rise in beech pollen.

# WIS-1867.

# $\mathbf{3190}~\pm~\mathbf{80}$

Gyttja from 393.7 to 401.2cm depth. Dates high pine and oak pollen percentages, with rise in hickory and decrease in hemlock.

# WIS-1868.

# $1180 \pm 70$

Gytta from 195 to 204cm depth. Dates high oak and hickory pollen percentages.

# Minnesota

# WIS-1766. Simonson Swamp

# $\mathbf{2380} \pm \mathbf{70}$

Livingstone core, 5cm diam, from Simonson Swamp, Otter Tail Co (46° 13' 24" N, 95° 19' 14" W) coll March 1985 by J E Almendinger *et al* and

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subm by J E Almendinger and E J Cushing, Univ Minnesota, Minneapolis. Organic lake sediment from just above peat-marl contact, 132 to 138cm below peat surface.

# WIS-1767. Greip Fen

#### $10,200 \pm 100$

Livingstone core, 5cm diam, from Greip Fen, Otter Tail Co (46° 13' 11" N, 95° 14' 37" W). Same as WIS-1766, above. Organic lake sediments from just above peat-marl contact, 240 to 245cm below peat surface.

#### WIS-1768. North Maple Fen

## $5090~\pm~80$

Livingstone core, 5cm diam, from North Maple Fen, Otter Tail Co (46° 11' 17" N, 95° 14' 11" W). Same as WIS-1766, above. Organic lake sediments from just above peat-marl contact, 274 to 282cm below peat surface.

#### South Maple Lake series

Livingstone core, 5cm diam, from South Maple Lake, Otter Tail Co (46° 10' 29" N, 95° 13' 47" W) coll Feb 1984, by J E Almendinger *et al* and subm by J E Almendinger. Measurements from water surface, water depth 117cm. Previously dated (R, 1986, v 28, p 1218).

#### WIS-1784.

#### $1560 \pm 70$

Organic lake sediment from 173 to 181cm. Dates rise in concentration of fine-grained magnetic particles, possibly related to "Little Ice Age."

#### WIS-1785.

#### $4970 \pm 70$

Organic lake sediment from 303 to 311cm. Dates oldest undisturbed limnic sediment, marking time that basin was perennially filled with water.

## **Upper Graven Lake series**

Livingstone core, 5cm diam, from Upper Graven Lake, Otter Tail Co (46° 11' 04" N, 95° 18' 25" W) coll Feb 1984, by J E Almendinger *et al* and subm by J E Almendinger. Measurements from water surface, water depth 111cm (R, 1986, v 28, p 1219).

#### WIS-1786.

# $1440 \pm 70$

Organic lake sediment from 186 to 194cm (same comment as WIS-1784, above).

## WIS-1787.

# $8240~\pm~90$

Organic lake sediment from 522 to 532cm (same comment as WIS-1785, above).

# WIS-1835. $b^{I3}C = -28.4\%$

Wood Picea sp from 453 to 456cm.

#### WIS-1836.

## $10,890 \pm 100$

Organic lake sediment from 448 to 463cm. Dated and compared to WIS-1835, above, to provide correction term to account for old carbonate errors.

## WIS-1788. Cora Lake

# $1010~\pm~70$

Livingstone core, 5cm diam, from Cora Lake, Otter Tail Co (46° 09' 54" N, 95° 19' 27" W) coll Feb 1984, by J E Almendinger *et al* and subm by J E Almendinger. Organic lake sediment from 269 to 277cm below water surface. Water depth 227cm. Same comment as WIS-1784, above (R, 1986, v 28, p 1219).

# **Reidel Lake series**

Livingstone core, 5cm diam, from Reidel Lake, Otter Tail Co (46° 12′ 43″ N, 95° 17′ 03″ W) coll Feb 1984, by J E Almendinger *et al* and subm by J E Almendinger. Measurements from water surface. Water depth 382cm (R, 1986, v 28, p 1219).

## WIS-1789.

# $2180~\pm~70$

Organic lake sediment from 650 to 660cm (same comment as WIS-1784, above).

# WIS-1790.

# $5940~\pm~80$

Organic lake sediment from 1160 to 1170cm. Dates small peak in grain size of magnetic particles.

# Montana

# Guardipee Lake series

Core coll Sept 1984 from Guardipee Lake, Glacier Co (48° 33' 30" N, 112° 43' W) and subm by C W Barnosky, Carnegie Mus Nat Hist, Pittsburgh. Depths measured from water surface, water depth 2.2m. Acid treatment only.

WIS-1769.	$10,360 \pm 100$
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Silty, marly clay from 425 to 440cm depth.

WIS-1770.	$14,860 \pm 140$

Silty, marly clay from 763 to 780cm depth.

# WIS-1791. Lost Lake

 $17,040 \pm 210$ 

Core coll July 1985 from Lost Lake, Choteau Co (47° 38' N, 110° 29' W) and subm by C W Barnosky. Lake sediment from 2243 to 2258cm below water surface, water depth 718cm. Acid treatment only.

# New York

# **Burden Lake series**

Livingstone core, 5cm diam, from Burden Lake, Rensselaer Co (42° 36' 16" N, 73° 34' W) coll by D C Gaudreau *et al* and subm by D C Gau-

dreau, Brown Univ. Core dated to provide Holocene pollen analysis. Water depth 11.2m; measurements from sediment surface. Dates previously reported (R, 1983, v 25, p 161).

# WIS-1737. 1600 ± 70

Gyttja from 50 to 55cm depth. Uppermost date.

## WIS-1738.

# $\mathbf{2500}~\pm~\mathbf{70}$

Gyttja from 150 to 155cm depth. Dates increase in chestnut (*Castanea*) pollen.

## WIS-1739.

## $4000~\pm~70$

Gyttja from 420 to 425cm depth. Dates increase in chestnut (*Castanea*) pollen.

# WIS-1740.

# $4820~\pm~70$

Gyttja from 580 to 585cm depth. Dates peak in hemlock (Tsuga) pollen.

# WIS-1741.

# Gyttja from 650 to 655cm depth. Dates peak in hickory (Carya) pollen.

# WIS-1742.

# $7340~\pm~80$

 $5510~\pm~80$ 

Gyttja from 820 to 825cm depth. Dates increase in hickory (Carya) pollen.

# WIS-1743.

# $8250 \pm 90$

Gyttja from 940 to 945cm depth. Dates increase in beech (Fagus) pollen.

# Oregon

# Warner Valley series

Samples coll 1984 from Swamp Lake, Warner Valley, Lake Co (42° 32' N, 119° 50' W) and subm by S P Harrison, School Geog, Oxford, UK.

# WIS-1779.

# $510~\pm~70$

Sandy clay loam with finely disseminated charcoal fragments.

# WIS-1780.

# $210~\pm~70$

Organic plant debris.

# $\frac{280 \pm 70}{\delta^{13}C} = -10.0\%0$

Anodonta shell fragments from 20cm below lake level. Base and acid treatment (Yapp, 1978).

# WIS-1781.

WIS-1783.

WIS-1782.

 $830 \pm 70 \\ \delta^{13}C = -10.1\%$ 

Anodonta shell fragments from 20cm below lake level. Base and acid treatment (Yapp, 1978).

# **Modern** $\delta^{13}C = -10.5\%$

Living shell from Hart Lake (42° 23' N, 119° 5' W). Base and acid treatment (Yapp, 1978).

## Pennsylvania

## **Spring Lake series**

Core coll Sept 1985 from Spring Lake, Bradford Co (41° 37' N, 76° 20' W) and subm by C W Barnosky. Measurements from water surface, water depth 3.3m.

## WIS-1837.

#### $9280~\pm~100$

Fine detritus gyttja from 1105 to 1115cm depth; dates increase in *Fagus* pollen percentages.

# WIS-1838.

## $10,250 \pm 110$

Fine detritus gyttja from 1305 to 1315cm depth; dates increase in *Tsuga* and *Quercus* pollen percentages.

# WIS-1839.

# $12,670 \pm 120$

 $1420 \pm 80$ 

Fine detritus gyttja from 1425 to 1435cm depth; dates increase in *Pinus* pollen percentages.

# Wisconsin

# WIS-1777. Otter Island Bog

Hiller core coll Aug 1985 from Otter I. Apostle Is., Ashland Co (46° 57' N, 90° 32' 30" W) and subm by A M Swain, Univ Wisconsin-Madison. Sample from 118 to 125cm depth just above transition from inorganic sediment to *Sphagnum* peat.

# Wyoming

# **Emerald Lake series**

Core coll Aug 1985 from Emerald Lake, Teton Natl Forest (44° 04' 30" N, 110° 17" W) and subm by C W Barnosky. Measurements from water surface, water depth 5.9m. Glacier Peak B ash (ca 11,200 yr BP) occurs at 1119cm below surface.

#### WIS-1840.

# $10,260 \pm 110$

Fine detritus gyttja from 1000 to 1010cm depth; dates increase in *Pinus* pollen percentage.

# WIS-1841.

#### $10,700 \pm 110$

411

Fine detritus gyttja from 1037.5 to 1052.5cm depth, dates increase in *Picea* pollen percentages.

#### Lily Lake Fen series

Core coll Aug 1985 from Lily Lake Fen, Teton Natl Forest (46° 12' 50" N, 110°19' 30" W) and subm by C W Barnosky. Measurements from surface.

# WIS-1842.

#### $11,130 \pm 110$

Fine detritus gyttja from 1082 to 1092cm depth; dates increase in *Picea* pollen percentages and spread of Engelmann spruce near site.

#### WIS-1843.

#### $12,370 \pm 120$

Fine detritus gyttja from 1152.5 to 1167.5cm depth; dates increase in *Betula* and decrease in Cyperaceae pollen percentages. Glacier Peak B ash (ca 11,200 yr BP) occurs at 1140cm.

#### Mariposa Lake series

Core coll Aug 1985 from Mariposa Lake, Yellowstone Natl Park (44° 09' N, 110° 17" W) and subm by C W Barnosky. Measurements from water surface, water depth 143cm.

#### WIS-1844.

## $9810 \pm 110$

Fine detritus gyttja from 400 to 418cm depth; dates decrease in *Artemisia* pollen percentages.

#### WIS-1845.

#### $10,570 \pm 110$

Fine detritus gyttja from 460 to 480cm depth; dates increase in *Picea* pollen percentages.

