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PRESENT STATUS OF RADIOCARBON CALIBRATION AND COMPARISON RECORDS BASED ON POLYNESIAN CORALS AND IBERIAN MARGIN SEDIMENTS

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ABSTRACT. In this paper, we present updated information and results of the radiocarbon records based on Polynesian corals and on Iberian Margin planktonic foraminifera. The latter record was first published by Bard et al. (2004a,b), with the subsequent addition of some data by Shackleton et al. (2004). These data sets are compared with the IntCal98 record (Stuiver et al. 1998) and with data sets based on other archives, such as varves of Lake Suigetsu (Kitagawa and van der Plicht 1998, 2000), speleothems from the Bahamas (Beck et al. 2001), and Cariaco sediments (Hughen et al. 2004). Up to 26,000 cal BP, the Iberian Margin data agree within the errors of the other records. By contrast, in the interval between 33,000 and 41,000 cal BP, the Iberian Margin record runs between the Lake Suigetsu and Bahamian speleothem data sets, but it agrees with the few IntCal98 coral data and the Cariaco record.

POLYNESIAN CORALS

In order to check the accuracy and to improve the precision of the radiocarbon ages used for IntCal, several of our coral samples were reanalyzed at the Gif-sur-Yvette Accelerator Mass Spectrometry (AMS) facility (Paterne et al. 2004). Table 1 (a fraction of the samples published by Bard et al. 1998) compares both sets of ^{14}C ages illustrated by Figure 1. Overall, the new ^{14}C ages generally agree within error to the previous ones. An error multiplier of 1.5 for 1-σ errors of ^{14}C ages has been determined by using these replicated measurements (Hughen et al., this issue).

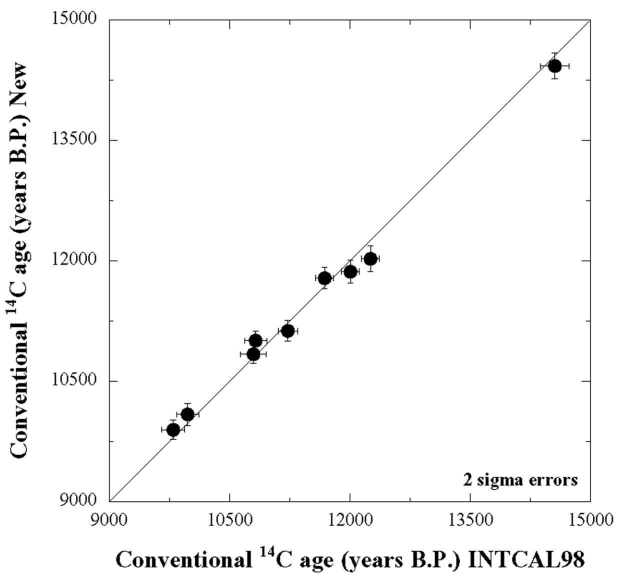

Figure 1 New ^{14}C measurements of Tahiti and Mururoa corals already used in IntCal98. Age errors are given at the 95% confidence level (2 σ). See Table 1 for more details.

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Table 1 New versus old ^{14}C measurements of several Tahiti and Mururoa corals used in IntCal98. Age errors are given at the 95% confidence level (2 σ). Values in italics are the weighted mean and errors based on 2 ^{14}C measurements.

Coral sample code	^{14}C age –300 (BP) used for IntCal98	2-σ error (yr)	^{14}C age –300 (BP) new determinations	2-σ error (yr)
Ta-P7-8	9800	140	*9900*	*120*
Ta-P7-9	9980	140	*10,090*	*140*
Ta-P7-11	10,830	140	*11,010*	*120*
Ta-P7-12	10,800	160	*10,840*	*110*
Ta-P8-1	*11,230*	*120*	*11,130*	*130*
Ta-P8-2	*11,690*	*110*	*11,790*	*130*
Ta-P8-3	*12,010*	*110*	*11,870*	*140*
Ta-P8-4	*12,260*	*110*	*12,030*	*160*
Mu-8-30-315	14,560	180	*14,430*	*160*

IBERIAN MARGIN SEDIMENTS

Core MD952042 (37°45′N, 10°10′W, 3146 m water depth) was recovered on the Iberian Margin by Research Vessel *Marion Dufresne*. To construct its ^{14}C chronology (first published by Bard et al. 2004a,b), we selected the planktonic foraminifera *Globigerina bulloides*, which has been shown to yield reliable results in a shorter core from the same location (Bard et al. 1987a, 2000). To minimize the bias of bioturbation on ^{14}C ages, monospecific samples were picked in the abundance maxima observed for this species, expressed as number of shells per gram of sediment (see Figure 2). As illustrated by Bard et al. (1987b), this procedure is crucial to obtain reliable ^{14}C ages. Picking foraminifera in an abundance minimum would result in a rather unconstrained ^{14}C age, since most shells would have been transported from higher abundance levels within the same core (i.e. from below or above the dated level).

After hand-picking at CEREGE and prior to the carbonate hydrolysis, the shells were leached in order to eliminate residual contamination by recent carbon. This pretreatment consisted of 3 steps: mechanical cleaning by sonication in distilled water (repeated until the surnatant remains clear), acid-leaching HNO_3 0.001N for a few seconds, and a repeated rinse with distilled water. The AMS analyses were performed at the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility in Woods Hole (USA). Table 2 provides the numerical values for the monospecific samples which were composed of about 2000 *G. bulloides* shells. Age uncertainties are quoted at the 95% confidence level (2 σ). Blank values measured on carbonate standards have been used to correct the ages (McNichol et al. 2001). This table has been updated since our previous publication (Bard et al. 2004a,b). In fact, the blank corrections for our samples were reassessed by comparing carbonate blank values measured during each run with long-term blank averages. The ^{14}C ages and their errors have been recalculated accordingly (Ann McNichol, written communication, 28 Jan 2004). For each sample, the difference between the 2 ^{14}C age calculations is quite minor and always less than the size of the error bar.

Overall reproducibility of the ^{14}C age determination at NOSAMS can be assessed by considering 4 pairs of adjacent samples taken at intervals of a few cm apart in the core: 458.5 and 459.5; 538.5 and 539.5; 918.5 and 921.5; and 1078.5 and 1079.5 cm. In these 4 pairs of "duplicates," the differences in age are much less than the error bars (Figure 3). The test is stringent because these foraminifera samples were not homogenized and thus do not represent true replicates.

