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A REPORT ON PHASE 1 OF THE 5TH INTERNATIONAL RADIOCARBON INTERCOMPARISON (VIRI)

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ABSTRACT. The Fifth International Radiocarbon Intercomparison (VIRI) continues the tradition of the TIRI (third) and FIRI (fourth) intercomparisons (Scott 2003) and operates as an independent check on laboratory procedures in addition to any within-laboratory procedures for quality assurance. VIRI is a 4-yr project, with the first suite of samples (grain) sent out in September 2004 and the second suite (bone) sent out in December 2005. Further stages will include samples of peat, wood, and shell with a range of ages.

The 4 grain samples included 2 samples (A and C) of barley mash (20 g for radiometric analysis and 2 g for AMS), a grain (barley) byproduct from the manufacture of Glengoyne malt whiskey. The 2 remaining charred grain samples (B and D) were from excavations at Beth Saida and Tel Hadar, respectively (10 g for radiometric analysis and 4 seeds for AMS) and were provided by Elisabetta Boaretto of the Weizmann Institute. Consensus values for samples A and C are 109.2 (standard deviation [1 σ] = 2.73) and 110.6 pMC (1 σ = 2.48), and 2805 (1 σ = 162.7) and 2835 BP (1 σ = 190.8) for samples B and D, respectively. Sample A is a new sample that was collected in 2001, while sample C was used in the FIRI trial as samples G & J (consensus value 110.7 pMC) and was collected in 1998. The expected ages (on archaeological grounds) of samples B and D are 2800 BP and 2850–2900 BP, respectively. The second suite of samples comprises bone, ranging in age from Medieval to "close to background," and was distributed in December 2005. Samples for both radiometric and AMS laboratories include E: mammoth bone (>5 half-lives); F: horse bone (from Siberia, excavated in 2001); and H, I: whalebone. Finally, sample G (human bone) was only for AMS laboratories. Some of the issues related to using bone in a laboratory intercomparison will be discussed.

INTRODUCTION

The Fifth International Radiocarbon Intercomparison (VIRI) has continued the tradition of the TIRI (third) and FIRI (fourth) intercomparisons (Scott 2003) as a ^{14}C community project, with samples provided by participants and a substantial participation rate. VIRI has been designed to address some of the criticisms of TIRI and FIRI while retaining some of their important features, namely, using natural samples and ensuring the anonymity of participating laboratories to prevent the creation of laboratory league tables. The particular changes in design are that VIRI is a 4-yr project, with the first suite of samples (grain) sent out in September 2004. Samples are being distributed regularly over the 4-yr period, with 3 or 4 samples being distributed in each of years 1 to 3, and finally, in year 4 a more general intercomparison is to be organized. Each year, a particular material is the focus of testing. Year 1 focused on grain, year 2 on bone, and year 3 will be wood, while the final intercomparison will include a variety of sample types and ages.

The grain samples used in Phase 1 comprised 2 modern samples (A and C), byproducts from the manufacture of malt whiskey (sample C was first used in the FIRI trial as samples G & J [consensus value 110.7 pMC]), and 2 archaeological samples of charred grain from Beth Saida and Tel Hadar (samples B and D). These samples had associated archaeological ages of 2800 BP and 2850–2900 BP, respectively.

A total of 70 laboratories, which are identified in Table 1, reported results by the main deadline. A further small number of laboratories submitted results after the deadline but before the circulation of

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a preliminary report. As always, the actual number of results submitted was greater than the number of laboratories since several laboratories submitted results using several independent systems. As a consequence, more than 100 sets of results were returned. There were some differences in the format in which results were reported, and AMS laboratories in particular were able to submit replicate results (sometimes as many as 6) for individual samples. This paper summarizes the results obtained in Phase 1 and provides some further details on the Phase 2 samples distributed in December 2005.

Table 1 Participating laboratories.

Laboratory name	Lab method	Country
Laboratorio de Tritio y Radiocarbono, La Plata	LSC	Argentina
ANSTO	AMS	Australia
VERA, University of Vienna	AMS	Austria
Belarus Academy of Sciences	LSC	Belarus
Royal Institute for Cultural Heritage	AMS	Belgium
Institute of Heavy Ion Physics, Peking University	AMS	China
Institute of Earth Environment, CAS	AMS	China
Ruđjer Bošković Institute	GPC	Croatia
Charles University, Prague	LSC	Czech Republic
Aarhus AMS Dating Laboratory	AMS	Denmark
Dating Laboratory, University of Helsinki	AMS	Finland
Centre de Datation par le Radiocarbone, Lyon	AMS, LSC	France
Heidelberg Akademie der Weissenschaften	GPC	Germany
Radiocarbon Laboratory, Köln	GPC	Germany
AMS Laboratory, Erlangen	AMS	Germany
Deutches Archäologisches Institut, Berlin	LSC and GPC	Germany
Leibniz Institute for Applied Geosciences, Hannover	GPC	Germany
Leibniz-Labor, Kiel	AMS	Germany
Laboratory of Archaeometry, Attiki	GPC	Greece
Laboratory of Environmental Studies of INR/HAS	GPC	Hungary
Birbal Sahni Institute of Palaeobotany	LSC	India
Division of Geosciences, Physical Research Laboratory, Navrangpura	LSC	India
Radiocarbon Dating Lab, Physical Research Lab	LSC	India
Weizmann Institute, Israel	LSC	Israel
Radiocarbon Dating Laboratory of Rome	LSC	Italy
CEDAD, University of Lecce	AMS	Italy
CIRCE, University of Naples	AMS	Italy
ENEA, Bologna	LSC	Italy
INFN, Florence	AMS	Italy
Center for Chronological Research, Nagoya University	AMS	Japan
University Museum, University of Tokyo	AMS	Japan
Radioisotope Research Laboratory, Vilnius	LSC	Lithuania
Radiocarbon Laboratory, University of Mexico	LSC	Mexico
Universiteit Utrecht	AMS	Netherlands
Centre for Isotope Study, Groningen	AMS and GPC	Netherlands
Rafter Radiocarbon Laboratory	AMS	New Zealand
University of Waikato	AMS and LSC	New Zealand
Radiocarbon Lab, Trondheim	AMS	Norway
Poznań Radiocarbon Laboratory	AMS	Poland
Kraków Radiocarbon Laboratory	LSC	Poland