#### **Divide Lake series**

Core coll Aug 1985 from Divide Lake, Teton Natl Forest (43° 46' 30" N, 110° 14' W) and subm by C W Barnosky. Measurements from water surface, water depth 7.2m. Glacier Peak B ash (ca 11,200 yr BP) occurs at 1020cm below surface.

#### WIS-1862.

 $9800~\pm~90$ 

Fine detritus gyttja from 970 to 980cm depth.

# WIS-1863.

 $11,840 \pm 110$ 

Fine detritus gyttja from 997.5 to 1012.5cm depth.

Canada

#### Ferry Lake series

Livingstone core, 5cm diam, coll Aug 1985 from Ferry Lake (unofficial name), Quebec (51° 19' N, 61° 31' W) by G A King and D R Foster and

subm by G A King, Univ Minnesota. Lake elev 396m, water depth 6.31m. All measurements from water surface. Dated to calculate time of deglaciation, tree arrival, sediment accumulation rates and pollen influx (King, 1985). Acid treatment only.

WIS-1805.	$5190~\pm~90$
Gyttja from 833 to 842cm, near base of Picea ze	one.
WIS-1806.	$3220~\pm~80$
Gyttja from 787 to 796cm.	
WIS-1807.	$2610~\pm~80$
Gyttja from 739 to 749cm.	
WIS-1808.	$1790~\pm~70$
Gyttja from 692 to 702cm.	
WIS-1852.	$8230~\pm~110$
Cilturenttia from 995 to 900 am basel date and t	imo of doglaciation

Silty gyttja from 885 to 890cm, basal date and time of deglaciation.

 $\pm$  100

WIS-1820.	Cirrus Lake	6310
10-1040.	CITTUS Luke	

Core coll Aug 1985 from Cirrus Lake (unofficial name), Labrador (52° 18' N, 58° 22' W) by G A King and D R Foster and subm by G A King. Lake elev 360m, water depth 102cm. Sample is light brown silty gyttja from 303 to 313cm below water surface. Dates early peak in organic matter (King, 1985). Acid treatment only.

# **Chili Lake series**

Core coll Aug 1985 from Chili Lake (unofficial name), Labrador (52° 19' N, 60° 23' W) by G A King and D R Foster; subm by G A King. Lake elev 410m, water depth 3.22m. Same comments as Ferry Lake, above (King, 1985).

WIS-1821.	$2440~\pm~80$
Dark brown gyttja from 365 to 375cm.	
WIS-1822.	$3710~\pm~80$
Dark brown gyttja from 413 to 423cm.	
WIS-1823.	$5310~\pm~90$
Dark brown gyttja from 461 to 471cm.	
WIS-1824.	$6220~\pm~90$
Dark brown gyttja from 505 to 512cm.	
WIS-1850.	$7520\pm120$

Silty gyttja from 546 to 552cm, sample gives basal date and time of deglaciation.

#### **Claude Lake series**

Core coll Aug 1985 from Claude Lake (unofficial name) Labrador (53° 35' N, 58° 35' W) by G A King and H E Wright, Ir and subm by G A King. Lake elev 480m, water depth 9.93m. Same comments as Ferry Lake, above.

## WIS-1825.

 $1610 \pm 70$ 

Light brown gyttja from 1061 to 1067cm.

#### WIS-1826.

 $\mathbf{2440} \pm \mathbf{80}$ 

Light brown gyttja from 1132 to 1137cm. Dates abrupt decrease in organic matter and change in color.

#### WIS-1827.

### $5250 \pm 90$

Light brown gyttja from 1187 to 1194cm. Dates abrupt increase in organic matter and change in color.

### WIS-1828.

 $6300 \pm 90$ 

Green silty gyttja from 1266 to 1273cm.

# Fred's Lake series

Core coll Aug 1985 from Freds Lake (unofficial name), Labrador (53° 30' N, 63° 42' W) by G A King and H E Wright, Jr and subm by G A King. Dated to calculate deglaciation time, sediment accumulation, pollen influx and arrival of Boreal tree spp, Picea mariana, P glauca, and Abies balsamea in area. Lake elev 430m, water depth 344cm. All depths from water surface (King, 1985). Acid treatment only.

WIS-1846.	$2210 \pm 70$
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Brown gyttja from 398 to 407cm.

WIS-1847.

Brown gyttja from 452 to 460cm.

#### WIS-1848.

Brown gyttja from 514 to 523cm, dates slight decrease in percent organic matter after initial rapid increase.

#### WIS-1849.

#### $6520 \pm 110$

 $5640 \pm 100$ 

Silty gyttja from 578 to 583cm, basal date and time of deglaciation.

# WIS-1851. Traffic Lake

Core coll Aug 1985 from Traffic Lake (unofficial name), Labrador (53° 16' N, 62° 27' W) by G A King and H E Wright, Jr and subm by G A King. Lake elev 460m, water depth 2.52m. Brown gyttja from 482 to 489cm below water surface, dates second major increase in percent organic matter in core. Acid treatment only.

#### 413

 $5030 \pm 90$ 

 $4010 \pm 80$ 

#### WIS-1855. Sardine Lake

#### $7050 \pm 80$

Core coll Aug 1985 from Sardine Lake (unofficial name), Labrador (53° 03' N, 61° 29' W) by G A King and H E Wright, Jr and subm by G A King. Lake 370m, water depth 2.38m. Silty gyttja from 410 to 415cm below water surface, basal date and time of deglaciation. Acid treatment only.

### **Access Lake series**

Core coll Aug 1985 from Access Lake (unofficial name), Labrador (53° 27' N, 60° 34' W) by G A King and H E Wright, Jr and subm by G A King. Lake elev 200m, water depth 2.89m. All depths from water surface. Dates used to calculate sediment accumulation rates, pollen influx and when major Boreal tree spp, *Picea mariana*, *P glauca*, and *Abies balsamea* colonized region. Acid treatment only.

$2220 \pm 90$
<b>2220</b> ±

Brown gyttja from 348 to 356cm.

WIS-1857.

Brown gyttja from 409 to 419cm.

#### WIS-1858.

#### $5200 \pm 100$

 $3590 \pm 80$ 

Brown gyttja from 476 to 486cm, dates slight decrease in percent organic matter after initial rapid increase.

#### Portugal

#### WIS-1778. Logoa dos Perus

# $9980~\pm~100$

Sample coll May 1980 from Lagoa dos Perus, near town of Covilha (40° 15' N, 07° 45' W) by W A Watts and B Huntley and subm by W A Watts, Botany Dept, Trinity Coll, Dublin 2, Ireland. Silty gyttja from 1232 to 1237cm below lake surface (basal date). Date is min for disappearance of local ice cover at end of last glaciation (Janssen & Woldringh, 1981).

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#### NOTES AND COMMENTS

# RADIOCARBON DATES FROM TWO COASTAL SITES IN THE MANU'A GROUP, AMERICAN SAMOA

#### T L HUNT and P V KIRCH

# The Burke Museum, University of Washington Seattle, Washington 98195

Samples of inshore marine shell species (various taxa, see description below) were collected from controlled excavation of ceramic-bearing strata of two archaeologic sites in the Manu'a Island group, American Samoa. Located on the closely adjacent islands of Ta'u and Ofu (14° 14′ 30″ S, 169° 30′ 40″ E and 14° 10′ 55″ S, 169° 39′ 0″ E, respectively), these sites represent human occupation along shorelines undergoing a parallel depositional sequence of calcareous sand dune development and concomitant seaward progradation. Our primary objective was to obtain an initial age estimate for prehistoric ceramics from eastern Samoa. On stylistic and technologic criteria, the ceramics recovered from our excavations can be classified as thick-coarse Polynesian Plainware. Based on previous studies in Western Samoa, Polynesian Plainware represents a terminal phase of prehistoric pottery manufacture in the Samoan Islands, believed to date from ca 200 BC to AD 300 (Green & Davidson, 1974).

The samples selected for radiocarbon analysis were collected from secure stratigraphic context associated with pottery, flaked basalt tools, and food remains represented by bone and artificially fractured marine shell (primarily gastropods). There were no indications of post-depositional disturbance or other factors that might render the shell samples non-contemporaneous with other cultural contents of the strata from which they were collected (Hunt & Kirch, in press).

<sup>14</sup>C measurements were made by Beta Analytic, Inc (see below) who report pretreatment of the outer layers of the shell with dilute acid. The benzene syntheses and counting proceeded normally. The <sup>13</sup>C/<sup>12</sup>C ratio was measured to establish a <sup>13</sup>C adjusted age. Corrections for specific <sup>14</sup>C activity, and for the reservoir effect (Stuiver & Polach, 1977), taking into account regional ocean variation (Delta-R estimates), as well as calibration for secular effects were made following the recent work of Stuiver, Pearson and Braziunas (1986). These calibrations were made using a FORTRAN program on a floppy disk provided to the authors by M Stuiver and P Reimer (Stuiver & Reimer, 1986).

The radiocarbon significance of these age estimates from marine shell is their close contemporaneity with corrected (after Stuiver & Becker, 1986) radiocarbon assays of wood charcoal associated with stylistically and technologically similar ceramic assemblages from Upolu Island in Western Samoa (Green & Davidson, 1974, p 214–217; see Fig 1). Thus, corrected shell estimates and those of wood charcoal are, on comparative archaeologic evidence, closely comparable in calibrated age (AD/BC). This demonstration of comparability in <sup>14</sup>C ages determined on marine shell and wood charcoal samples is especially noteworthy in light of the skepticism with



Fig 1. Calibrated age ranges (1 & 2 sd) of marine shell samples from the Manu'a Group, American Samoa compared with calibrated dates (1 & 2 sd) of wood charcoal samples from Upolu Island, Western Samoa. The age estimates are stratigraphically associated with stylistically and technologically near-identical ceramic assemblages of thick-coarse Polynesian Plainware.

which some Pacific archaeologists have viewed <sup>14</sup>C ages on marine shell samples.

In sum, marine shell samples from archaeologic contexts in the Samoan Islands have been demonstrated to yield <sup>14</sup>C ages that closely agree with associated results from wood charcoal.

#### ACKNOWLEDGMENTS

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#### ARCHAEOLOGIC SAMPLES

#### Beta-19741. Ta'u Island

Marine shell (Trochus sp, Cypraea spp, Conus sp, Drupa cf ricinus, Cymatiidae and Mitridae) from Site AS-11-51, Unit 1, Layer D, Level 6 in an organically-enriched midden of calcareous sand matrix; thick-coarse pottery abundant. <sup>14</sup>C age ( $^{13}$ C adjusted) years BP 1880 ± 50; cal AD range 0 (70) 128 at 1σ; cal BP range 1950 (1880) 1822 at 1σ.