Also listed in Table 2 and shown in Figure 3 are ^{14}C analyses obtained on *G. bulloides* samples from the same core that were measured in the Gif-sur-Yvette and Kiel AMS laboratories (Shackleton et al.

2004). Although the precision is not as high as that obtained at NOSAMS (see Table 2), these 12 additional ages clearly agree within error of our larger data set obtained at NOSAMS. In addition, the ^{14}C ages obtained at NOSAMS have been systematically picked in foraminiferal abundance maxima (see Figure 2), which should ensure their reliability.

Table 2 AMS-^{14}C ages measured on planktonic foraminifera sampled in deep-sea core MD952042 (monospecific samples composed of *Globigerina bulloides*). ^{14}C ages are conventional ages corrected for a local sea-surface reservoir age of 500 yr. Columns labeled "GISP2" and "GRIP" age provide the calendar ages (in yr before AD 1950) calculated by tuning the stratigraphy of core MD952042 with Greenland Summit ice cores (see text and Figures 4 and 5). Note that the GRIP values were slightly updated with respect to our previous publication (Bard et al. 2004a,b) by using the same tie points for matching with GISP2 and GRIP (see Figures 4 and 5). Columns labeled "Δ^{14}Cgisp2" and "Δ^{14}Cgrip" provide the Δ^{14}C in ‰ calculated between the ^{14}C age and both calendar ages. The data measured at NOSAMS have been slightly corrected with respect to Bard et al. (2004a,b); the data from GifA and Kiel are reported by Shackleton et al. (2004). All analytical errors are given at the 95% confidence level (2 σ) and are those used for figures. The additional column labeled "Overall error" corresponds to a calculation based on propagating into the error calculation different sources of uncertainty: analytical error at 2 σ and estimated errors for the reservoir age correction (±100 yr, see text for details), the curve matching (±180 yr, same value as used by Hughen et al., this issue), and the GISP2 ice-core chronology (2% for ages between 8000 and 40,000 cal BP, Meese et al. 1997).

Accession #	Core depth (cm)	^{14}C age –500 (BP)	2-σ error (yr)	GISP2 age (BP)	Δ^{14}Cgisp2 (‰)	2-σ error Δgisp2 (‰)	Overall error (‰)	GRIP age (BP)	Δ^{14}Cgrip (‰)	2-σ error Δgrip (‰)
NOSAMS OS-40272	458.5	13,050	120	15,635	306	20	63	15,515	287	19
NOSAMS OS-39555	459.5	13,000	110	15,659	318	18	63	15,543	299	18
NOSAMS OS-39556	538.5	14,200	110	17,743	460	20	76	17,407	402	19
NOSAMS OS-40273	539.5	14,150	130	17,770	474	24	78	17,430	415	23
NOSAMS OS-40268	658.5	16,350	200	20,766	610	40	99	20,076	482	37
GifA100547	800	19,620	420	23,599	510	79	123	22,936	394	73
NOSAMS OS-39557	841.5	20,400	220	24,364	503	41	105	23,813	406	39
NOSAMS OS-40270	918.5	21,800	220	25,734	490	41	108	25,507	450	40
NOSAMS OS-39558	921.5	21,800	260	25,808	504	49	113	25,573	462	47
GifA100548	1012	24,450	540	27,957	402	94	138	27,540	333	90
NOSAMS OS-39559	1019.5	24,400	240	28,096	435	43	113	27,690	366	41
GifA100549	1048	25,260	580	28,622	374	99	142	28,260	315	95
NOSAMS OS-40271	1078.5	25,700	240	29,395	428	43	116	29,177	391	42
NOSAMS OS-39560	1079.5	25,500	220	29,424	469	40	118	29,214	432	39
GifA100550	1175	28,530	780	32,345	435	139	183	32,678	494	145
NOSAMS OS-39305	1199.5	29,100	480	33,433	524	91	158	33,523	541	92
GifA100551	1216	29,450	720	33,842	533	137	190	33,951	554	139
GifA100552	1267	31,910	840	35,074	310	137	180	35,263	341	140
NOSAMS OS-39306	1279.5	31,300	720	35,578	503	135	191	35,731	531	137
KIA14285	1336	33,820	1440	38,139	497	268	304	38,055	482	266
NOSAMS OS-39307	1361.5	34,800	920	38,877	449	166	218	38,847	443	165
NOSAMS OS-39308	1378.5	35,200	980	39,318	454	177	228	39,342	458	178
KIA15625	1404	35,510	1200	39,979	515	226	272	40,085	535	229
KIA14284	1416	36,140	1940	40,325	461	353	382	40,548	501	362
GifA100554	1439	37,200	1360	41,059	399	237	277	41,652	503	254
GifA100555	1483	41,700	2200	42,291	–73	254	272	43,196	35	283
GifA100556	1548	46,400	3600	45,190	–266	329	339	47,094	–76	414
NOSAMS OS-39309	1581.5	45,600	>	46,468	–54	<	<	48,638	230	<

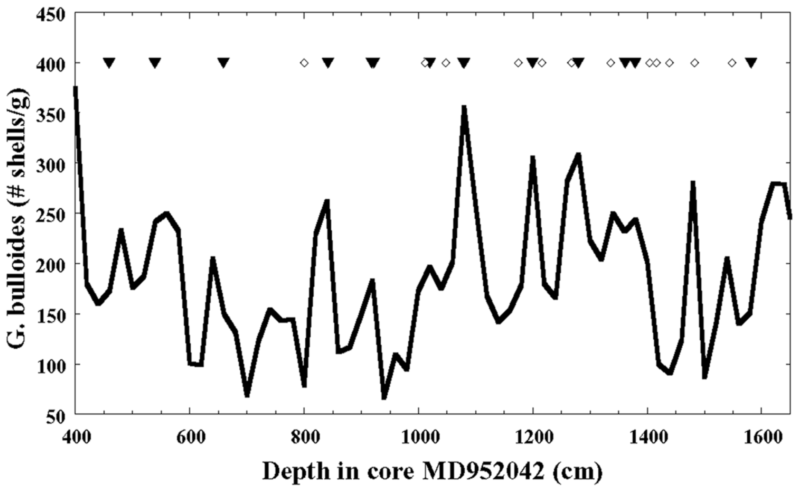


Figure 2 Abundances of *Globigerina bulloides* in core MD952042 expressed in terms of number of shells per gram of sediment (raw data from Cayre et al. 1999). Symbols represent the depths for which ^{14}C ages on monospecific samples were measured: black triangles (Bard et al. 2004a,b) and open diamonds (Shackleton et al. 2004). Note that the latter data set has an additional uncertainty linked to the fact that shells were not always sampled in abundance maxima observed for this species of foraminifera.