Table 1 Participating laboratories. *(Continued)*

Laboratory name	Lab method	Country
Gliwice Radiocarbon Laboratory	GPC, AMS, and LSC	Poland
Archaeological and Ethnographical Museum, Łódź	LSC	Poland
GIN, Moscow	LSC	Russia
Radiocarbon Laboratory, Russian Academy of Sciences	LSC	Russia
CIR, St. Petersburg	LSC	Russia
Institute of Geology, RAS	LSC	Russia
Radiocarbon Laboratory of Institute Geography, RAS	LSC	Russia
Geochron Laboratory, Geographical Research Institute	LSC	Russia
QUADRU, Pretoria	GPC	South Africa
Instituto de Quimica-Fisca Rocasolano, Madrid	GPC	Spain
Radiocarbon Lab, Barcelona	LSC	Spain
Laboratorio de Datación, Universidad de Granada	LSC	Spain
Tandem Laboratory, Uppsala University	AMS	Sweden
Physics Institute, Bern	GPC	Switzerland
ETH/PSI, Zürich	AMS	Switzerland
National Taiwan University	LSC	Taiwan
Ukraine Academy of Sciences, Kiev	LSC	Ukraine
Institute of Hygiene and Medical Ecology, Kiev	LSC	Ukraine
Radiocarbon Dating Facility, Queen's University	AMS and LSC	UK
Oxford Radiocarbon Accelerator Lab	AMS	UK
NERC, East Kilbride	LSC and AMS	UK
SUERC, East Kilbride	AMS	UK
INSTARR, University of Colorado	AMS	USA
Applied Isotope Studies, Georgia	LSC and AMS	USA
KCCAMS, University of California	AMS	USA
NOSAMS, WHOI	AMS	USA
Lawrence Livermore National Laboratory	AMS	USA
Illinois State Geographical Survey	LSC	USA
Beta Analytic, Miami	LSC and AMS	USA
Arizona AMS Facility	AMS	USA

RESULTS

In the analyses reported here, the replicate results from individual laboratories have been included as though they were an independent set of results, an assumption that is not unreasonable. Table 1 lists the laboratories that took part in the study, while Table 2 presents the results as reported for samples A–D. An * indicates that a piece of information is missing. Table 3 lists the summary statistics for each sample (including the mean, median, standard deviation, minimum, and maximum), while Table 4 summarizes the results by laboratory type. Figures 1 and 2 show the distribution of results in the form of a boxplot including any outliers, which are identified. The boxplot shows the median and lower and upper 25th and 75th percentiles; any outliers are identified by *. The results are shown for the "matched" samples and then for each sample by laboratory type (Table 2 on pages 416–426).

Comments

Figure 1 allows comparison of the 2 pairs of samples (A and C and B and D). A clear difference in pMC is observed between samples A and C, reflecting the 4-yr change in atmospheric ^{14}C in the

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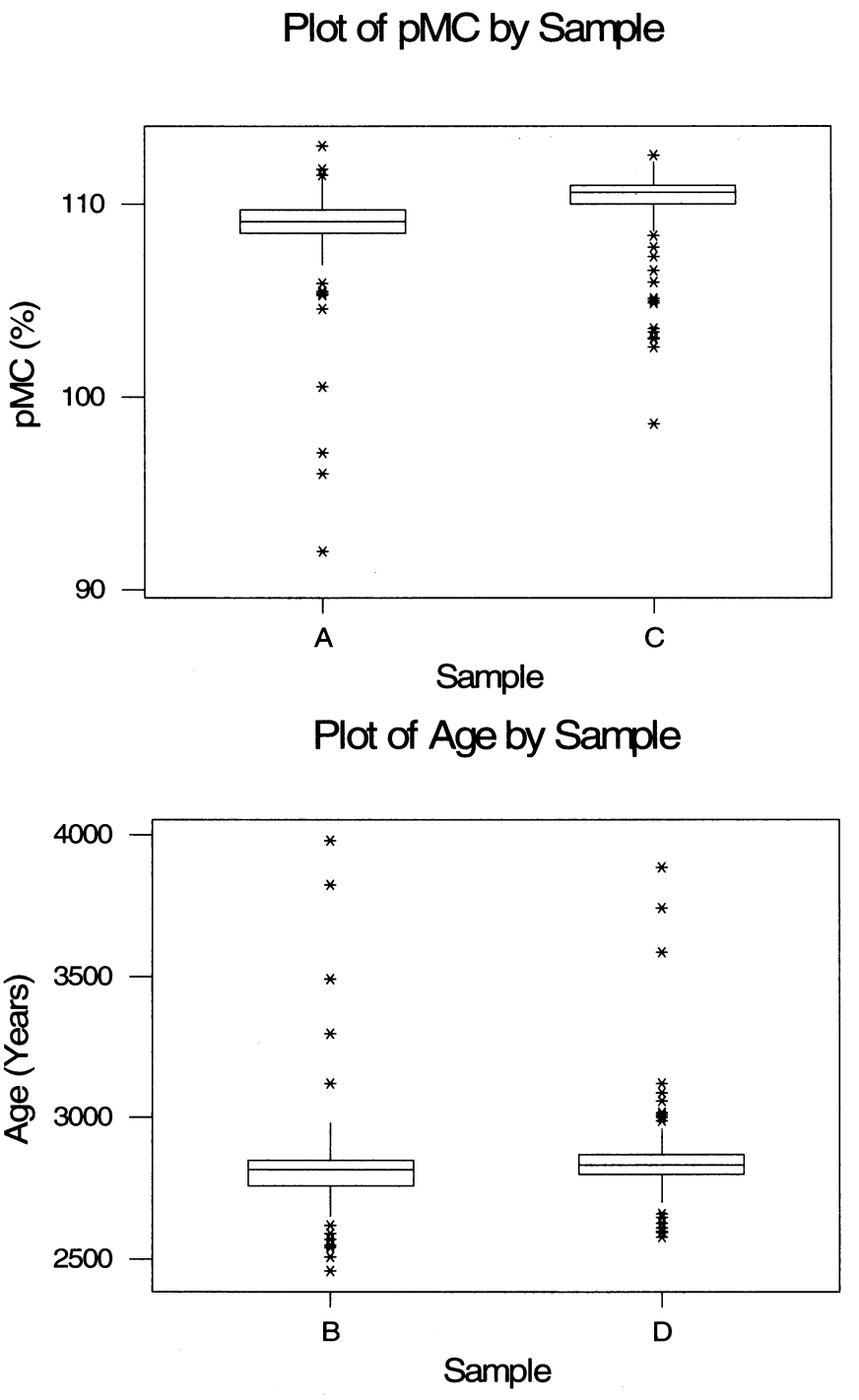

Figure 1 Boxplot showing the distribution of results for paired samples A and C (top) and B and D (bottom). Outliers are marked by *.