#### Beta-19742. Ofu Island

Marine shell (Turbo sp) from Site AS-13-1, Unit 1, Layer D, Level 10 in an organically-enriched midden of calcareous sand matrix; thick-coarse pottery present (not abundant). <sup>14</sup>C age yr BP 1890 ± 50; cal 28 BC (cal AD 45) 108 at 1σ; cal BP 1977 (1905) 1842 at 1σ.

 $\delta^{13}C = +2.6\%$ 

 $2330 \pm 50$ 

 $2350 \pm 50$  $\delta^{13}C = +2.9\%$ 

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#### LABORATORIES\*

- A ARIZONA Dr Austin Long Laboratory of Isotope Geochemistry Geosciences Department University of Arizona Tucson, Arizona 85721
- AC INGEIS Dr. Enrique Linares Pabellón INGEIS, Ciudad Universitaria 1428 Buenos Aires, Argentina
- ALG ALGIERS Omar Rahmouni Bd Frantz Fanon BP 1147 Algiers, Algeria
- ANL ARGONNE NATIONAL LABORATORY Mr James Gray, Jr Argonne National Laboratory 9700 South Cass Avenue Argonne, Illinois 60439
- ANTW ANTWERP UNIVERSITY Prof R Vanhoorne Dept of General Botany State University Centre Antwerp Groenenborgerlaan 171 B-2020 Antwerp, Belgium
- ANU AUSTRALIAN NATIONAL UNIVERSITY Henry A. Polach Radiocarbon Dating Research Australian National University PO Box 4, Canberra 2600 Australia
- AU UNIVERSITY OF ALASKA William S Reeburgh and M Springer Young Institute of Marine Science University of Alaska Fairbanks, Alaska 99701
- B BERN Prof H Oeschger Physikalisches Institut Universität Bern Sidlerstrasse 5 CH-3012 Bern, Switzerland
- Ba BRATISLAVA Prof Dr P Povinec, Dr Sc Department of Nuclear Physics Comenius University 842 15 Bratislava Czechoslovakia
- BC BROOKLYN COLLEGE Prof Evan T Williams Department of Chemistry Brooklyn College Brooklyn, New York 11210

\* Please notify the Managing Editor of staff or address changes.

422	Laboratories
BETA	BETA ANALYTIC M A Tamers and J J Stipp Beta Analytic, Inc 8199 NW 33rd St Miami, Florida 33122
Birm	BIRMINGHAM R E G Williams Department of Geological Sciences, PO Box 363 University of Birmingham Birmingham B15 2TT, England
Bln	BERLIN Dr Günther Kohl Akademie der Wissenschaften der DDR Zentralinstitut für Alte Geschichte und Archäologie 1086 Berlin, Liepziger Str 3/4 German Democratic Republic
ВМ	BRITISH MUSEUM Sheridan Bowman Research Laboratory The British Museum London WC1B 3DG, England
BS	BIRBAL SAHNI INSTITUTE Dr G Rajagopalan Radiocarbon Laboratory Birbal Sahni Institute Paleobotany Post Box 106 Lucknow—226 007 India
CAR	CARDIFF Quentin Dresser Radiocarbon Laboratory University College Cardiff CF1 1XL, Wales
CRCA	CAIRO Dr Shawki M Nakhla Cairo Carbon-14 Dating Laboratory Center of Research and Conservation of Antiquities Organization of Egyptian Antiquities Midan El Tahrir Cairo, Egypt
CSM	COSMOCHEMISTRY LABORATORY A K Lavrukhina and V A Alexeev VI Vernadsky Institute of Geochemistry and Analytical Chemistry USSR Academy of Sciences Moscow, USSR
CU	CHARLES UNIVERSITY Jan Šilar Department of Hydrogeology and Engineering Geology Charles University Albertov 6 CS-128 43 Praha 2, Czechoslovakia
Dak	DAKAR

DAKAR Dr Cheikh Anta Diop Directeur du Laboratoire de Radiocarbone IFAN Université de Dakar République du Sénégal

- DAL DALHOUSIE UNIVERSITY Prof J Gordon Ogden, III Department of Biology Dalhousie University Halifax, Nova Scotia, Canada B3H 3J5
- DE UNITED STATES GEOLOGICAL SURVEY Dr I C Yang U S Geological Survey WRD Box 25046, Mail Stop 407 Denver Federal Center Denver, Colorado 80225
- Deb DEBRECEN Eva Csongor Institute of Nuclear Research Hungarian Academy of Sciences (ATOMKI) Bem tér 18/c, Pf 51 Debrecen, Hungary
- DIC DICARB RADIOISOTOPE COMPANY Irene C Stehli DICARB Radioisotope Company 7711 SW 103 Avenue Gainesville, Florida 32608-6214
- F FLORENCE Dr C M Azzi, L Bigliocca, and F. Gulisano Radiocarbon Dating Laboratory Istituto di Antropologia Università di Firenze Via del Proconsolo 12 50122, Florence, Italy
- Fr FREIBERG Dr Klaus Fröhlich Sektion Physik Bergakademie Freiberg DDR 92 Freiberg
- Fra FRANKFURT Prof Dr Reiner Protsch Radiocarbon Laboratory J W Goethe-Universität Siesmayerstrasse 70 6000 Frankfurt am Main West Germany
- FZ FORTALEZA Prof M F Santiago Departamento de Fisica UFCe, Cx Postal 12 62 60,000 Fortaleza/CE, Brazil
- GaK GAKUSHUIN UNIVERSITY Prof Kunihiko Kigoshi Gakushuin University Mejiro, Toshima-ku Tokyo, Japan
- Gd GLIWICE Mieczystaw F Pazdur and Andrzej Zastawny Radiocarbon Laboratory Silesian Technical University Institute of Physics, C-14 Laboratory ul Bolestawa Krzywoustego 2 P1-44-100 Gliwice, Poland

424	Laboratories
Gif	GIF-SUR-YVETTE Dr J Labeyrie or Mme G Delibrias Centre des Faibles Radioactivités Laboratoire mixte CNRS-CEA 91190 Gif-sur-Yvette, France
GrN	GRONINGEN Prof W G Mook Isotopes Physics Laboratory University of Groningen Westersingel 34 9718 CM Groningen, Netherlands
GSC	OTTAWA Dr Roger N McNeely Radiocarbon Dating Laboratory Geological Survey of Canada 601 Booth Street Ottawa, Ontario K1A OE8, Canada
GU	SCOTTISH UNIVERSITIES RESEARCH & REACTOR CENTRE Prof M S Baxter and Dr G T Cook GU Radiocarbon Dating Laboratory Scottish Universities Research & Reactor Centre East Kilbride Glasgow G75 OQU, Scotland
GX	GEOCHRON LABORATORIES Harold W Krueger Division Krueger Enterprises, Inc 24 Blackstone Street Cambridge, Massachusetts 02139
НАМ	UNIVERSITY OF HAMBURG Prof Dr H W Scharpenseel and P Becker-Heidmann Ordinariat für Bodenkunde Universität Hamburg Allende-Platz 2 D-2000 Hamburg 13 West Germany
HAR	HARWELL R L Otlet Isotope Measurements Laboratory Nuclear Applications Centre Bldg 10.46 AERE, Harwell Oxfordshire OX11 ORA, England
Hd	HEIDELBERG Prof K O Münnich, D Berdau, and Marianne Münnich Institut für Umweltphysik Universität Heidelberg Im Neuenheimer Feld 366 D-69 Heidelberg, West Germany
Hel	HELSINKI Högne Jungner Radiocarbon Dating Laboratory University of Helsinki Snellmaninkatu 5 SF-00170 Helsinki 17, Finland
HIG	HAWAII INSTITUTE OF GEOPHYSICS Robert W Buddemeier Hawaiian Institute of Geophysics University of Hawaii 2525 Correa Road Honolulu, Hawaii 96822

- Hv HANNOVER Dr M A Geyh Niedersächsisches Landesamt für Bodenforschung D-3000 Hannover-Buchholz, Postf 510153 West Germany
- I TELEDYNE ISOTOPES James Buckley Teledyne Isotopes 50 Van Buren Avenue Westwood, New Jersey 07675
- IRPA INSTITUT ROYAL DU PATRIMOINE ARTISTIQUE M Dauchot-Dehon, J Heylen, and M Van Strydonck Institut Royal du Patrimoine Artistique I Parc du Cinquantenaire Brussels 4, Belgium
- ISGS ILLINOIS STATE GEOLOGICAL SURVEY Dr Dennis D Coleman and Chao-li Liu Section of Analytical Chemistry Illinois State Geological Survey Natural Resources Building Urbana, Illinois 61801
- JGS GEOLOGICAL SURVEY OF JAPAN Dr Shigeko Togashi Geochemical Section Geological Survey of Japan 1-1-3, Higashi, Yatabe Tsukuba, Ibaraki 305, Japan
- K COPENHAGEN Dr Henrik Tauber Geological Survey of Denmark and National Museum DKK-1220 Copenhagen K, Denmark
- KAERI KOREA ATOMIC ENERGY RESEARCH INSTITUTE Dr Kyung Rin Yang Radioanalytical Division Korean Advanced Energy Research Institute PO Box 7, Cheong Ryang Seoul, Korea
  - KIEL Dr Horst Willkomm and Dr H Erlenkeuser Institut für Reine und Angewandte Kernphysik Universität Kiel Olshausenstrasse 40-60 23 Kiel, Germany
  - KÖLN Dr J C Freundlich Universität Köln, Institut für Ur-und Frühgeschichte C<sup>14</sup>-Laboratorium Köln-Lindenthal Weyertal 125, W Germany
- KSU KYOTO SANGYO UNIVERSITY Prof Osamu Yamada Faculty of Science Kyoto Sangyo University Kita-ku, Kyoto Japan 603

ΚI

KN

L LAMONT Dr Tsung-Hung Peng Lamont-Doherty Geological Observatory of Columbia University Palisades, New York 10964