^{14}C ages obtained on planktonic foraminifera need to be corrected for the difference in ^{14}C composition between the atmosphere and the sea surface [see Bard (1988), for a review on this topic and the comprehensive compilation available on the internet by Reimer and Reimer (2004), http://radiocarbon.pa.qub.ac.uk/marine/]. Core MD952042 is located away from the high-latitude zones, where ^{14}C reservoir ages are large and variable, such as the northern part of the North Atlantic and the Southern Ocean. In our previous work on this site, we used a typical reservoir age of 400 yr and assumed that it remained constant through time. However, the Marine Reservoir Correction Database (Reimer and Reimer 2004) provides several results measured on molluscs from the south Portuguese coast which seem older than 400 yr (original data in Monge Soares 1993). Based on 4 shells collected alive before 1950 and corrected for the Suess effect (#263, 264, 265, and 266 of the database), the average reservoir age is estimated at 600 yr (ΔR of 200 yr) with a standard deviation of 100 yr. The 2 molluscs samples (#264 and 265) collected on the coast, at a similar latitude to core MD952042, yield reservoir ages of 490 ± 100 yr and 600 ± 180 yr (2-σ errors). Nevertheless, these high ^{14}C reservoir age values may only be applicable to the coastal area, and the site of the core is far offshore (about 75 km). To check this issue, it is useful to consider chemical oceanography transects measured at the same exact latitude (Coste et al. 1986). The hydrological sections clearly reveal that the site of core MD952042 lies outside the coastal upwelling anomaly characterized by low sea-surface temperature (gradient steeper than 2 °C) and high surface chlorophyl concentrations (gradient of more than 3 µg/L). Hence, to acknowledge the uncertainty and possible time variability of the reservoir age, we have used 500 ± 100 yr as a more appropriate correction. This conservative value overlaps with both the 400 yr assumed previously and the 500–600 yr observed directly at the coast. The standard error is 100 yr at the 95% confidence level, as calculated with the 4 ^{14}C age values observed at the coast (Monge Soares 1993).

As described below, the calendar chronology for core MD952042 is based on the identification of well-dated paleoclimatic events. Thus, it is important to emphasize that foraminifera ^{14}C ages are representative for the different sediment fractions. We discussed this issue previously (Bard et al. 2004a,b) by mentioning several specific factors which limit the potential decoupling between sediment fractions in the particular case of core MD952042. An additional pragmatic argument is that

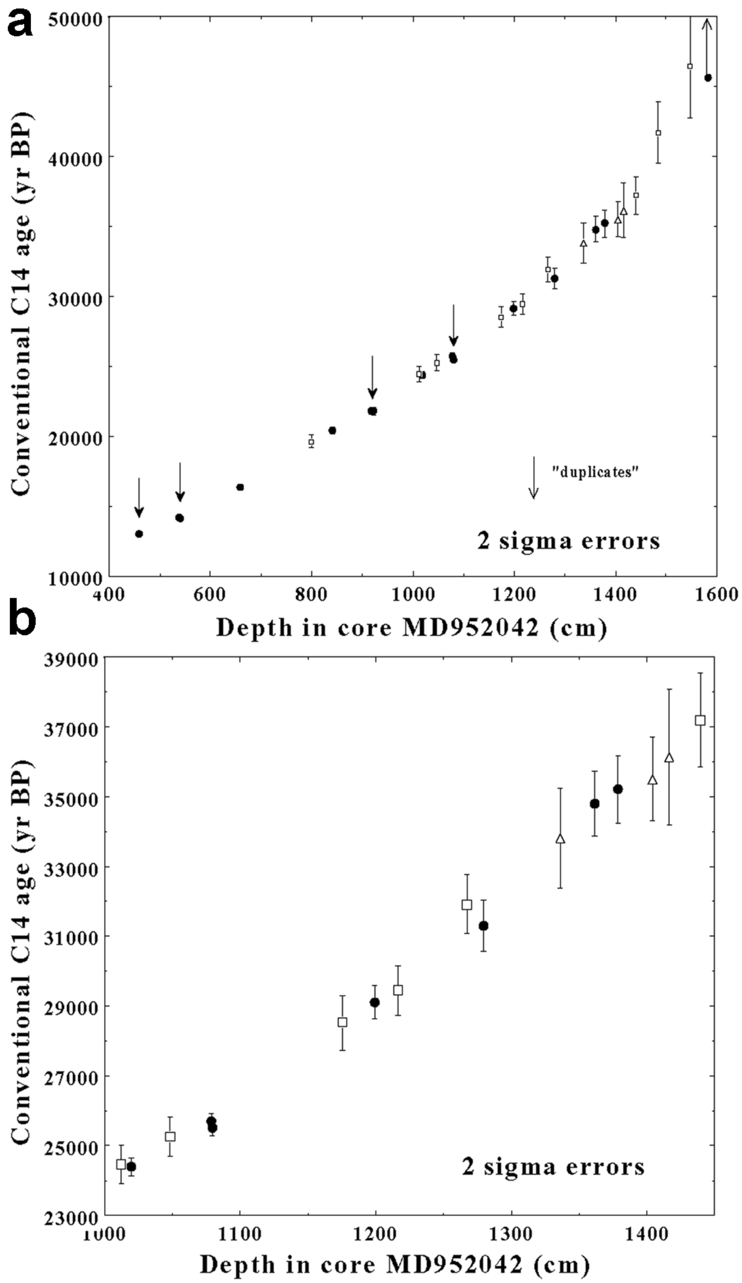


Figure 3 ^{14}C ages from Table 2 plotted versus depth in core MD952042: (a) data between 400 and 1600 cm; (b) expanded view of the data between 1000 and 1450 cm. Black dots are samples dated at NOSAMS (Bard et al. 2004a,b); open squares and triangles are data from GifA and Kiel, respectively (Shackleton et al. 2004). Downward arrows indicate depths for which "duplicate" measurements were performed at NOSAMS (see text for more details). All ^{14}C errors are quoted at the 2-σ level. An upward arrow has been used for the lower-bound ^{14}C age obtained for the 1581.5-cm section (see Table 2).