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Northern Hemisphere. Similarly, a discernible difference can be seen in the age of samples B and D. Figure 2 allows the comparison of the results for the 3 laboratory types; it underlines the broad agreement in the results, but also highlights the more extreme outliers reported by LSC laboratories and the much-reduced range of results reported by AMS laboratories. Thus, the preliminary results show there is broad agreement across all laboratories, but there is clearly considerable scatter in the results when outliers are included (they correspond to approximately 10–15% of the full set of results, but are reported by only a small number of the laboratories).

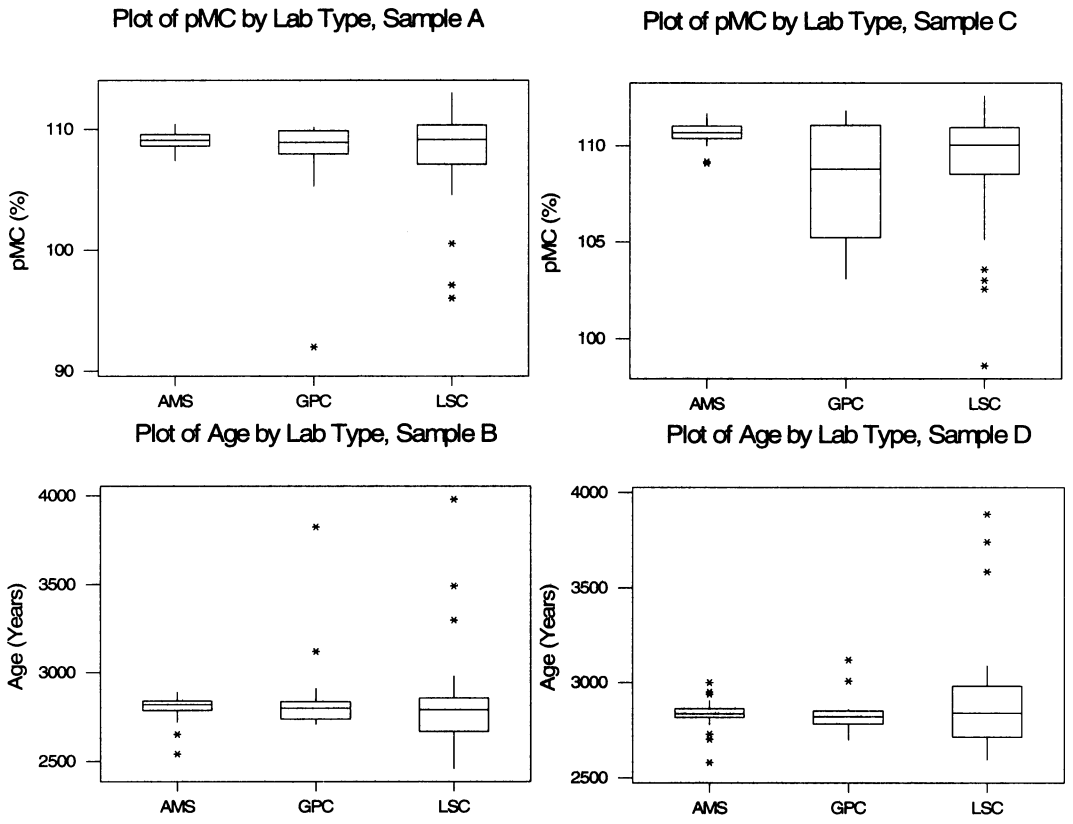

Figure 2 Boxplots of the distribution of results by laboratory type (AMS, GPC, and LSC) for samples A–D. Outliers are marked by *.

Table 3 Overall summary statistics.

	Mean	Median	Standard deviation	Minimum	Maximum
Sample A (pMC)	108.6	109.1	2.78	92	113
Sample C (pMC)	109.8	110.6	2.35	98.6	112.6
Sample B (BP)	2825	2815	198.7	2460	3979
Sample D (BP)	2859	2835	185.2	2580	3998

Sample A is a new barley mash sample that was collected in 2001, while sample C was used in the FIRI trial as samples G & J (consensus value 110.7 pMC) and was collected in 1998. Thus, the overall result (median) of 110.6 is very close to the previously published FIRI consensus value.

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The expected ages (on archaeological grounds) of samples B and D are 2800 BP and 2850–2900 BP, respectively. Sample B has a median age of 2815 BP, very close to the expected archaeological age, but there is a suggestion (based on the median) that the overall age for D is younger (2835 BP) than expected.

The ranges of the results for samples A and C are 21 and 16 pMC, respectively, while for B and D the ranges are both approximately 1500 yr; however, the interquartile ranges are much narrower at only 1 pMC and 90 yr, respectively. There is a very strong and compelling argument for the removal of these outliers for later analyses.

From Table 4, it is notable that the interquartile range (IQR) (Q_3–Q_1) is much narrower than the full range, which is again dominated by outliers. The standard deviation and mean are summary statistics that are relatively sensitive to outlying values, so the table also includes the median and IQR, which are relatively robust. The difference between the mean and median highlights the effect of the outliers.

Table 4a Detailed summary statistics for sample A (pMC) by laboratory type.

	Nr of results	Mean	Median	Standard deviation	Lower quartile	Upper quartile	Min	Max
AMS	61	109.1	109.1	0.665	108.6	109.6	107.4	110.4
GPC	14	107.6	108.9	4.690	108.2	109.8	92.0	110.2
LSC	32	108.1	109.15	3.870	107.6	110.3	96.0	113.0

Table 4b Detailed summary statistics for sample B (yr BP) by laboratory type.

	Nr of results	Mean	Median	Standard deviation	Lower quartile	Upper quartile	Min	Max
AMS	53	2809	2820	57.4	2790	2840	2540	2890
GPC	17	2865	2799	265.3	2750	2835	2710	2824
LSC	32	2830	2793	292.2	2683	2856	2460	3979

Table 4c Detailed summary statistics for sample C (pMC) by laboratory type.

	Nr of results	Mean	Median	Standard deviation	Lower quartile	Upper quartile	Min	Max
AMS	59	110.7	110.7	0.537	110.4	111.0	109.1	111.6
GPC	16	108.2	108.8	3.059	105.8	111.0	103.1	111.8
LSC	30	109.0	110.1	3.213	108.7	110.9	98.6	112.6

Table 4d Detailed summary statistics for sample D (yr BP) by laboratory type.