•

LAR	LIEGE STATE UNIVERSITY Prof Dr Jean Govaerts Lab d'application des radioéléments Chimie B6, Sart Tilman Liège, Belgium
LE	LENINGRAD Radiocarbon Laboratory Institute of Archaeology (Leningrad Section) Dvortsovaya Nab 18 Leningrad 192041, USSR
LJ	UNIVERSITY OF CALIFORNIA, SAN DIEGO Prof H E Suess Mt Soledad Radiocarbon Laboratory S-003 University of California, San Diego La Jolla, California 92093
LOD	LODZ Andrzej Kanwiszer and Pawet Trzeciak Radiochemical Laboratory Archaeological and Ethnographical Museum in Lódz pl Wolności 14 91-415 Lódz, Poland
LP	LA PLATA Prof Anibal Juan Figini Laboratorio de Tritio y Radiocarbono Facultad de Ciencias Naturales y Museo Paseo del Bosque 1900 La Plata, Argentina
Lu	LUND Prof Björn Berglund and Mr Sören Håkansson Radiocarbon Dating Laboratory University of Lund Tunavägen 29 S-223 63 Lund, Sweden
Lv	LOUVAIN LA NEUVE Mr Etienne Gilot Laboratoire de Carbon 14 Chemin du Cyclotron 2 1348 Louvain la Neuve, Belgium
Ly	UNIVERSITY OF LYON Mr Jacques Evin Laboratoire de Radiocarbone Centre de datations et d'Analyses Isotopiques Université Claude Bernard—Lyon I 43, Boulevard du 11 Novembre 1918 69621, Villeurbanne-Lyon France
MC	MONACO Dr Jean Thommeret and Dr Y Thommeret Laboratoire de Radioactivité Appliquée Centre Scientifique de Monaco Avenue Saint Martin Monaco
MGU	MOSCOW Prof P Kaplin and Dr A Schulkov Laboratory of Recent Deposits and Pleistocene Paleogeography Geographical Faculty Moscow State University Moscow 117234, USSR

Laboratories

- ML MIAMI Dr H G Östlund Rosenstiel School of Marine and Atmospheric Science University of Miami Miami, Florida 33149
- Mo VERNADSKI INSTITUTE OF GEOCHEMISTRY Vernadski Institute of Geochemistry Academy of Sciences of the USSR Moscow, USSR Address: Prof V L Barsukov Vorobevskoye shosse, d47-A Moscow, USSR
- MOC MOST E F Neustupny Archaeological Institute Czechoslovak Academy of Sciences Letenská 4 Prague I, Czechoslovakia 118 01
- MRRI MARINE RESOURCES RESEARCH INSTITUTE Thomas D Mathews Marine Resources Research Institute P O Box 12559 Charleston, South Carolina 29412
- N NISHINA MEMORIAL (TOKYO) Dr Fumio Yamasaki The Japan Radioisotope Association 2-28-45 Honkomagome, Bunkyo-ku, Tokyo Japan 113
- NSTF NUCLEAR SCIENCE AND TECHNOLOGY FACILITY C C Thomas, Jr, Director Radiocarbon Laboratory Nuclear Science and Technology Facility State University of New York at Buffalo Rotary Road Buffalo, New York 14214
- NTU NATIONAL TAIWAN UNIVERSITY Yuin-Chi Hsu Department of Physics National Taiwan University Taipei, Taiwan, China
- Ny NANCY Pr René Coppens et Dr Pierre Richard Laboratoire de Radiogéologie ENS de Géologie Appliquée et de Prospection Minière Institut National Polytechnique de Lorraine BP 452 54001 Nancy Cedex, France
- NZ NEW ZEALAND Dr B J O'Brien Institute of Nuclear Sciences DSIR, Private Bag Lower Hutt, New Zealand

Pi

PISA Prof E Tongiorgi Laboratorio di Geologia Nucleare dell'Università Via S Maria, 22 Pisa, Italy

428	Laboratories
PIT	UNIVERSITY OF PITTSBURGH Robert Stuckenrath Carbon-14 Lab, U-PARC 365 William Pitt Way Pittsburgh, Pennsylvania 15238
Pr	PRAGUE Alois Dubansky Laboratory for Isotopes Geochemistry and Geochronology Geological Institute Czechoslovak Academy of Sciences Prague-8 Na Hrazi 26
PRL	PHYSICAL RESEARCH LABORATORY Devendra Lal and D P Agrawal Physical Research Laboratory Navrangpura Ahmedabad-380009, India
Pta	PRETORIA Dr J C Vogel Natural Isotopes Division National Physical Research Laboratory CSIR PO Box 395 Pretoria, South Africa
Q	CAMBRIDGE Dr V R Switsur University of Cambridge Godwin Laboratory Free School Lane Cambridge, England CB2 3RS
QL	QUATERNARY ISOTOPE LABORATORY Prof Minze Stuiver Quaternary Isotope Laboratory AJ-20 Department of Geological Sciences University of Washington Seattle, Washington 98195
QU	QUEBEC Dr Louis Barrette and Claude Samson Centre de Recherches Minérales Complexe Scientifique du Québec 2700 rue Einstein Ste-Foy, Québec Canada, GIP 3W8
R	ROME Dr Francesco Bella, Istituto di Fisica and Dr Cesarina Cortesi, Istituto di Geochimica Radiocarbon Dating Laboratory University of Rome Città Universitaria 00100-Rome, Italy
RL	RADIOCARBON, LTD Charles S Tucek Radiocarbon, Ltd Route 2, Box 21E Lampasas, Texas 76550
RT	REHOVOT GEOISOTOPE LABORATORY Dr Aaron Kaufman and Mr I Carmi Geoisotope Laboratory Department of Isotope Research Weizmann Institute of Science Rehovot, Israel

- RU RICE UNIVERSITY J A S Adams Department of Geology Rice University Houston, Texas 77001
- S SASKATCHEWAN Mr A Rutherford Saskatchewan Research Council University of Saskatchewan Saskatoon, Saskatchewan, Canada
- SFU SIMON FRASER UNIVERSITY Dr Erle Nelson Archaeology Department Simon Fraser University Burnaby, British Columbia Canada V5A 1S6
- SI SMITHSONIAN INSTITUTION Dr W H Klein, Director Radiation Biology Laboratory Dr Robert Stuckenrath C<sup>14</sup> Laboratory 12441 Parklawn Drive Rockville, Maryland 20852
- SMU SOUTHERN METHODIST UNIVERSITY Dr Herbert Haas Institute for the Study of Earth and Man Southern Methodist University Dallas, Texas 75275
- SRR SCOTTISH UNIVERSITIES RESEARCH AND REACTOR CENTRE Dr D D Harkness NERC Radiocarbon Laboratory Scottish Universities Research and Reactor Centre East Kilbride Glasgow G75 0QU, Scotland
- St STOCKHOLM Dr Eric Welin Laboratory for Isotope Geology Swedish Museum of Natural History S-104 05 Stockholm 50, Sweden
- Su FINLAND Tuovi Kankainen Geological Survey of Finland SF-02150 Espoo 15, Finland
- SUA SYDNEY UNIVERSITY, AUSTRALIA Dr Mike Barbetti Macintosh Centre Madsen Building F09 University of Sydney Sydney NSW 2006, Australia
- T TRONDHEIM Dr Reidar Nydal, Steinar Gulliksen, and Knut Lövseth Radiological Dating Laboratory The Norweigian Institute of Technology 7034 Trondheim, Norway

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Laboratories
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- TA TARTU Evald Ilves and A Liiva Radiocarbon Laboratory Institute of Zoology and Botany Academy of Sciences of the Estonian SSR Vanemuise St 21 Tartu, Estonia, USSR
- TAM TEXAS A & M UNIVERSITY Dr David Schink Dept of Oceanography Texas A & M University College Station, Texas 77843
- TB TBILISI Dr A A Burchuladze Radiocarbon Laboratory Tbilisi University 1 Chavchavadze Avenue Tbilisi, USSR 380028
- TK UNIVERSITY OF TOKYO Dr Naotune Watanabe C-14 Dating Laboratory University Museum (Shiryokan) University of Tokyo 3-1 Hongo 7-chome Bunkyo-ku, Tokyo 113 Japan
- Tln TALLINN J M Punning Institute of Geology Academy of Sciences of the Estonian SSR Tallinn, Estonia puiestee 7 ESSR
- TUNC TEHRAN UNIVERSITY NUCLEAR CENTRE Dr A Mahdavi Tehran University Nuclear Centre PO Box 2989 Tehran, Iran
- Tx TEXAS Mr S Valastro, Jr or Dr E Mott Davis Radiocarbon Laboratory University of Texas at Austin Balcones Research Centre 10,100 Burnet Road Austin, Texas 78758
- U UPPSALA Dr Ingrid U Olsson Institute of Physics University of Uppsala Box 530 S-751 21 Uppsala, Sweden
- UB BELFAST Gordon W Pearson Palaeoecology Laboratory The Queen's University Belfast, BT7 1NN Northern Ireland
- UCLA UNIVERSITY OF CALIFORNIA, LOS ANGELES Prof Rainer Berger Institute of Geophysics University of California Los Angeles, California 90024

- UCR UNIVERSITY OF CALIFORNIA, RIVERSIDE Dr R E Taylor Department of Anthropology Institute of Geophysics and Planetary Physics University of California Riverside, California 92512
- UD UDINE Dr Valerio Barbina, Prof Franco Calligaris, Dr Adriano Del Fabbro, and Dr Alessandro Turello Centro di Ricerca Applicata e Documentazione Viale Leonardo da Vinci 16 33100 Udine, Italy
- UGa THE UNIVERSITY OF GEORGIA John E Noakes and Betty Lee Brandau Center for Applied Isotope Studies The University of Georgia 110 Riverbend Road Athens, Georgia 30602
- UGRA UNIVERSITY OF GRANADA Prof Cecilio González-Gómez Laboratorio de Datación por Carbono-14 Facultad de Ciencias Universidad de Granada 18071 Granada, Spain
- UM UNIVERSITY OF MIAMI Dr J J Stipp, G Treadgold, and D Hood Radiocarbon Dating Laboratory Department of Geology University of Miami Coral Gables, Florida 33124
- USGS US GEOLOGICAL SURVEY MENLO PARK, CALIFORNIA Dr Stephen W Robinson US Geological Survey 345 Middlefield Road Menlo Park, California 94025
- UW UNIVERSITY OF WASHINGTON Dr A W Fairhall Department of Chemistry University of Washington Seattle, Washington 98195
- VRI VIENNA RADIUM INSTITUTE Dr Edwin Pak Institut für Radiumforschung und Kernphysik Universität Wien Boltzmanngasse 3 A-1090 Vienna, Austria
- W US GEOLOGICAL SURVEY Dr Meyer Rubin US Geological Survey National Center, 971 Reston, Virginia 22092
- WAT UNIVERSITY OF WATERLOO Dr Peter Fritz Department of Earth Sciences Isotopes Laboratory University of Waterloo Waterloo, Ontario, Canada N2L 3G1