all paleoceanographic proxies based on the different sediment fractions are in good stratigraphic agreement in core MD952042. The different panels on Figures 4 and 5 summarize the stratigraphy developed for core MD952042 based on the correspondence between the following paleoceanographic proxies: the $U_{37}^{K'}$ index of alkenones, which is directly linked to sea-surface temperature (Brassell et al. 1986); the magnetic susceptibility of sediments, the maxima of which are linked to the injection of ice-rafted minerals (Thouveny et al. 2000; note the inverted log-scale in Figures 4c and 5c); the $\delta^{13}C$ of benthic foraminifera, which correlates positively with the strength of the deep-sea ventilation (Vidal et al. 1997); and the $\delta^{18}O$ of planktonic foraminifera, a complex signal of global sea-level changes and local variations of sea-surface temperature and evaporation-precipitation balance (Duplessy et al. 1993).

CALENDAR TIME SCALE

We correlated the observed climatic events mentioned above with those observed in Greenland Summit cores (Dansgaard et al. 1993; Stuiver and Grootes 2000) in order to build a calendar time scale for core MD952042. The curves used for the final tuning are the $U_{37}^{K'}$ record of Iberian Margin sediments and the $\delta^{18}O$ record of the GISP2 ice core. Both of these geochemical indicators are proxies for temperature change which are expected to be synchronous in Greenland and the North Atlantic over millennium-scale events. Matching the 2 $\delta^{18}O$ curves directly would be less reliable because the seawater $\delta^{18}O$ experienced large shifts during abrupt climatic changes off the Iberian Margin (Duplessy et al. 1993). These shifts are not necessarily in phase with temperature variations.

For matching of Dansgaard-Oeschger interstadials and Heinrich events, we also took into account differences in amplitude between the Greenland and North Atlantic temperature records. As shown by numerous data and confirmed by numerical models (e.g. Ganopolski and Rahmstorf 2001), the maximal cooling during a Heinrich event is located at a lower latitude than the maximal warming of the Dansgaard-Oeschger interstadial. Therefore, Dansgaard-Oeschger events stand out more clearly in Greenland ice than in North Atlantic sediments, while Heinrich events, although not always much colder than other cold stadials in the Greenland record, are conspicuous in the North Atlantic.

Tie points were chosen visually and the match was performed with the Linage software (Paillard et al. 1996). To explore uncertainty in the calendar time scale, we used both the GISP2 scale (file and time scale in Cross 1997; Meese et al. 1997) and the GRIP core age scale (version by Johnsen et al. 2001). Similar calendar chronologies are obtained with these 2 Greenland ice cores. As illustrated in Figures 6 and 7, the difference between the two is less than a millennium between 18,000 and 24,000 cal BP, and less than a few centuries for the interval between 25,000 and 39,000 cal BP. However, it increases beyond 40,000 cal BP to about 3 millennia.

It is possible to calculate an overall uncertainty on the estimated $\Delta^{14}C$ by propagating into the error calculation the estimated uncertainties linked, respectively, to the reservoir age correction (±100 yr), to the curve matching (±180 yr, same value as used by Hughen et al., this issue), and to the ice-core chronology (2% for ages between 8000 and 40,000 cal BP, Meese et al. 1997). Depending on the age, this procedure increases the $\Delta^{14}C$ error by 10 to 80‰. Most of this increase is linked to the uncertainty in the ice-core chronology, especially for old ages (see Table 2).

COMPARISON WITH OTHER DATA SETS

In order to validate this approach, the Iberian Margin results are first compared with available data in the range of the current IntCal98 calibration (Stuiver et al. 1998; Figures 6a and 7a). In the interval between 15,000 and 24,000 cal BP, the IntCal98 curve was based on corals from Barbados and Mururoa (Bard et al. 1998). Also plotted on Figure 6a are results based on the Lake Suigetsu varves