	Nr of results	Mean	Median	Standard deviation	Lower quartile	Upper quartile	Min	Max
AMS	54	2838	2838	59.20	2818	2864	2580	3000
GPC	13	2841	2822	111.4	2795	2842	2700	3120
LSC	32	2903	2841	305.8	2718	2968	2595	3887

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CONSENSUS VALUES

As in previous studies, consensus values for the 4 samples have been calculated following the procedure in Scott (2003). Most importantly, individual results are excluded from the final calculation based on 2 criteria (their absolute value and size of quoted error). The final results are then calculated as a weighted average of the remaining results, and these are reported in Table 5.

Table 5 Consensus values for VIRI Phase 1 samples.

Sample	Consensus value	Error (1 σ)
A	109.1 (pMC)	0.04
C	110.7 (pMC)	0.04
B	2820 (BP)	3.3
D	2836 (BP)	3.3

Sample C has the same consensus value as originally reported (Scott 2003), while sample B has a consensus value within 20 yr of the expected archaeological age. However, the consensus value for sample D falls just outside the expected archaeological age.

PHASE 2

Phase 2 focuses on bone, and because of the difficulty in obtaining bone in sufficient quantity, one sample was distributed to AMS laboratories only. For radiometric laboratories, we have distributed samples ranging from 60–100 g. The limiting factor for bone samples, especially for radiometric laboratories, is both the quantity and quality of material required. The samples were dispatched in December 2005 and results should be returned by June 2006. A smaller number of laboratories accepted the bone samples, since for some laboratories such material is not routinely dated. This phase of VIRI will provide information on the different pretreatment procedures used in dating bone and of their contribution to variation in the results. The samples span an age range of <500 yr to close to background and are described below.

Sample E: Mammoth Bone (>5 half-lives)

This mammoth bone is from a site called Quartz Creek, Dawson City, Yukon Territory. The bone is a portion of the pelvis of a *Mammuthus* sp. specimen. The sample was collected in August 2003 by Ross Barnett of the Zoology Department, University of Oxford. It was supplied by Tom Higham of ORAU. In an initial test of the material, 0.58 g of collagen was recovered from 5 g of bone. The % carbon of this collagen sample was 41%.

Sample F: Horse Bone (from Siberia, excavated in 2001, <1 half-life)

This sample was provided by Ganna Zaitseva of the Institute of History of Material Culture, St. Petersburg, and is from an archaeological investigation in Siberia at one of the Scythian burial sites; 0.34 g of collagen was recovered from 1.67 g of bone. The % carbon of this sample was 30.3%.

Sample G: Human Bone

This is a sample from a young female buried with a neonate in a waterlogged dendrodated coffin and was provided by Alex Bayliss of English Heritage. This sample was sent to AMS laboratories only.

Sample H: Whalebone (approximately 2 half-lives)

This whale bone sample was submitted to the University of Washington in August 1983 and is the jawbone of a whale from sand deposits of a raised beach at Svalbard, Spitsbergen, Norway. It was provided by Paula Reimer of Queen's University, Belfast.

Sample I: Whalebone (approximately 2 half-lives)

This whale bone is from the cranium of a whale, species not determined. It was found in August 1997 on Svalbard. This sample was provided by Steinar Gulliksen of the National Dating Laboratory, Trondheim.

CONCLUSIONS

The preliminary analysis of results from Phase 1 of VIRI has highlighted again the general and broad agreement among laboratories, but underlines the persistent problem with outlying data values from a relatively small number of laboratories. As mentioned earlier, no corrections have been made to the results (e.g. where a fractionation correction has not been applied), nor have we so far, as in the past, explored the source of variation and outlying values.

The demographic shift to more AMS and fewer radiometric laboratories is apparent from the list of participating laboratories. Overall, numbers of participating laboratories are slightly lower than in FIRI, but still represent a very healthy participation rate.

Phase 2 represents a more challenging material, and indeed because of size constraints implicit in acquiring the material, laboratories have received typical (perhaps non-optimal) sample sizes. Pretreatment method will also become a greater issue in understanding the variation in reported results. We have asked for additional (where possible) analyses, including some stable isotope analyses. Preliminary analyses of the Phase 2 results are expected to be completed by the end of 2006, and Phase 3 will then begin in January 2007.

ACKNOWLEDGMENTS

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Table 2a Sample A data table.

Lab identifier	Method	$\delta^{13}C$	Delta error	pMC	pMC error
1	LSC	*	*	111.531	*
2	GPC	–27.600	0.20	105.300	0.40
3	GPC	–29.900	*	109.200	0.20
4	AMS	–28.300	*	110.000	0.40
5	AMS	–26.500	1.50	108.580	0.29
6	AMS	–28.000	*	109.020	0.23

Table 2a Sample A data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Delta error	pMC	pMC error
6	AMS	–28.000	*	109.100	0.15
7	LSC	–29.316	*	108.480	0.49
8	AMS	–28.350	*	110.120	0.26
9	LSC	–30.457	0.20	109.190	0.44
10	AMS	–32.400	0.20	109.540	0.41
11	LSC	–26.920	*	109.450	0.84
12	AMS	–28.300	*	110.300	0.40
13	AMS	–25.900	0.30	109.590	0.37
13	AMS	–25.700	1.00	109.870	0.36
14	LSC	*	*	108.770	1.00
15	GPC	–30.230	*	109.620	0.31
16	AMS	–29.000	*	109.460	0.37
16	AMS	–29.000	*	109.330	0.48
17	LSC	–30.590	0.09	111.810	1.42
18	LSC	–29.560	*	105.400	0.30
19	LSC	–30.830	0.02	96.030	0.48
20	GPC	–29.000	*	109.000	0.30
21	AMS	–26.830	0.50	108.780	0.38
22	AMS	–29.600	*	109.000	0.32
22	AMS	–28.500	*	109.200	0.34
23	AMS	–28.000	*	108.900	0.20
24	LSC	–29.100	*	109.390	0.62
24	LSC	–29.300	*	110.000	0.59
25	AMS	–28.100	0.40	109.740	0.28
25	AMS	–25.200	0.20	109.350	0.25
25	AMS	–28.100	0.40	109.230	0.20
25	AMS	–28.900	0.60	109.350	0.19
25	AMS	–30.300	0.20	109.480	0.18
26	AMS	–29.100	*	109.690	0.35
27	AMS	–29.620	*	109.750	0.49
27	AMS	–29.000	*	109.600	0.49
28	LSC	*	*	104.600	1.20
29	LSC	–31.770	0.04	113.000	3.00
30	LSC	–29.900	*	110.800	0.80
31	LSC	–31.720	*	109.300	0.40
32	LSC	–25.000	2.00	109.100	0.74
33	LSC	–29.600	*	110.240	0.43
34	GPC	–27.680	*	110.120	0.35
35	AMS	–28.150	*	108.670	0.31
36	LSC	–31.720	*	108.900	0.40
37	AMS	–28.900	*	108.420	0.32
37	AMS	–29.600	*	108.350	0.61
37	AMS	–28.900	*	107.730	0.55
37	AMS	–28.900	*	107.440	0.36
37	AMS	–28.600	*	108.400	0.46
37	AMS	–29.400	*	108.260	0.47
37	AMS	–29.500	*	108.310	0.58
37	AMS	–28.800	*	108.820	0.48
37	AMS	–29.600	*	108.460	0.42
37	AMS	–28.700	*	108.610	0.47