#### Laboratories

WHOI WOODS HOLE OCEANOGRAPHIC INSTITUTION Dr Ellen R M Druffel Radiocarbon Laboratory Department of Chemistry Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543

WIS WISCONSIN Raymond L Steventon IES Center for Climatic Research University of Wisconsin 1225 W Dayton St Madison, Wisconsin 53706

Wk UNIVERSITY OF WAIKATO Dr A G Hogg and Dr C H Hendy Radiocarbon Laboratory University of Waikato Private Bag Hamilton, New Zealand

WRD US GEOLOGICAL SURVEY, WATER RESOURCES DIVISION Dr F J Pearson, Jr US Geological Survey, Water Resources Division Isotope Hydrology Laboratory National Center, MS 432 Reston, Virginia 22092

- WSU WASHINGTON STATE UNIVERSITY Dr John C Sheppard Department of Chemical and Nuclear Engineering Washington State University Pullman, Washington 99164
- X WHITWORTH COLLEGE Dr Edwin A Olson Department of Earth Science Whitworth College Spokane, Washington 99218
- Ya YALE Prof Karl K Turekian Department of Geology and Geophysics Yale University New Haven, Connecticut 06520
- Z ZAGREB Dr Adela Sliepcevic and Dr Dušan Srdoc Institute "Ruder Boškovic" 41001 Zagreb, POB 1016, Yugoslavia

# **ACCELERATOR FACILITIES**

AA NSF-ARIZONA ACCELERATOR FACILITY D J Donahue and P E Damon NSF-Arizona Accelerator Facility for Radioisotope Analysis Department of Physics University of Arizona Tucson, Arizona 85721

#### Laboratories

ETH/ACCELERATOR MASS SPECTROMETER FACILITY ETH Willy Wölfli ETH/AMS Facility Institut für Mittelenergiephysik Eidgenössische Technische Hocschule CH-8093 Zürich, Switzerland GIF SUR YVETTE TANDETRON AMS FACILITY F Yiou and G M Raisbeck Laboratoire René Bernas 91406 Orsay, France and I C Duplessy and M Arnold Centre des Faibles Radioactivités 91190 Gif sur Yvette, France OXFORD RADIOCARBON ACCELERATOR UNIT OxA R E M Hedges Oxford Radiocarbon Accelerator Unit Research Laboratory for Archaeology and the History of Art Oxford University 6 Keble Road Oxford OX1 3QJ, England UNIVERSITY OF WASHINGTON ACCELERATOR MASS SPECTROMETRY QLA FACILITY George W Farwell and Pieter M Grootes University of Washington Accelerator Mass Spectrometry Facility Nuclear Physics Laboratory, Department of Physics University of Washington GL-10 Seattle, Washington 98195 ROCHESTER TANDEM ELECTROSTATIC ACCELERATOR SYSTEM H E Gove Nuclear Structure Research Laboratory University of Rochester Rochester, New York 14627 RIDDL SIMON FRASER UNIVERSITY RIDDL GROUP D E Nelson Simon Fraser University RIDDL Group Archaeology Department Simon Fraser University Burnaby, British Columbia V5A 1S6 Canada ISOTRACE RADIOCARBON FACILITY TO **Roelf P Beukens** Isotrace Laboratory University of Toronto Toronto, Ontario M5S 1A7 Canada UPPSALA TANDEM ACCELERATOR LABORATORY Ua Dr Göran Possnert Tandem Accelerator Laboratory University of Uppsala Box 533 S-751 21 Uppsala, Sweden UTRECHT VAN DE GRAAFF LABORATORIUM UtC Dr K van der Borg Robert J van der Graaff Laboratorium Rijksuniversiteit Utrecht Princetonplein 5 PO Box 50.000 3508 TA Utrecht, The Netherlands

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### INDEX Volume 29, Nos. 1 to 3, 1987 ARCHAEOLOGIC SAMPLES

Date	Culture or Period	Sample No.	No.	Page	Date	Culture or Period	Sample No.	No.	Page
	ÅI AND			8-	BI	RITISH ISLES (c	ontinued)		
		1	0	970	5660 + 80		HAR-6207	1	96
$2570 \pm 50$	Late Bronze Age	Lu-2002 9603	3	318	5440 + 70		-4865	<i>"</i>	91
$2430 \pm 50$ $9330 \pm 50$	,,	-2005	"	"	$5360 \pm 50$		BM-2353	2	187
2330 ± 30		2001			$5180 \pm 70$		HAR-3195	1	87
	ALGERIA				$5160 \pm 45$	Contaminated	BM-2355	2	180
$9390 \pm 130$	Typical Capsian	SMU- 712	2	233	$4950 \pm 80$		HAR-2845	1	90
$9100 \pm 130$	"	-1108	"	234	$4820 \pm 120$		-2378		84
$8580 \pm 150$	"	- 704	"	233	$4790 \pm 80$		-0203		89
$8390 \pm 170$	"	-1121	"	234	$4740 \pm 70$ 4790 - 90		-0210		97
$7780 \pm 250$	Capsian	-1135	"	235	$4720\pm80$ $4680\pm70$		-5726	"	89
$7750 \pm 50$	Upper Capsian	-1082	"	233	$4680 \pm 70$ $4680 \pm 110$		-2371	"	84
$7590 \pm 60$	"	-1095	"		4660 + 80		-6264	"	89
$7350 \pm 50$	<i>"</i>	-1120	"	234	$4640 \pm 70$		-4544	"	91
$7330 \pm 390$	Contaminated	-1152	,,	235	$4610 \pm 90$		-2374	"	84
$7210 \pm 340$ $7150 \pm 900$	upper Capsian	-1080	"	233	$4610 \pm 90$		-5721	"	92
$6770 \pm 200$	"	-1154	"	234	$4610 \pm 100$		-5722	"	"
$6750 \pm 70$	"	-1098	"	"	$4600 \pm 120$	Neolithic	-2274	"	63
$6620 \pm 110$	"	-1084	"	233	$4590 \pm 70$		-3078	"	87
$6520 \pm 170$	"	-1099	"	234	$4580 \pm 70$		-4739		88
$1230 \pm 150$	Islamic	BM-2368	"	178	$4560\pm80$		-5/24		92
$1170 \pm 50$	"	-2369	"	"	4540±80		-2919		90
					4520±70		-2920 LIAD 9844	1	90
	AMERICAN SA	MOA			4520±90	Neolithic	RM_9309	9	189
$2350 \pm 50$	Terminal Prehistoric	Beta-19742	3	418	4500±00	Neonune	HAR-5793	í	92
$2330 \pm 50$	"	-19741	"	"	4500±70	Neolithic	BM-9438	9	186
					4480 + 100	"	HAR-2273	ĩ	63
	AUSTRIA				$4450 \pm 100$		-2846		90
$7180 \pm 100$		VRI- 908	3	394	$4440 \pm 70$	Neolithic	-2284	"	64
$4990 \pm 90$		- 892	"	395	$4420 \pm 70$	"	BM-2393	2	182
$3080 \pm 70$		- 955	"	394	$4420 \pm 80$	"	HAR-3386	1	88
$2350 \pm 70$		- 933	"	396	$4420 \pm 90$	"	-2272	"	63
$2280 \pm 70$		- 934	"		$4350 \pm 70$	"	-2283	"	64
$1520 \pm 60$		-1003	".	394	$4340 \pm 80$		-3387	"	88
$1390 \pm 60$		- 931		395	$4330 \pm 80$	Neolithic	BM-2391	2	182
870±00 640±60		- 932	"	396	$4320 \pm 130$	"	-2390	1	
$400 \pm 60$		- 893	"	395	4300±70		FIAK-3727 4549	1	92
$\frac{400 \pm 00}{370 \pm 60}$		- 894	"	"	4230±80	Neolithic	-4940 BM-9870	9	181
$350 \pm 60$		- 977	"	396	$4150 \pm 90$ $4150 \pm 50$	Neontine "	-9397		183
$310 \pm 70$		- 984	"	394	$4130\pm 30$ $4140\pm 80$	"	-2396	"	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
$280 \pm 60$		- 927	"	395	4140+60	"	-2406	"	185
$260 \pm 80$		- 929	"	"	4120 + 45	"	-2346	"	179
$210 \pm 60$		- 928	"	"	$4080 \pm 50$	"	-2407	"	185
$180 \pm 60$		- 895	"	"	$4060 \pm 90$	"	-2377	"	181
	PELCIUM	r			$4040 \pm 90$	"	-2395	"	183
	BELGIOM				$3990 \pm 100$		HAR-4542	1	90
$4940 \pm 70$		IRPA-718	2	205	$3870 \pm 50$	Beaker	-2325	"	62
$3670 \pm 60$		-719		907	$3810 \pm 60$	Neolithic	BM-2380	2	181
$3670 \pm 80$	Roman	-702		207	$3810 \pm 70$		HAK-5054	1	00
3400±90	Iron Age	-092	"	200	3800±80		-5566	,,	70
$2390 \pm 60$ $9490 \pm 60$	"	-691	"	206	3790±70		HAR-3064	1	95
$2490 \pm 00$ $9480 \pm 60$	"	-693	"		$3720\pm80$ $3670\pm60$	Beaker	BM-2191	;,	62
$2480 \pm 60$	Iron-La Têne	-645	"	205	3670 ± 100	Deuker	HAR-3067	"	95
$2410 \pm 70$	Iron	-688	"	205	$3650 \pm 70$	Bronze Age	BM-2281	"	64
$2350 \pm 50$	"	-689	"	206	$3640 \pm 70$	"	-2282	"	"
$2320 \pm 60$	"	-690	"	"	$3570 \pm 40$	"	-2326	"	62
$1980 \pm 50$	Roman	-699	"	206	3500±70		HAR-3682	"	87
$1930 \pm 50$	"	-716	"	204	$3490 \pm 70$	Bronze Age	BM-2430	2	186
$1860 \pm 50$	"	-717	"	205	$3480 \pm 50$	"	-2428	"	185
$1840 \pm 60$	"	-698		206	$3460 \pm 90$	Neolithic	-2394	"	182
$1830 \pm 90$	"	-703		207	$3450 \pm 50$	Bronze Age	-2327	1	63
$1800 \pm 50$	"	-097		200	3420±90	D	HAK-4204		69
$1/40\pm50$		-090		200	3390±45	Bronze Age	DWI-2109 9497	9	195
1690±00	Domon	-715	"	207	3370±40		9490	<i>,</i>	186
$1350 \pm 50$ $1450 \pm 80$	Kollian	-700	"	205	3320±90 3390±180	Misseoc	-2729	"	179
$140 \pm 50$	Medieval	-684	"	207	3910+45	Bronze Age	-2355	1	69
$1110 \pm 50$ 1110 + 50	"	-683	"	207	3210+80	prome nge	HAR-5710	;,	89
$1110 \pm 50$	"	-701	"	206	3200+110	Bronze Age	BM-2271	"	66
$990 \pm 50$	11th-13th century	-666	"	205	$3190 \pm 70$	,, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	-2324	"	62
000-00					$3150 \pm 80$		HAR-2759	"	86
	BRITISH IS	LES			$3130 \pm 80$	Bronze Age	BM-2336	"	66
10,220 + 130	Late Glacial	BM-2431	2	178	$3110 \pm 100$	"	-2192	"	62
$10,190 \pm 130$	"	-2318	"	"	$3090 \pm 60$	"	-2316	"	67
$9790 \pm 180$	Boreal	-2350	"	180	$3060 \pm 70$		HAR-5086		88
$9130 \pm 180$		HAR- 455	1	79	$3020 \pm 60$		-4998		
$8090 \pm 140$		- 456	"		$2960 \pm 70$		-2773		89
$7090 \pm 120$	Misassoc	BM-2208A	. "	61	2940±70	D 4 -	-6206	," G	170
$5890 \pm 100$	Mesolithic	-2404	- 2	184	· 2900±70	bronze Age	DM-2339	2	118