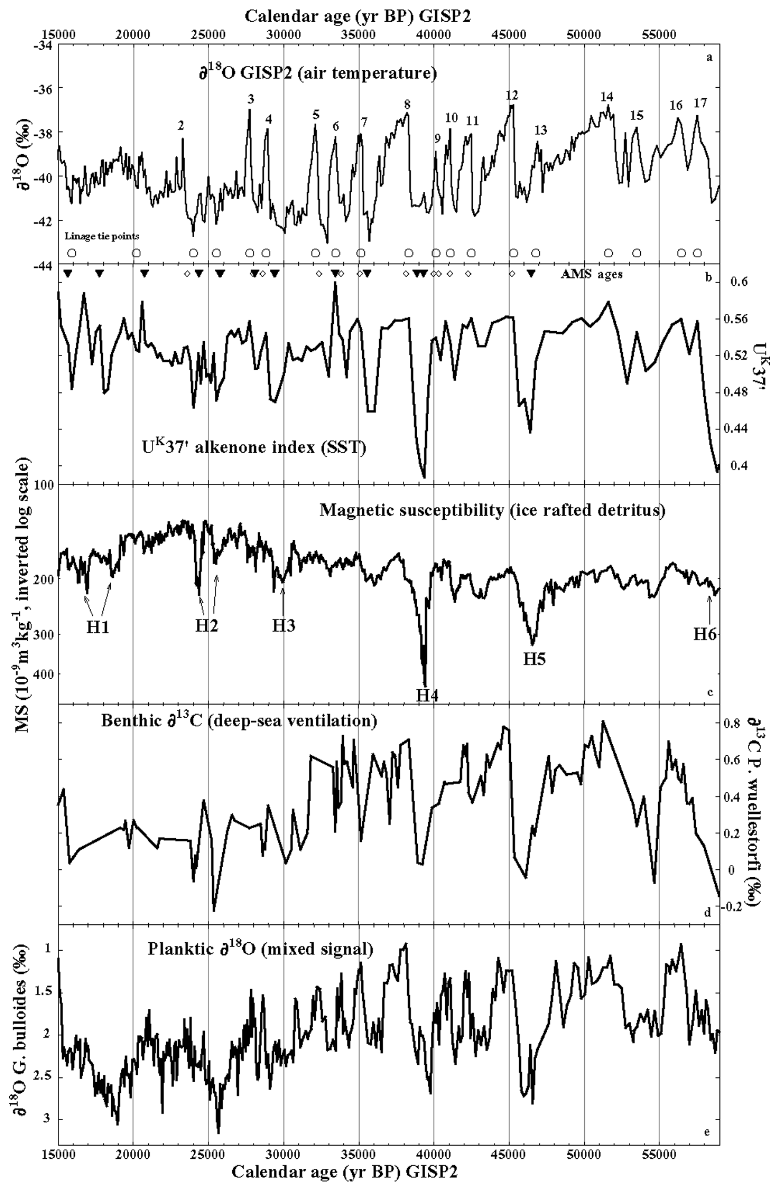


Figure 4 Time series of climatic and oceanographic variations in Greenland and the Iberian Margin during the last 59,000 yr before AD 1950: (a) $\delta^{18}O$ measured in the Greenland Summit GISP2 core (Stuiver and Grootes 2000). The data set and its time scale were extracted from the file gispd18o.dat in the CD-ROM compiled by Cross (1997) distributed jointly by the World Data Center for Paleoclimatology at NOAA-NGDC and the Institute of Arctic and Alpine Research. Numbers depict the Dansgaard-Oeschger events following Dansgaard et al. (1993). Small open circles represent the tie points used for the correlation with the deep-sea core $U_{37}^{K'}$ index (Figure 4b); (b–e): stratigraphy of core MD952042 along a time scale tuned to the curve in (a) by means of the Linage software (Paillard et al. 1996); (b) $U_{37}^{K'}$ alkenone index a proxy for sea-surface temperature (SST; raw data from Pailler and Bard 2002). Symbols locate the samples used for AMS dating (black triangles are data from NOSAMS [Bard et al. 2004a,b]; open diamonds are the data from GifA and Kiel [Shackleton et al. 2004]); (c) magnetic specific susceptibility record plotted on an inverted log scale (raw data from Thouveny et al. 2000). Maximum values (i.e. troughs in the curve) are used to identify the ice-rafted detritus injected during Heinrich and other events. The numbers represent the 6 classical Heinrich events. Off the Iberian Margin, these events (e.g. H1 and H2) often contain 2 peaks which can be seen both on (b) and (c) (see discussion in Thouveny et al. 2000; and Bard et al. 2000 and references therein); (d) $\delta^{13}C$ measured on benthic foraminifera and used as a proxy for the ventilation of the deep Atlantic (raw data from Shackleton et al. 2000); (e) $\delta^{18}O$ values for planktonic foraminifera (raw data from Cayre et al. 1999; Shackleton et al. 2000).