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Table 2a Sample A data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Delta error	pMC	pMC error
38	LSC	–29.200	*	111.400	0.63
39	AMS	–26.800	0.20	108.430	0.42
40	LSC	–28.120	*	108.790	0.76
41	GPC	–30.300	0.10	108.560	0.48
41	GPC	–30.300	0.10	108.200	1.20
42	GPC	–30.200	*	108.300	0.30
43	AMS	–28.480	*	110.300	0.52
43	AMS	–28.480	*	109.080	0.52
43	AMS	–28.450	*	109.260	0.43
44	AMS	–30.200	0.20	109.500	0.50
45	AMS	–28.000	1.00	109.600	0.20
45	AMS	–27.000	1.00	109.700	0.20
46	AMS	–29.300	*	108.660	0.31
46	AMS	–28.700	*	108.460	0.29
46	AMS	–28.900	*	108.480	0.29
46	AMS	–28.500	*	108.770	0.29
46	AMS	–28.200	*	108.690	0.29
47	AMS	–29.100	*	109.190	0.44
48	LSC	–25.000	*	105.500	0.50
49	LSC	–25.000	*	97.090	0.48
50	GPC	–28.000	0.20	108.800	0.50
50	GPC	–30.400	0.20	109.700	0.50
50	GPC	–28.900	0.20	110.200	0.50
51	LSC	*	*	105.940	2.62
52	LSC	*	*	100.550	3.04
53	GPC	–30.510	*	109.840	0.25
54	GPC	–29.600	*	109.950	0.36
55	AMS	–29.100	0.60	109.490	0.35
56	LSC	–31.100	0.20	109.200	0.40
57	AMS	–30.590	0.09	110.430	0.49
58	AMS	–30.600	*	109.390	0.35
59	LSC	–30.900	*	109.700	0.50
60	AMS	–26.600	1.3	109.200	0.45
61	LSC	–29.100	0.05	110.640	0.52
61	LSC	–29.810	0.05	110.710	0.56
62	AMS	*	*	108.800	0.24
62	AMS	*	*	108.800	0.24
62	AMS	*	*	109.080	0.32
63	AMS	–28.600	1.10	109.660	0.50
63	AMS	–27.400	1.10	109.770	0.49
64	AMS	–28.300	*	110.400	0.40
65	LSC	–29.070	*	109.000	0.20
66	AMS	–31.400	*	108.650	0.51
67	GPC	–25.000	*	107.300	0.80
67	LSC	–25.000	*	106.900	0.60
69	LSC	–25.000	*	107.800	0.60
69	LSC	–26.500	*	108.200	0.60
70	AMS	–29.100	*	107.800	0.30
70	AMS	–29.100	*	108.900	0.30
70	AMS	–29.100	*	108.500	0.50

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Table 2a Sample A data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Delta error	pMC	pMC error
72	LSC	–30.300	*	110.390	0.87
73	AMS	–27.8	*	110.20	0.45
74	LSC	–28.98	0.2	101.05	0.24
75	AMS	–30.1	*	108.96	0.26
76	AMS	–33	2	109.39	0.22
77	LSC	–24	1	108.61	1.06
78	LSC	–29.3	*	108.0	0.44
79	AMS	–22.36	0.45	108.84	0.32
67	LSC	–25.000	*	106.900	0.60
69	LSC	–25.000	*	107.800	0.60
69	LSC	–26.500	*	108.200	0.60
70	AMS	–29.100	*	107.800	0.30
70	AMS	–29.100	*	108.900	0.30
70	AMS	–29.100	*	108.500	0.50
72	LSC	–30.300	*	110.390	0.87
73	AMS	–27.8	*	110.20	0.45
74	LSC	–28.98	0.2	101.05	0.24
75	AMS	–30.1	*	108.96	0.26
76	AMS	–33	2	109.39	0.22
77	LSC	–24	1	108.61	1.06
78	LSC	–29.3	*	108.0	0.44
79	AMS	–22.36	0.45	108.84	0.32

Table 2b Sample B data table.

Lab identifier	Method	$\delta^{13}C$	Error	Age BP	Age error	pMC	pMC error
1	LSC	*	*	2660	110	71.81	0.98
2	GPC	–22.700	0.20	3120	35	67.80	0.30
3	GPC	–23.000	*	2835	15	70.26	0.13
4	AMS	–22.200	*	2838	35	70.24	0.31
5	AMS	–22.700	3.10	2759	39	70.92	0.34
5	AMS	–21.300	1.70	2771	26	70.82	0.23
6	AMS	–22.000	*	2840	15	70.24	0.12
7	LSC	–22.737	*	2955	50	69.22	0.42
8	AMS	–21.060	*	2855	30	70.09	0.26
9	LSC	–23.279	0.20	2850	37	70.13	0.46
10	AMS	–24.000	0.20	2847	35	70.16	0.31
11	LSC	–23.300	*	2550	70	72.80	0.63
12	AMS	–23.400	*	2885	40	69.80	0.40
13	AMS	–16.500	1.50	2786	26	70.69	0.23
13	AMS	–19.100	1.40	2817	29	70.42	0.25
14	LSC	*	*	2690	80	71.56	0.71
15	GPC	–23.750	*	2771	28	70.83	0.25
16	AMS	–22.500	*	2820	20	70.45	0.24
16	AMS	–22.500	*	2820	20	70.35	0.25
17	LSC	–23.250	0.24	2506	149	73.20	1.31
18	LSC	–23.200	*	2800	120	70.50	0.30
19	LSC	–22.550	0.03	3979	81	60.94	0.61
20	GPC	–22.600	*	2781	30	70.70	0.30