Archaeologic Samples

Date	Culture or Period	Sample No.	No	. Page	Date	Culture or Period	Sample No.	No.	Page
	BRITISH ISLES (c	ontinued)			F	BRITISH ISLES (con	tinued)		
$2810 \pm 90$	· · · · · · · · · · · · · · · · · · ·	HAR-4477	1	88	170±50	Medieval	BM-2303	1	66
$2800 \pm 80$ $2780 \pm 00$	Loto Provinci Ame	HAR-2745	"	79	$150 \pm 40$	"	-2304	"	"
$2700 \pm 30$ 2700 ± 80	Bronze Age	HAR-2911	"	65 94		CAMEROON	N		
$2650 \pm 90$	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	BM-2331	2	179	$4180 \pm 160$		 BM-2425	2	187
$2630 \pm 110$ $2600 \pm 70$		HAR-2893	1	94	$2770 \pm 120$		-2426	"	"
$2590 \pm 170$	Peat	BM-2398	2	183		CYPRUS			
$2520 \pm 70$	D	HAR-1058	1	80	$5710 \pm 100$	Neolithic	BM-2280	1	67
$2470 \pm 250$ $2450 \pm 110$	Peat Iron Age	BM-2399	2	183	$4030 \pm 110$	"	-2279	"	68
$2450\pm80$	Peat	-2400	"	184	$3930 \pm 100$ 2090 + 50	"	-2278	"	67
$2410 \pm 80$ $2400 \pm 100$	Peat	HAR-2523	1	84	2030130	CODOMOST ON	-2294		08
$2390 \pm 70$	reat	HAR-2401	1	184 84		CZECHOSLOVA	KIA		
$2370 \pm 80$	Late Bronze Age	BM-2314	"	65	$8420\pm60$ $8230\pm60$		TB-428	2	254
$2310\pm50$ $2270\pm70$	Misassoc	-2290 HAR-2825	"	64	7990±45		-430	"	"
$2150 \pm 70$		-1928	"	81		FDANCE			
$2150 \pm 60$ $2150 \pm 150$	Misassoc	BM-2315	"	67	90 870 + 370	Paleolithic	DM 9911	1	60
$2130 \pm 130$ $2090 \pm 70$		-5002	"	80 91	$18,090\pm650$	"	-2307	1 //	09 "
$2080\pm60$		-5000	"	"	$14,770 \pm 270$	"	-2309	"	"
$2080 \pm 100$ $2050 \pm 80$	Pronze Am	-2805	"	93	$12,590 \pm 980$ 11,930 + 190	"	-2286	"	"
$2050 \pm 80$ $2050 \pm 80$	Bronze Age	HAR-1129	"	80	$11,690 \pm 170$	"	-2310	"	"
$2040 \pm 70$		-2932	"	95	$11,600 \pm 380$	"	-2285	"	68
$1980 \pm 110$ $1970 \pm 70$		-1021	"	79		HUNGARY			
$1950 \pm 150$	Iron Age	-2552 BM-2207A	"	61	$6250 \pm 190$	Neolithic	BM-2322	2	188
$1930 \pm 70$	0	HAR-1418	"	81	$6120 \pm 40$	"	-2323	7	"
$1930 \pm 70$ 1910 + 80	Iron Age	-1765 BM-9999	"	" 65	6020±170	"	-2321	"	"
$1900 \pm 70$		HAR-2534	"	85		INDIA			
$1900 \pm 70$ $1840 \pm 40$	Iron Age	-3017	"	95	$2360 \pm 50$	Ancient metallurgy	BM-2381	2	189
$1840 \pm 60$	11011 Age	HAR-1866	"	65 81	$2240\pm 60$ 1810+35	"	-2356	"	"
$1840 \pm 70$		HAR-1416	"	80	170±50	"	-2338	"	"
$1830 \pm 70$ $1820 \pm 70$		HAR-1927 -9530	"	81		IRAO			
$1820 \pm 70$		HAR-1417	"	81	$4210 \pm 70$	Early Dynastic	BM-2330	1	70
$1810 \pm 70$	Demons D 111	-2930	"	95	$4090 \pm 60$	"	-2329	"	,,
$1750\pm80$ $1740\pm60$	Komano-British Iron Age	-1729	"	81	$3700\pm60$	"	-2328	"	"
$1710 \pm 70$	Romano-British	-6209	"	97	2010±80	100.00	-2295		"
$1710 \pm 70$ $1620 \pm 60$	"	-6212	"	<i>"</i>	0110 000	ISRAEL			
$1590 \pm 80$	Post-Roman	-2382 -2281	,,	80	$9110 \pm 300$ 8690 + 90	Neolithic "	BM-2299 2800	1	71
$1560 \pm 60$	Contaminated	BM-2423	2	181	$8250 \pm 70$	"	-2298	"	"
$1550 \pm 10$ $1530 \pm 60$	Romano-British Post-Roman	HAR-6211 -3081	1	97 89	$8140 \pm 130$ $8100 \pm 150$	PPNB	RT-707	"	102
$1490\pm80$	"	-3080	"	"	7460±210	PPN	-650 -702B	"	104
$1470\pm80$ $1450\pm80$		-2814	"	93	$6670 \pm 140$	PNA	-682B	"	100
$1370 \pm 60$	Medieval	-2813 BM-2387	"	181	$6560 \pm 90$ $6470 \pm 130$	Late Neolithic PNA	-628A	"	103
$1340 \pm 70$		HAR-2812	"	93	$6400 \pm 200$	Late Neolithic	-628B	"	103
$1230\pm80$ 1140 + 70	Middle Saxon (?)	-1412	"	80 83	$6150 \pm 180$ 5750 + 180	Chalcolithic	-649D	"	104
$1090 \pm 80$	Middle Saxon (:)	-2806	"	92	$5750 \pm 180$ 5670 ± 90	"	-649B -648A	"	103
$1080 \pm 80$ $1080 \pm 50$	Saxon	-2594	"	85	$5570 \pm 220$	EBI	-702A	"	105
$1030\pm50$ $1020\pm50$	Medieval	BM-2432 -2405	2	187	$5540 \pm 110$ 5440 + 80	Chalcolithic	-718	"	105
$960 \pm 70$	Anglo-Saxon	HAR-3106	1	94	$4800 \pm 70$	"	-598B	"	104
$960 \pm 70$ $960 \pm 80$	Medieval	-2835	"	87	$4800 \pm 70$	Early Bronze Age	-640A	"	103
$950 \pm 60$	Late Saxon	-2427	"	83	$4400\pm80$ $4280\pm80$	Middle Bronze Age	-640B -640C	"	108
$950 \pm 80$	11th century	-2301	"	"	$4250 \pm 50$	EBII-MBI	-648B	"	105
$940 \pm 70$ $920 \pm 60$	"	-2300 -2578	"	82	$4070 \pm 100$ 3850 + 100	"	-714A	"	"
$910 \pm 70$	11th century	-2302	"	83	$3640 \pm 200$	LB	-7146	"	104
$880 \pm 70$ $870 \pm 70$	Saxon	HAR-2559	"	85	$3540 \pm 70$		-612A	"	105
$860 \pm 70$	Norman	-2595	"	93 85	$3220\pm50$ $3090\pm50$	Ancient metallurgy	BM-2382 RT-619B	2	189
$840 \pm 90$	<b>c</b>	-2804	"	92	$2830 \pm 70$	Iron II	-630	,,	105
$780 \pm 70$	Saxon Norman	-2326 -2697	"	83	$2310 \pm 50$ $9910 \pm 100$	Hellenistic	-652	"	101
$780 \pm 80$	Anglo-Saxon	-2864	"	94	$2100 \pm 110$	Hellenistic	-031A -681	"	102
$750 \pm 70$ 730 + 80		-3121	"	96	$1990 \pm 100$	Herodian	-680B	"	101
$730 \pm 50$	Medieval	BM-2306	"	66	$1990 \pm 140$ 1990 + 150	Herodian "	-653B	"	"
$720 \pm 60$	13th-14th century	HAR-2863	"	94	$1970 \pm 70$	Herodian	-631B	"	101
$600 \pm 45$ $600 \pm 80$	Norman	BM-2305 HAR-2606	"	66 86	$1930 \pm 220$ $1870 \pm 60$	"	-680A	"	"
$570 \pm 70$	13th-14th century	-2865	"	94	$1800 \pm 100$ $1800 \pm 100$	Roman	-645 -710	"	102
$310 \pm 80$	16th-17th century	-6208	"	96	$1590 \pm 110$	Byzantine	-686A	"	101