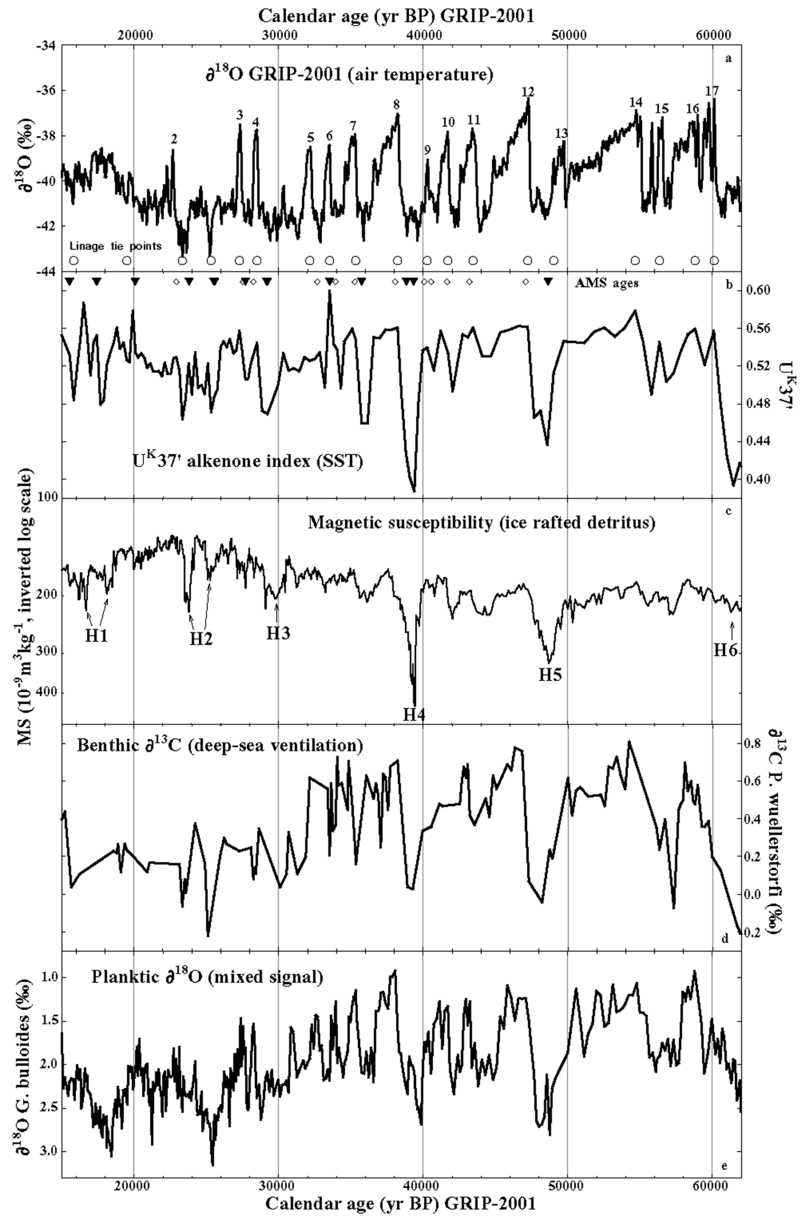


Figure 5 Time series of climatic and oceanographic variations in Greenland and the Iberian Margin during the last 62,000 yr before AD 1950: (a) $\delta^{18}O$ measured in the Greenland Summit GRIP core (Dansgaard et al. 1993; Johnsen et al. 2001). The time scale is from Johnsen et al. (2001). Numbers depict the Dansgaard-Oeschger events following Dansgaard et al. (1993). Small open circles represent the tie points used for the correlation with the deep-sea core $U_{37}^{K'}$ index (Figure 5b). These tie points are the same as those used for the matching with GISP2 (minor update with respect to Bard et al. 2004a,b, which is responsible for small differences in the calendar age estimates listed in Table 2). (b–e): stratigraphy of core MD952042 along a time scale tuned to the curve in (a) by means of the Linage software (Paillard et al. 1996); (b) $U_{37}^{K'}$ alkenone index, a proxy for sea-surface temperature (SST; raw data from Pailler and Bard 2002). Symbols locate the samples used for AMS dating (black triangles are data from NOSAMS [Bard et al. 2004a,b]; open diamonds the data from GifA and Kiel [Shackleton et al. 2004]); (c) magnetic specific susceptibility record plotted on an inverted log scale (raw data from Thouveny et al. 2000). Maximum values (i.e. troughs in the curve) are used to identify the ice-rafted detritus injected during Heinrich and other events. The numbers represent the 6 classical Heinrich events. Off the Iberian Margin, these events (e.g. H1 and H2) often contain 2 peaks which can be seen both on (b) and (c) (see discussion in Thouveny et al. 2000; and Bard et al. 2000 and references therein); (d) $\delta^{13}C$ measured on benthic foraminifera and used as a proxy for the ventilation of the deep Atlantic (raw data from Shackleton et al. 2000); (e) $\delta^{18}O$ values for planktonic foraminifera (raw data from Cayre et al. 1999; Shackleton et al. 2000).

(Kitagawa and van der Plicht 1998, 2000), on speleothems from the Bahamas (Beck et al. 2001), and on Cariaco sediments (Hughen et al. 2004). In general, the Iberian Margin results broadly agree with the IntCal98 curve, but the remaining differences can be of the order of a few centuries. The residual differences may reflect the limitations of the stratigraphic approach or a small variability of the reservoir age.

In a second step, the Iberian Margin results are used beyond the IntCal98 calibration curve (Figures 6b and 7b). Large discrepancies exist between these records even though they seem to converge towards the 2 corals at about 26,000 and 36,000 ^{14}C BP. Agreement with the other data sets prevail between 25,000 and 31,000 cal BP. In the interval between 34,000 and 40,000 cal BP, where previous records disagree by up to 5000 cal yr, the Iberian Margin record falls between the Lake Suigetsu and Bahamian speleothem data sets but agrees closely with the Cariaco record. These general conclusions do not depend on the choice of the Greenland chronology; indeed, except for ages older than 40,000 ^{14}C BP, Greenland's GISP2 and GRIP records yield similar calendars.

The 2 time scales derived for core MD952042 yield calendar age estimates for each individual ^{14}C age (see the right columns on Table 2). The resulting pairs of ^{14}C and calendar ages can then be used to calculate $\Delta^{14}C$, plotted along with other data sets used for calibrating ^{14}C (Figure 8). Altogether, the different calibration methods led to the reconstruction of significant variations of atmospheric $\Delta^{14}C$. It is noticeable that there are no significant differences between the reconstructions based on the GISP2 and GRIP tunings of the Iberian Margin record (Figures 8a,b). Furthermore, these data sets agree within error of the Cariaco Basin record, pointing towards a relatively stable atmospheric $\Delta^{14}C$ value of 400–500‰ between 30,000 and 40,000 yr. No excursions to extreme values, such as +1500‰ at 44,000 yr (Bahamian speleothems) or 0‰ at 35,000 yr (Lake Suigetsu varves), are seen in either stratigraphic record. Although it needs to be confirmed by additional ^{14}C dates to increase the temporal resolution, none of these large peaks seem to be superimposed on this average value. Lastly, these records suggest that $\Delta^{14}C$ was minimal beyond 44,000 yr. However, given the uncertainties associated with old ages, more precise dating is needed in that time range (for both ^{14}C and ice-core chronologies).

CONCLUSIONS

Replicated ^{14}C ages for several of our Polynesian corals confirm that the ^{14}C ages used for IntCal are reliable.

The study of deep-sea core MD952042 collected off the Iberian Margin shows that the stratigraphic method can be used successfully to calibrate ^{14}C ages. This method is based on correlating known paleotemperature events dated by ^{14}C with their equivalent events in a Greenland ice core which is precisely dated by means of techniques independent of ^{14}C.

The important observation is that in the interval between 33,000 and 41,000 cal BP for which previous records disagree by up to 5000 cal yr, the Iberian Margin record agrees with the few IntCal98 coral data and the Cariaco record, but it runs between the Lake Suigetsu and Bahamian speleothem data sets.

We emphasize that the Iberian Margin ^{14}C record remains tentative and preliminary. Indeed, significant progress is expected in the near future: First, we will increase its data density, taking advantage of new deep-sea cores collected by the Research Vessel *Marion Dufresne* at the Iberian Margin. Second, the recently drilled NorthGRIP ice core (Johnsen et al. 2001) will result in an improved accuracy for the calendar time scale—the backbone of the stratigraphic method.