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Table 2b Sample B data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Error	Age BP	Age error	pMC	pMC error
21	AMS	–22.440	0.71	2834	35	70.27	0.31
22	AMS	–21.600	*	2819	28	70.40	0.25
22	AMS	–21.500	*	2842	28	70.20	0.24
23	AMS	–23.100	*	2819	34	70.40	0.30
24	LSC	–22.800	*	2790	56	70.66	0.48
25	AMS	–20.900	0.50	2820	20	70.41	0.15
25	AMS	–21.900	0.70	2790	20	70.66	0.16
25	AMS	–17.600	0.40	2820	15	70.37	0.13
25	AMS	–18.700	0.50	2840	15	70.24	0.12
25	AMS	–20.500	0.40	2805	15	70.54	0.12
26	AMS	–23.200	*	2777	32	70.78	0.28
27	AMS	–22.360	*	2835	40	70.26	0.36
28	LSC	*	*	2855	65	70.09	0.57
29	LSC	–25.000	*	2700	200	71.45	1.78
30	LSC	–23.300	*	2770	85	70.80	0.80
31	LSC	–25.250	*	2750	40	71.01	0.35
32	LSC	–25.000	2.00	2620	60	72.19	0.56
33	LSC	–24.800	*	2761	36	70.91	0.32
34	GPC	–21.800	*	2710	30	71.35	0.28
35	AMS	–21.820	*	2850	25	70.13	0.20
36	LSC	–25.250	*	2750	40	71.01	0.35
37	AMS	–21.900	*	2890	50	69.80	0.46
37	AMS	–22.000	*	2840	35	70.22	0.31
37	AMS	–21.900	*	2780	35	70.76	0.31
37	AMS	–22.100	*	2730	30	71.16	0.26
37	AMS	–21.900	*	2790	30	70.62	0.29
38	LSC	–24.100	*	2620	70	72.84	0.63
39	AMS	–21.600	0.20	2540	45	72.89	0.41
40	LSC	–22.590	*	2850	70	70.14	0.58
41	GPC	–24.260	0.10	2910	50	69.57	0.46
41	GPC	–24.260	0.10	2720	40	71.24	0.27
41	GPC	–24.260	0.10	2780	70	70.72	0.61
41	GPC	–24.260	0.10	2730	180	71.20	1.60
41	GPC	–24.260	0.10	2710	160	71.40	1.40
41	GPC	–24.260	0.10	2800	170	70.60	1.50
41	GPC	–24.260	0.10	2750	100	71.08	0.86
42	GPC	–23.400	*	2815	45	70.40	0.20
43	AMS	–22.180	*	2834	35	70.27	0.31
43	AMS	–22.180	*	2830	60	70.29	0.54
43	AMS	–22.190	*	2768	44	70.85	0.39
43	AMS	–22.190	*	2836	47	70.26	0.42
44	AMS	–23.300	0.20	2802	33	70.60	0.30
45	AMS	–22.000	1.00	2752	18	71.00	0.20
46	AMS	–22.400	*	2840	25	70.22	0.19
46	AMS	–22.400	*	2850	25	70.15	0.19
46	AMS	–23.000	*	2860	25	70.05	0.18
46	AMS	–23.200	*	2855	25	70.10	0.19
47	AMS	–22.400	*	2835	35	70.26	0.31

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Table 2b Sample B data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Error	Age BP	Age error	pMC	pMC error
48	LSC	–25.000	*	2460	50	73.62	0.46
49	LSC	–25.000	*	3490	50	64.76	0.38
50	GPC	–22.500	0.20	2810	30	70.50	0.20
51	LSC	*	*	2570	80	72.62	0.72
52	LSC	*	*	3296	281	67.16	2.29
53	GPC	–22.800	*	2840	25	70.20	0.21
54	GPC	–24.800	*	2799	33	70.58	0.29
55	AMS	–24.700	0.20	2800	30	70.56	0.27
56	LSC	–22.600	0.20	2855	32	70.10	0.30
57	AMS	–23.250	0.24	2811	40	70.47	0.35
58	AMS	–22.900	*	2805	27	70.52	0.24
59	LSC	–22.800	*	2890	70	69.78	0.61
60	AMS	–21.5	0.4	2820	40	69.89	0.35
61	LSC	–23.150	0.05	2850	75	69.72	0.66
62	AMS	*	*	2815	20	70.42	0.19
62	AMS	*	*	2795	25	70.59	0.20
63	AMS	–24.200	1.10	2721	44	71.27	0.39
63	AMS	–24.000	1.10	2652	44	71.88	0.39
64	AMS	–22.500	*	2760	35	70.92	0.31
65	LSC	–22.600	*	2857	25	70.07	0.22
66	AMS	–23.700	*	2855	40	70.08	0.36
66	LSC	–22.510	*	2795	30	70.60	0.27
67	GPC	–25.000	*	3125	71	67.80	0.60
67	LSC	–25.000	*	2851	49	70.10	0.40
69	LSC	–23.100	*	2860	70	70.00	0.60
69	LSC	–22.900	*	2980	60	69.00	0.60
70	AMS	–22.600	*	2770	40	70.80	0.30
70	AMS	–22.600	*	2860	30	70.00	0.30
70	AMS	–22.600	*	2880	30	69.80	0.30
71	LSC	–24.260	0.10	2760	60	70.92	0.53
72	LSC	–23.500	*	2590	80	72.45	0.68
73	AMS	–24.6	*	2770	40	70.87	0.34
74	LSC	–22.62	0.2	3070	60	*	*
75	AMS	–22.9	*	2782	28	70.73	0.24
76	AMS	–24	2	2815	30	70.44	0.26
78	LSC	–21.7	*	2825	35	*	*
79	AMS	–22.26	0.3	2824	38	70.36	0.33
80	LSC	–22.3	*	2820	50	*	*

Table 2c Sample C data table.