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D .	Culture or Sample		n	. D.	Culture or	Sample		D	
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	ISPAEL (continu	(ber				SPAIN (continue	d)		
	ISKAEL (CONTIN	<u>icu)</u>				SI AII (Continue	<u>-)</u>		
$1500 \pm 170$	Byzantine-Nabatean	-648G	1	104	$4350\pm80$	Eneolithic	BM-2360	2	193
$1470 \pm 50$	Byzantine	-609	"	101	$4150 \pm 40$	Copper Age	-2343	"	192
$1470 \pm 60$	Byzantine-Nabatean	-648F	"	104	$4120 \pm 70$	Encolithic	-2366		194
$1380 \pm 180$	A	-050	"	105	$4110\pm110$	Copper Age	-2344		192
$990 \pm 100$ 700 + 70	Arabic	-0800		102	4110±00	Bropze Age	-2307 UCDA 907	9	194
$700 \pm 70$ $320 \pm 70$		-014	"	"	4070±190	Eneolithic	BM-9365	9	103
$100 \pm 100$		-684	,,	101	4020+60	Copper Age	-2347	-	192
100 1 100		-001		101	3870+60	copper inge	BM-2348	"	192
	ITALY				$3820 \pm 40$	"	-2345	"	
6290 + 60	Neolithic	BM-9950	1	79	$3770 \pm 90$	Bronze Age	UGRA-238	3	385
$6250 \pm 90$	"	-2252	,	"	$3760 \pm 100$	Megalithic	-233	"	386
$5800 \pm 120$	"	-2256	"	73	$3710 \pm 60$	Bronze Age	BM-2359	2	193
$5720 \pm 120$	"	-2258	"	"	$3710 \pm 90$	" -	UGRA-262	3	385
$5620 \pm 130$	"	-2257	"	"	$3690 \pm 90$	"	-217	"	384
$4880 \pm 210$	"	-2253	"	72	$3670 \pm 100$	"	-237		385
$4870 \pm 90$	"	-2260	"	73	$3610 \pm 60$		BM-2358	2	193
$4810 \pm 180$	"	-2302	"	74	$3530 \pm 70$	Start Neolithic	UGRA-260	3	386
$4230 \pm 100$	"	-2254	"	72	3450±90	Bronze Age	-212	0	384
$4070 \pm 60$	"	-2259	"	73	3440±50 9490±100		BM-2354	2	192
3190±80	<i>"</i>	-2255	~	72	$3420\pm100$ $3960\pm100$	"	-911	"	304
$2390 \pm 50$	Roman	1KPA-735	z	208	3260±100	Neolithic /Eneolithic	-193	"	389
2350 ± 50	"	-736	"	"	3210+80	Misassoc	BM-2312	1	75
$2230 \pm 00$ $2230 \pm 80$	"	-730	"	"	$3090 \pm 130$	Neolithic/Eneolithic	UGRA-189	3	382
$2090 \pm 70$	"	-737	"	"	$2990 \pm 90$	Bronze Age	-263	"	385
$1380 \pm 50$	"	-705	"	"	$2920 \pm 90$	"	-218	"	384
$1180 \pm 50$	"	BM-2301	1	74	$2850 \pm 90$	"	-264	"	385
$100 \pm 100$		RT-705	"	102	$2840 \pm 70$	Iron Age	BM-2357	2	193
					$2740 \pm 90$	Bronze Age	UGRA-235	3	384
	JORDAN				$2670 \pm 100$	"	-231	"	"
$8190 \pm 60$	PPNB	BM-2349	2	190	$2670 \pm 90$	<i>"</i>	-232	"	
					$2640 \pm 120$	Neolithic/Encolithic	-192		382
	PARISTAN	4			2010±110	Meganthic	-191	,,	
$4170 \pm 50$	Kot Dijian	BM-2402	2	190	2590±100	Momlithic	-197	"	"
$3840 \pm 110$	"	-2403	"	"	2360±00	megantine	-195	"	888
	DOI AND				2330+80	Farly metallurgy	BM-2337	1	75
	POLAND				2210+110	Early metanorgy	UGRA-214	3	384
$3150 \pm 80$	Bronze Age	BM-2383	2	191	$2070 \pm 410$		-199	"	383
$2890 \pm 110$	"	-2386	"	"	$2140 \pm 80$	Misassoc	BM-2297	1	75
$2800 \pm 100$	"	-2386A	"	"	$1190 \pm 110$		UGRA-182	3	381
$2780 \pm 80$	"	-2385A	"	"	$930 \pm 110$		-180	"	"
$2750 \pm 70$	"	-2385		"	$860 \pm 130$		-184	"	"
$2550 \pm 280$	"	-2384	"	"	$600 \pm 90$	Chalcolithic/Megalithic	-206	"	383
	PORTUGAI	Ĺ			$580 \pm 80$	"	-205	"	"
$4700 \pm 100$	Recent Prehistoric	UCPA-179	8	386		SWEDEN			
$4550 \pm 150$	Chalcolithic	-236	"	387	7040 + 70	Mesolithic	Lu-9563	8	878
$4280 \pm 100$	"	-234	"	"	6480 + 70	mesonance "	_9559	"	313
$3930 \pm 180$	Recent Prehistoric	-185	"	386	5930+60	Late Mesolithic	-2552	"	"
$2730 \pm 140$	"	-181	"	"	$5920 \pm 90$	2.410 hitesontine "	-2553	"	372
$2550 \pm 100$		-203	"	"	$5900 \pm 100$	"	-2628	"	372
$2410 \pm 50$	Iron Age	BM-2160	1	74	5710±70		-2629	"	"
$2340 \pm 100$		UGRA-221	3	386	$5670 \pm 90$	Ertebølle culture	-2564	"	373
$2280 \pm 45$	Iron Age	BM-2159	1	74	$5480 \pm 60$	Late Mesolithic	-2627	"	372
$2140 \pm 130$	"	-2287	"		$4990 \pm 60$	Early Neolithic	-2510	"	369
1440±100 1990 - 110	Missesso	DGKA-222 BM 9999	3 1	200 75	4810±60	" Example and the state	-2546		3/1
1220±110 800±60	wiisassoc "	DM-2200	1 //	15	4440±70	runneideaker culture	-2567		574
050±00		-2209			4430±70	Neolithic	-2008	"	0.08
	SPAIN				4130+70	Middle Neolithic	-2009	,,	371
$14.600 \pm 300$	Epeolithic /Neolithic	LIGPA-196	8	889	4120+60	middle recontine	-2595	"	370
$14,000\pm 300$ 14,300 + 290	Paleolithic	BM-2375	2	194	3960 + 70	Battle Axe culture	-2630	"	371
13,370+260	i alcontine	UGRA-225	3	383	3920+60	<i>"</i>	-2631	"	"
$13.270 \pm 220$	"	BM-2373	2	194	$3850 \pm 60$	"	-2554	"	"
$13,220 \pm 270$	"	<b>UGRA-208</b>	3	383	$3470 \pm 60$	Late Neolithic	-2559	"	374
$12,520 \pm 350$	"	-244	"	"	3300 ± 60	"	-2558	"	"
$12,460 \pm 180$	"	-201	"	383	$2970 \pm 60$	Bronze Age	-2611	"	375
$11,750 \pm 300$	"	BM-2370	2	194	$2940\pm50$	"	-2613	"	
$11,590 \pm 150$	"	UGRA-241	3	383	2940±60	"	-2551	"	373
$11,570\pm210$		-242	"		2930±50 9000,50		-2015	,,	3/0
11,410±010		-243 BM 9971	9	104	2500±50 9870±50	Late Bronze Age	-2008	"	375
10,100±410 7800±190	Fninaleolithic	DM-23/1	4	1094	2850+50	Bronze Age	-2519	"	375
7550 ± 120	Chalcolithic/Megalithic	· UGRA-209	3	384	$2840 \pm 50$	nonze nge	-2607	"	"
6400+980	Neolithic/Eneolithic	-194	"	382	$2820 \pm 50$	"	-2609	"	"
$6260 \pm 100$	Chalcolithic/Early	-259	"	385	$2800 \pm 50$	"	-2508	"	369
	Neolithic			-	$2750 \pm 50$	Late Bronze Age	-2548	"	372
$6200 \pm 100$	"	-261	"	"	$2630 \pm 50$	Bronze Age	-2606	"	375
$6160 \pm 100$	Neolithic	-254	"	"	$2620 \pm 50$	Late Bronze Age	-2523	"	370
$5190 \pm 90$	Chalcolithic/Early	-255	"	"	$2560 \pm 70$	" -	-2521	"	"
	Neolithic			0.0 -	$2530 \pm 70$	"	-2522	"	"
$5060 \pm 110$	Eneolithic/Neolithic	-188	"	381	2520±70	"	-2520	"	"
					•				