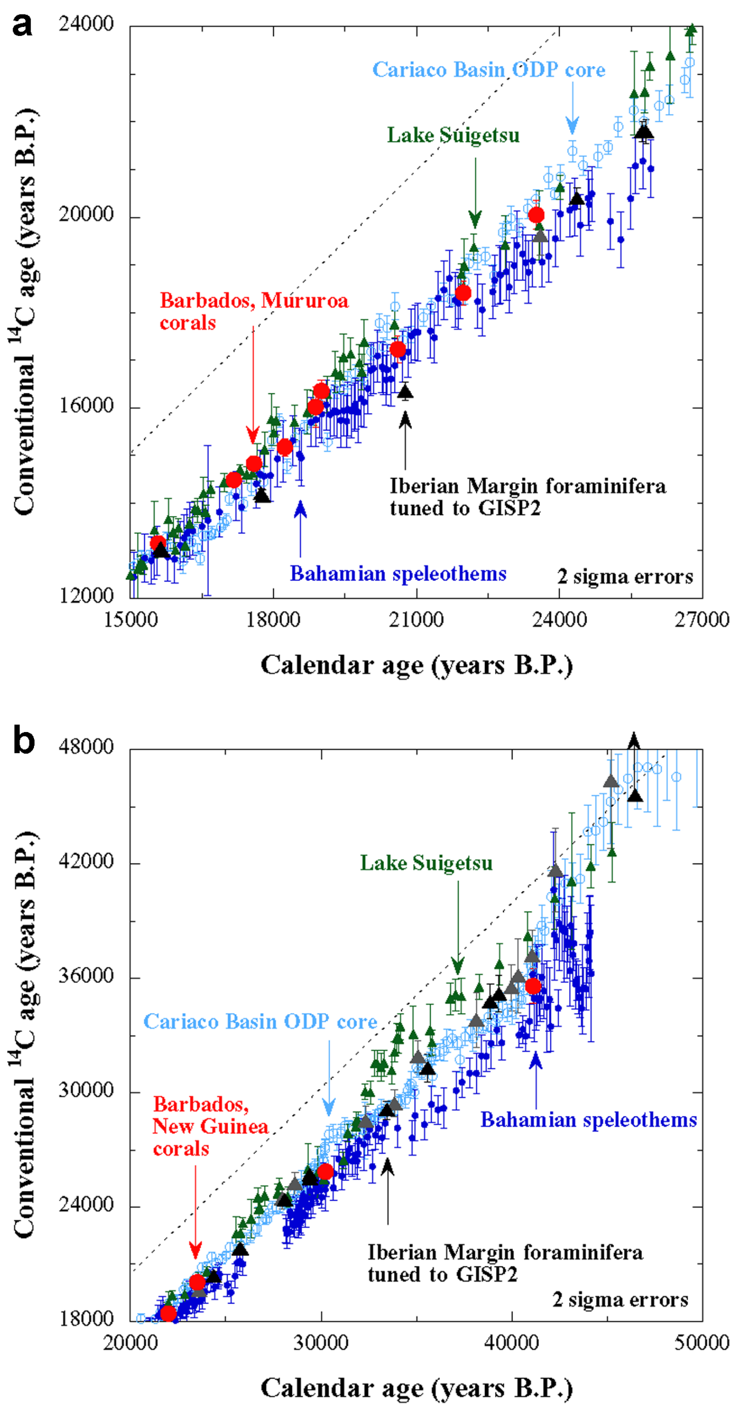
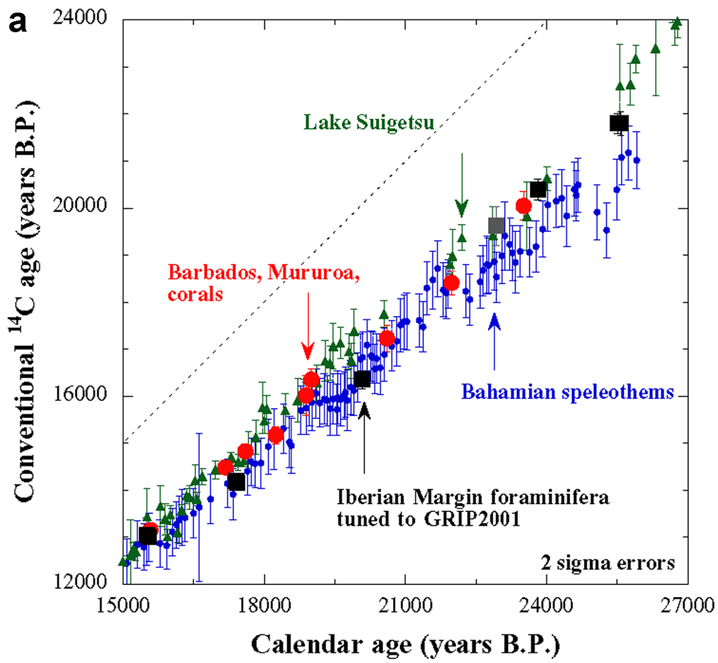


Figure 6 ^{14}C ages plotted versus calendar ages: (a) data within the range of IntCal98 in the interval between 15,000 and 24,000 cal BP; (b) data beyond the range of IntCal98 (Stuiver et al. 1998). Triangles show the data based on ^{14}C data of the Iberian Margin sediments tuned to GISP2. Black symbols are data from NOSAMS (Bard et al. 2004a,b); gray symbols are the data from GifA and Kiel (Shackleton et al. 2004). Red dots represent the IntCal98 data from Barbados, Mururoa, and New Guinea corals (Bard et al. 1998); green triangles = Lake Suigetsu varves (Kitagawa and van der Plicht 1998, 2000); blue dots = Bahamian speleothems (Beck et al. 2001); and open blue circles = Cariaco Basin ODP Core (Hughen et al. 2004). All ^{14}C errors are quoted at the 2-σ level. An arrow has been used for the lower-bound ^{14}C age obtained for the 1581.5-cm section (see Table 2).