Lab identifier	Method	$\delta^{13}C$	Error	pMC	pMC error
1	LSC	*	*	110.477	*
2	GPC	–27.70	0.20	107.300	0.50
3	GPC	–29.90	*	110.600	0.20
4	AMS	–28.00	*	110.100	0.40
5	AMS	–26.00	1.10	110.100	0.26
6	AMS	–29.00	*	110.330	0.29

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Table 2c Sample C data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Error	pMC	pMC error
6	AMS	–29.00	*	110.650	0.21
7	LSC	–29.16	*	110.170	0.50
8	AMS	–28.72	*	111.650	0.26
11	LSC	–30.18	*	111.230	0.81
12	AMS	–27.80	*	110.500	0.40
13	AMS	–26.30	0.30	111.200	0.36
13	AMS	–28.70	1.50	111.240	0.37
15	GPC	–28.57	*	111.220	0.36
16	AMS	–28.50	*	111.060	0.39
16	AMS	–28.50	*	110.750	0.49
17	LSC	–30.72	0.15	112.570	1.36
18	LSC	–28.30	*	98.600	0.30
19	LSC	–30.98	0.01	103.000	1.40
20	GPC	–29.00	*	111.100	0.30
21	AMS	–26.76	0.61	110.480	0.39
22	AMS	–28.80	*	110.800	0.36
22	AMS	–27.70	*	110.600	0.32
23	AMS	–28.40	*	110.400	0.21
24	LSC	–29.10	*	110.100	0.59
24	LSC	–29.10	*	111.020	0.60
25	AMS	–25.50	0.30	110.750	0.23
25	AMS	–24.40	0.20	110.600	0.19
25	AMS	–27.10	0.30	110.990	0.19
25	AMS	–24.40	0.40	110.920	0.20
25	AMS	–26.00	0.20	111.300	0.19
26	AMS	–28.40	*	110.890	0.36
27	AMS	–29.40	*	110.690	0.50
27	AMS	–28.25	*	111.450	0.61
28	LSC	*	*	109.000	1.00
29	LSC	–31.49	0.07	111.000	3.00
30	LSC	–30.00	*	110.700	0.80
31	LSC	–31.24	*	108.400	0.40
32	LSC	–25.00	2.00	109.900	0.71
33	LSC	–29.40	*	110.910	0.43
34	GPC	–27.14	*	110.080	0.55
35	AMS	–29.17	*	110.610	0.28
36	LSC	–31.24	*	108.400	0.40
37	AMS	–29.30	*	110.560	0.36
37	AMS	–29.30	*	110.680	0.45
37	AMS	–29.20	*	111.590	0.50
37	AMS	–29.00	*	110.850	0.39
37	AMS	–29.20	*	111.010	0.38
37	AMS	–29.20	*	110.020	0.42
37	AMS	–28.80	*	109.090	0.41
37	AMS	–29.20	*	110.730	0.38
38	LSC	–29.40	*	108.600	0.74
39	AMS	–26.30	0.20	110.670	0.30
40	LSC	–27.98	*	109.880	0.86

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Table 2c Sample C data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Error	pMC	pMC error
41	GPC	–31.59	0.10	103.360	0.46
41	GPC	–31.59	0.10	103.100	2.00
41	GPC	–31.59	0.10	106.600	1.90
41	GPC	–31.59	0.10	105.000	2.10
41	GPC	–31.59	0.10	104.900	1.20
42	GPC	–29.80	*	110.700	0.40
43	AMS	–28.65	*	111.040	0.44
43	AMS	–28.65	*	111.030	0.53
43	AMS	–28.61	*	109.190	0.71
43	AMS	–28.61	*	110.070	0.60
44	AMS	–30.40	0.20	111.000	0.40
45	AMS	–29.00	1.00	110.900	0.20
45	AMS	–28.00	1.00	110.700	0.20
46	AMS	–27.90	*	110.290	0.30
46	AMS	–28.00	*	110.260	0.30
46	AMS	–28.60	*	110.330	0.30
46	AMS	–28.20	*	110.000	0.30
46	AMS	–28.00	*	110.090	0.38
47	AMS	–29.30	*	110.420	0.44
48	LSC	–25.00	*	112.200	0.50
50	GPC	–28.80	0.20	111.800	0.50
50	GPC	–30.60	0.20	110.900	0.40
51	LSC	*	*	105.120	2.94
52	LSC	*	*	102.580	3.25
53	GPC	–30.55	*	109.820	0.25
54	GPC	–29.40	*	111.550	0.33
56	LSC	–31.90	0.20	111.000	0.40
57	AMS	–30.72	0.15	111.560	0.54
58	AMS	–31.20	*	110.780	0.35
59	LSC	–30.80	*	109.800	0.50
60	AMS	–25.7	1.2	111.05	0.46
61	LSC	–29.33	0.05	109.060	0.55
62	AMS	*	*	110.160	0.25
62	AMS	*	*	111.090	0.26
62	AMS	*	*	110.250	0.27
62	AMS	*	*	110.560	0.26
62	AMS	–27.10	0.10	110.510	0.13
63	AMS	–28.40	1.10	111.440	0.54
63	AMS	–29.10	1.10	111.420	0.53
64	AMS	–28.40	*	111.400	0.40
65	LSC	–29.04	*	110.700	0.20
66	AMS	–27.55	*	111.540	0.47
66	LSC	–30.83	*	110.340	0.44
67	GPC	–25.00	*	107.800	0.90
67	LSC	–25.00	*	110.400	0.60
69	LSC	–26.70	*	109.300	0.60
69	LSC	–25.60	*	110.000	0.70

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Table 2c Sample C data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Error	pMC	pMC error
70	AMS	–30.00	*	110.600	0.30
70	AMS	–30.00	*	110.800	0.30
70	AMS	–30.00	*	111.600	0.50
71	LSC	–31.59	0.10	103.590	0.85
72	LSC	–29.20	*	111.740	0.88
73	AMS	–27.6	*	110.84	*
74	LSC	–28.38	0.2	109.42	0.26
74	LSC	–29.19	0.2	109.81	0.28
75	AMS	–28.8	*	110.19	0.43
76	AMS	–27.3	3	110.31	0.39
77	LSC	–24	1	108.16	2.13
78	LSC	–30.1	*	109.85	0.45
79	AMS	–21.48	0.15	110.47	0.30

Table 2d Sample D data table.