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	SWEDEN (cont	inued)			MISSOURI (d	continued)			
2260+60	Farly Iron Age	-2616	3	376	2250 + 70		-478	9	999
$2190 \pm 50$	""""""""""""""""""""""""""""""""""""""	-2547	"	371	$2070 \pm 70$		-439	~	221
$2090 \pm 80$		-2610	"	376	$1910 \pm 100$		-455	"	"
$1960 \pm 50$ 1610 - 45	Iron Age	-2619	"	377	$1580 \pm 70$ 1460 ± 60		-447	"	"
$1010 \pm 45$ $1590 \pm 50$	"	-2018	,,	370	$1400\pm00$ $1390\pm70$		-438	,,	"
$1210 \pm 60$	Late Iron Age	-2550	"	372	$1060 \pm 100$		-474	"	222
$1030 \pm 45$	Viking Age/Medieval	-2580	"	374	$530 \pm 70$		-466	"	"
$940 \pm 50$	Late Iron Age	-2617	"	376	$200 \pm 70$		-467	"	991
$930\pm 50$ $680\pm 45$	Medieval time	-2549	"	372	200±00		-450		221
$550 \pm 45$	"	-2581	"	375	NEBRASKA				
$410 \pm 45$	Historic	-2586	"	377	$970 \pm 70$	Great Oasis	WIS-1763	3	398
$350 \pm 45$	"	-2623	"	"	$970 \pm 70$	Late Woodland	-1795	"	399
$350 \pm 45$ $330 \pm 45$	Historic	-2020	"	377	$940 \pm 70$	Great Oasis	-1764	"	398
$320 \pm 45$	"	-2622	"	"	$810 \pm 70$	Upper Republican	-1796	"	399
$310\pm60$	"	-2625	"	"	$690 \pm 70$	"	-1798	"	"
	SRILANKA				$670 \pm 70$	Central Plains	-1765	"	
$3790 \pm 70$	Mesolithic	: BM 9849	9	105	670±70 660±70	Upper Republican	-1814	"	400
$3550 \pm 70$ $3550 \pm 70$	"	-2341	<i>,</i> ,	"	$620 \pm 70$	"	-1800	"	333
$3520 \pm 45$	"	-2340	"	"	$530 \pm 70$	"	-1801	"	400
	UNITED ADAD FM	IDATES			$430 \pm 70$	"	-1799	"	399
8010 000	UNITED ARAD EM	DICODCO		105	NEW MEXIC	0			
$3010 \pm 220$ $2470 \pm 100$		BM-2263 -9961	2,,	195	$\frac{10.010 \pm 160}{10.010 \pm 160}$	Packrat midden	SMU-409	9	931
2170 1100		-2201			$10,010\pm100$ $3940\pm100$		-425	"	231
	UNITED STAT	ES			$3870 \pm 80$	"	-458	"	232
INIDIANA					$1950 \pm 60$	Seven Rivers Quadrant	-375	"	
INDIANA					$1890 \pm 40$ 1860 ± 50	Eddy County	-294	"	230
$1810 \pm 70$ $1800 \pm 70$	Middle Woodland	WIS-1746	3	398	1840±80	Eddy County	-394	"	252
$1660 \pm 70$ $1660 \pm 70$	"	-1745	"		$1550 \pm 60$	Packrat midden	-406	"	231
MICCOURT					$1400 \pm 80$	Eddy County	-299	"	232
MISSOURI					$1310\pm60$ 1280 ± 100	"	-286	"	"
5070 . 150	Phillips Spring	CM11 1019	0	010	$1200 \pm 100$ $880 \pm 60$	Los Esteros	-312	"	230
$\frac{5070 \pm 150}{4970 \pm 70}$	Squash & gourd zone	- 811	2 "	219	$850 \pm 80$	Old Coyote	-306	"	"
$4500 \pm 100$	"	-1214	"	219	$850 \pm 90$	Packrat midden	-437	"	231
$4220\pm60$	"	- 483	"	215	$820\pm60$ $810\pm70$	Los Esteros	-301	"	230
$4100 \pm 250$	Sedalia #1	-1167		218	$790 \pm 60$	Helter Shelter	-318	"	- "
$4010 \pm 420$	"	-1171	"	210	$750 \pm 40$	Eddy County	-283	"	232
$4000 \pm 100$	"	- 423	"	214	$610 \pm 40$	0. (C   F.II.	-304		
$3960 \pm 70$	"	- 556	"	216	300±60 930±80	Packrat midden	-420	"	231
$3940 \pm 70$	"	- 419		214	90±60	"	-418	"	231
$3920 \pm 70$	"	- 558	"	216	$5 \pm 50$	Tipi Ring	-322	"	"
$3850 \pm 230$	Sedalia #3	-1178	"	219	оню				
$3800 \pm 180$		- 559	"	216	$\frac{0110}{1460+70}$	Late Woodland Newton	WIS 1751	2	401
$3760 \pm 100$ $3750 \pm 50$	Contaminated	-1195	"	219	$1320 \pm 70$		-1750	"	400
$3650 \pm 70$	Sedalia #3	- 520	"	217	$1320 \pm 70$	"	-1792	"	401
$3480 \pm 50$	"	-1112	"	218	$1230 \pm 70$	"	-1747	"	400
$3400 \pm 50$	"	- 818	"	217	$1140 \pm 70$ 1080 - 70	"	-1749	"	"
$3300 \pm 50$ $3940 \pm 450$	Contaminated	- 331	"	214	$1030 \pm 70$ $820 \pm 70$	Ft Ancient tradition	-1793	"	"
$3170 \pm 90$	Inverted stratigraphy	-1172	"	219					
$3050 \pm 60$	Sedalia #5	- 235	"	214	OKLAHOMA	:			
$2910 \pm 50$	"	- 238	"		$1600 \pm 40$	Cedar Creek Shelter	SMU-497	2	230
$2800 \pm 250$ $2450 \pm 220$	Middle Woodland?	-1100	"	218	$1540 \pm 70$	"	-519	"	"
$2340 \pm 80$	Middle Woodland	- 236	"	214	970±40 880±60	Big Hawk Shelter	-495	"	
$2250 \pm 100$	"	- 554	"	216	$850 \pm 50$	Cut Finger Cave	-382	"	"
$2210\pm60$	"	-1114	"	218	$840 \pm 60$	Big Hawk Shelter	-372	"	"
$2040\pm60$		-1115	,,	215	$800 \pm 60$ 740 ± 50	" Cut Finger Court	-344	"	"
$1990 \pm 50$	"	- 234	"	214	740±50 700+60	Big Hawk Shelter	-330	"	,,
$1900 \pm 80$	<i>"</i>	- 538	"	215	$660 \pm 60$	"	-379	"	"
$1410 \pm 50$ 970 · 50	Late Woodland?	- 327	"	214	$390 \pm 60$		-381	"	"
270±50	Rodgers Shelter	- 237			390±80	Ft Sill Parade Ground	-405	"	230
$7960 \pm 130$	1005075 Onener	SMU-461	2	222	230 ± 100	big riawk Sneiter	-380	.,	229
$7260 \pm 290$		-507	"	223	SOUTH DAK	ОТА			
$7170 \pm 160$ 5130 + 160		-502	"	222	720 ± 70	Middle Missouri	WIS-1815	3	401
$3530 \pm 80$		-459	,,	221	$300 \pm 70$	Historic	-1794	"	"
$3430\pm50$		-524	"	223	TEVAC				
$3360 \pm 70$		-510	"		IEAAS	Deles Y P	CMU 07	0	000
3150±60 9690+140		-488	"	222	9330±80 9300±60	Paleo-Indian Aquilla Reservoir	5MU-274 -568	z "	228 997
$2520 \pm 60$		-448	"	221	2200±50	""""""""""""""""""""""""""""""""""""""	-540	"	
$2350 \pm 80$		-454	"	"	$1910 \pm 45$	"	-633	"	"

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TEXAS (cont	inued)				GEORGIAN S	SR			
$1410 \pm 120$	Cooper Lake	-880	9	995	15 700 . 190		TD 400	0	050
$1400 \pm 60$	Aquilla Reservoir	-479	-	997	$7350 \pm 70$	Farly Maalithia	18-422	2	253
$1360 \pm 140$	Cooper Lake	-335	"	225	6980±70	Early Neolithic	-300	"	240
$1320 \pm 190$	"	-349	"	226	6970+60	"	-309	,,	
$1300 \pm 150$	"	-476	"	-,,	6720+60	"	-277	,,	
$1230 \pm 70$	Elcor Burial Cave	-374	"	228	6700+60		- 32	"	951
$1180 \pm 60$	"Pick A Slab" Rockshelter	-324	"	227	$6630 \pm 60$		-301	"	231
$1070 \pm 60$	Cooper Lake	-338	"	225	$6600 \pm 140$	Early Neolithic	-331	"	240
$1090 \pm 100$	• "	-346	"	226	$6300 \pm 130$		-326	"	251
$1060 \pm 70$	"	-401	"	"	$5700 \pm 130$		-315	"	252
$1060 \pm 120$	"	-477	"	"	$4940 \pm 80$		-328	"	248
$1020 \pm 170$	Lake Lavon	-233	"	228	$4740 \pm 75$		-329	"	"
$990 \pm 130$	Hog Creek Basin	-272	"	227	$4600 \pm 130$		-316	"	252
$960 \pm 60$	Elcor Burial Cave	-434	"	228	$4340 \pm 60$		-416	"	253
$950 \pm 50$	~ "···	-387	"		$4150 \pm 50$		-242	"	247
$950 \pm 50$	Cooper Lake	-325	"	225	$4130 \pm 80$		-325	"	252
$950 \pm 60$	"	-316	"	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	$4110 \pm 50$		-243	"	247
$920 \pm 40$	Laba Laura	-396	"	226	$4060 \pm 40$		-417	"	253
880 ± 40	Elace Rurial Caus	-239		229	3940±50		-275	"	250
870 ± 50	Coopen Lake	-342		228	3890±50		-317	"	252
860+60		-310		225	3870±50		-274	"	250
$850 \pm 60$	"	398	"	"	3700±30 9740 - 70		-276		0 1
$850 \pm 60$	Aquilla Reservoir	-535	"	997	3740±70		-289		251
$720 \pm 100$	"	-528	"	-,,'	3630 ± 50	Ancient metallurg	-203	,,	941
$660 \pm 70$	Cooper Lake	-404	"	226	3590+60	Ancient metanurgy	-310	,,	241
$620 \pm 80$	Aquilla Reservoir	-498	"	997	3380+50		-334	"	959
$560 \pm 45$	Hog Creek Basin	-280	"		3310+50		-120	"	233
$280 \pm 70$	Cooper Lake	-471	"	226	3300+110		-296	"	948
$270 \pm 60$	• "	-363	"	"	$3250 \pm 45$		-248	"	247
$200 \pm 80$	"	-398	"	"	$3230 \pm 45$		-247	"	- ,
$165 \pm 70$	"	-402	"	"	$3230 \pm 50$	Iron smelting	-403	"	246
$160 \pm 45$	"	-417	"	"	$3200 \pm 40$	0	-249	"	247
$115.9 \pm 0.9\%$	"	-359	"	"	$3200 \pm 170$	Antimony mining	-302	"	241
mod					$3180 \pm 45$	, ,	-254	"	247
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003	"	"	-1240	"	128	-1447	"	136	-1665	"	"
004	"	"	-1241	"	"	-1449	"	136	-1666	"	"
005 006	"	"	-1242	"	"	-1450	"	137	-1668	"	"
007	"	125	-1246	"	128	-1452	"	"	-1669	"	"
008	"	"	-1250	n	128	-1453	"	136	-1670	"	"
)11	"	121	-1253	"	190	-1454	"		-1671	"	190
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