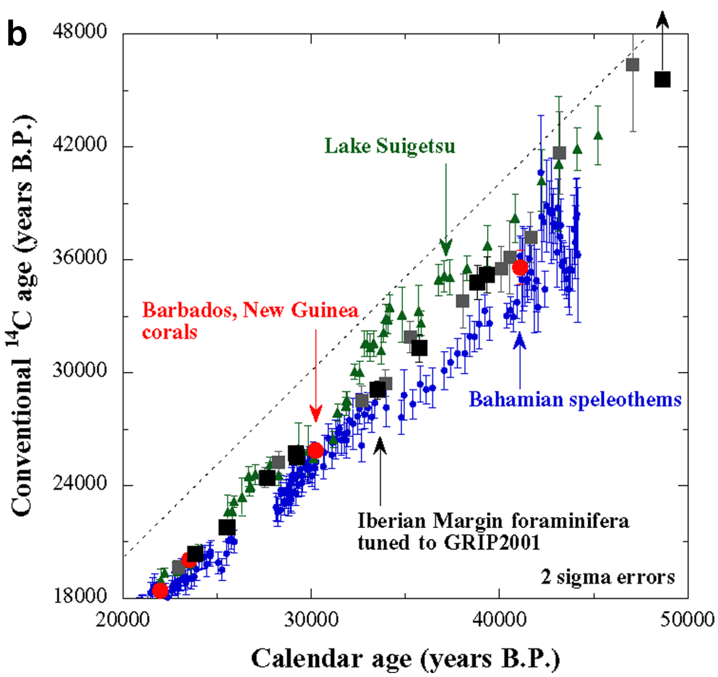
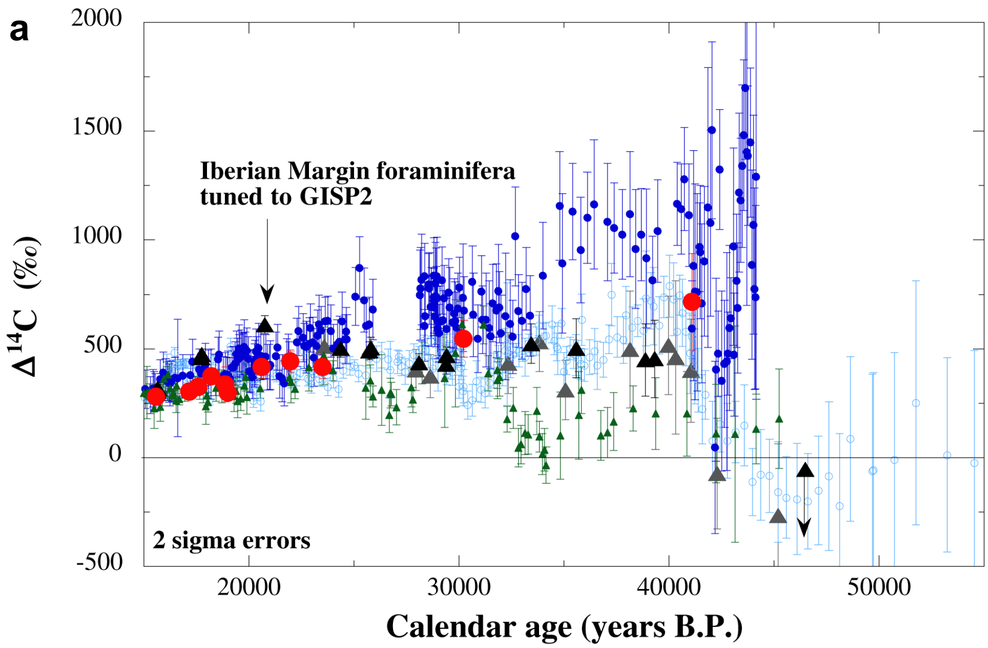


Figure 7 ^{14}C ages plotted versus calendar ages: (a) data within the range of IntCal98 in the interval between 15,000 and 24,000 cal BP; (b) data beyond the range of IntCal98 (Stuiver et al. 1998). Squares show the data based on ^{14}C data of the Iberian Margin sediments tuned to GRIP. Black symbols are data from NOSAMS (Bard et al. 2004a,b); gray symbols are the data from GifA and Kiel (Shackleton et al. 2004). Red dots represent data from Barbados, Mururoa, and New Guinea corals (Bard et al. 1998); green triangles = Lake Suigetsu varves (Kitagawa and van der Plicht 1998, 2000); and blue dots = Bahamian speleothems (Beck et al. 2001). All ^{14}C errors are quoted at the 2-σ level. An arrow has been used for the lower-bound ^{14}C age obtained for the 1581.5-cm section (see Table 2).



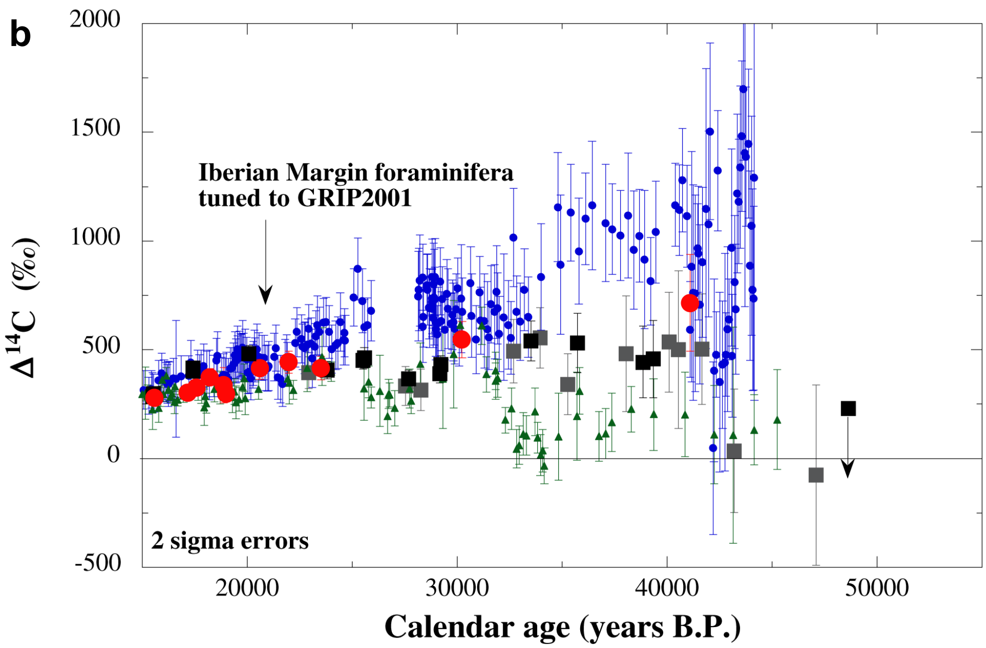


Figure 8 Atmospheric $\Delta^{14}C$ versus time as calculated using the AMS-^{14}C ages plotted in Figures 6 and 7. Triangles and squares show the data based on ^{14}C data of the Iberian Margin sediments tuned to GISP2 (a) and GRIP (b), respectively. Black symbols are data from NOSAMS (Bard et al. 2004a,b); gray symbols are the data from GifA and Kiel (Shackleton et al. 2004). Red dots represent data from Barbados, Mururoa, and New Guinea corals (Bard et al. 1998); green triangles = Lake Suigetsu varves (Kitagawa and van der Plicht 1998, 2000); blue dots = Bahamian speleothems (Beck et al. 2001); and open blue circles = Cariaco Basin ODP Core (Hughen et al. 2004). All ^{14}C errors are quoted at the 2-σ level. An arrow has been used for the higher-bound $\Delta^{14}C$ age obtained for the 1581.5-cm section (see Table 2).

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