Lab identifier	Method	$\delta^{13}C$	Error	Age BP	Age error	pMC	pMC error
1	LSC	*	*	3060	110	68.32	0.94
2	GPC	–22.300	0.20	3120	35	67.80	0.30
3	GPC	–22.500	*	2842	15	70.20	0.13
4	AMS	–22.200	*	2835	35	70.26	0.31
5	AMS	–20.200	0.60	2809	24	70.49	0.21
6	AMS	–23.000	*	2840	20	70.21	0.16
7	LSC	–22.340	*	2875	45	69.91	0.40
8	AMS	–20.710	*	2870	30	69.96	0.26
9	LSC	–23.055	0.20	2852	37	70.12	0.46
10	AMS	–25.400	0.20	2842	36	70.20	0.31
11	LSC	–22.330	*	2660	60	71.85	0.55
12	AMS	–23.100	*	3000	40	68.80	0.40
13	AMS	–23.900	0.10	2805	33	70.53	0.29
13	AMS	–19.900	1.20	2826	30	70.34	0.26
14	LSC	*	*	2650	60	71.93	0.54
15	GPC	–23.280	*	2819	29	70.40	0.25
16	AMS	–22.100	*	2850	20	70.17	0.25
16	AMS	–22.100	*	2850	20	70.12	0.24
17	LSC	–23.580	0.16	2928	101	69.45	0.82
18	LSC	–23.330	*	3887	170	61.60	0.20
19	LSC	–22.210	0.02	3740	57	62.78	0.45
20	GPC	–22.300	*	2822	22	70.40	0.20
21	AMS	–21.070	0.48	2859	28	70.05	0.24
22	AMS	–22.500	*	2894	26	69.75	0.23
22	AMS	–21.500	*	2851	28	70.12	0.24
23	AMS	–22.400	*	2842	34	70.20	0.30
24	LSC	–22.600	*	2867	50	69.98	0.43
25	AMS	–20.000	0.20	2875	20	69.90	0.16
25	AMS	–23.400	0.50	2825	20	70.36	0.15
25	AMS	–21.000	0.30	2855	20	70.07	0.16
25	AMS	–19.400	0.20	2845	15	70.18	0.12
25	AMS	–21.600	0.30	2850	15	70.15	0.12
26	AMS	–23.900	*	2866	32	69.99	0.28

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Table 2d Sample D data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Error	Age BP	Age error	pMC	pMC error
27	AMS	–22.040	*	2850	40	70.10	0.38
28	LSC	*	*	2595	50	72.39	0.45
29	LSC	–25.220	0.05	2710	140	71.37	1.24
30	LSC	–22.400	*	2760	60	70.90	0.50
31	LSC	–24.930	*	2820	40	70.39	0.35
32	LSC	–25.000	2.00	2720	60	71.29	0.55
33	LSC	–23.200	*	2784	35	70.71	0.31
34	GPC	–21.290	*	2730	40	71.18	0.36
35	AMS	–20.420	*	2900	25	69.72	0.21
36	LSC	–24.930	*	2815	40	70.44	0.35
37	AMS	–20.600	*	2950	30	69.27	0.28
37	AMS	–22.100	*	2730	30	71.15	0.29
37	AMS	–21.800	*	2800	35	70.58	0.33
37	AMS	–21.000	*	2580	30	72.50	0.29
38	LSC	–23.200	*	2600	84	73.06	0.74
39	AMS	–21.000	0.10	2702	35	71.44	0.31
40	LSC	–22.240	*	2700	70	71.42	0.59
41	GPC	–23.650	0.10	2860	35	70.03	0.31
41	GPC	–23.650	0.10	3010	45	68.70	0.38
41	GPC	–23.650	0.10	2700	60	71.43	0.53
42	GPC	–29.800	*	2770	45	70.90	0.30
43	AMS	–22.700	*	2862	45	70.02	0.40
43	AMS	–22.700	*	2820	55	70.39	0.50
43	AMS	–21.530	*	2889	41	69.79	0.36
44	AMS	–21.300	0.20	2804	32	70.50	0.30
45	AMS	–20.000	1.00	2811	19	70.50	0.20
45	AMS	–19.000	1.00	2832	18	70.30	0.20
46	AMS	–22.100	*	2840	25	70.23	0.18
46	AMS	–23.000	*	2870	25	69.96	0.21
46	AMS	–23.000	*	2865	25	70.00	0.20
46	AMS	–22.900	*	2815	25	70.43	0.18
46	AMS	–21.400	*	2835	30	70.26	0.25
47	AMS	–22.600	*	2885	35	69.83	0.30
48	LSC	–25.000	*	2840	50	70.22	0.44
49	LSC	–25.000	*	3090	50	68.04	0.39
50	GPC	–22.100	0.20	2800	40	70.60	0.30
51	LSC	*	*	2990	50	68.92	0.43
52	LSC	*	*	3584	242	64.81	1.90
53	GPC	–22.320	*	2835	25	70.25	0.21
54	GPC	–23.200	*	2795	36	70.61	0.32
55	AMS	–22.400	0.40	2830	30	70.31	0.26
56	LSC	–22.500	*	2842	33	70.20	0.30
57	AMS	–23.580	0.16	2832	43	70.29	0.38
58	AMS	–22.600	*	2833	23	70.29	0.20
59	LSC	–22.500	*	2960	70	69.18	0.60
60	AMS	–22.3	0.3	2790	40	70.22	0.36
61	LSC	–22.350	0.05	2610	50	71.81	0.41
62	AMS	*	*	2835	30	70.26	0.28
62	AMS	*	*	2820	30	70.38	0.25
62	AMS	*	*	2870	25	69.97	0.21

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Table 2d Sample D data table. *(Continued)*

Lab identifier	Method	$\delta^{13}C$	Error	Age BP	Age error	pMC	pMC error
62	AMS	*	*	2800	30	70.59	0.26
63	AMS	–24.500	1.10	2817	44	70.42	0.38
63	AMS	–22.900	1.10	2796	45	70.61	0.39
64	AMS	–22.200	*	2780	35	70.75	0.31
65	LSC	–22.260	*	2829	25	70.07	0.22
66	AMS	–20.450	*	2905	40	69.66	0.36
66	LSC	–22.240	*	3020	45	68.68	0.38
67	GPC	–25.000	*	2824	72	70.40	0.60
67	LSC	–25.000	*	2865	49	70.00	0.40
69	LSC	–21.500	*	3000	60	68.90	0.50
69	LSC	–22.100	*	2800	50	70.60	0.50
70	AMS	–22.900	*	2940	30	69.30	0.30
70	AMS	–22.900	*	2830	30	70.30	0.30
70	AMS	–22.900	*	2800	40	70.30	0.30
71	LSC	–23.650	0.10	2780	60	71.09	0.52
72	LSC	–22.300	*	2630	70	72.08	0.65
73	AMS	–24.0	*	2770	40	70.80	0.35
74	LSC	–22.35	0.20	3040	60	*	*
75	AMS	–22.5	*	2807	49	70.51	0.43
76	AMS	–23	2	2862	23	70.03	0.20
78	LSC	–21.5	*	2865	35	*	*
79	AMS	–22.37	0.22	2805	27	70.53	0.23
80	LSC	–22.3	*	2820	50	*	*

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