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Progress and pitfalls in radiocarbon dating

Arising from: P. Mellars *Nature* 439, 931–935 (2006)

The review by Mellars[1] provides an archaeological perspective on some of the latest developments in radiocarbon dating of bone. However, his presentation, calibration and interpretation of radiocarbon ages are misleading in some cases, and important technical advances in the pretreatment of other sample types that have increased dating accuracy have been overlooked. These considerations may undermine the conclusions drawn about past human dispersals.

As Mellars points out[1], ultrafiltration of bone samples can yield final age determinations that are significantly different from ages derived by traditional methods[1,2]. The latest results from ultrafiltration show that the ages originally reported from archaeological contexts should be considered as only minimum estimates. Although Mellars says that bones are the most widely available materials for dating[1], most (75%) of the ages plotted in Fig. 3 of ref. 1 are based on charcoal (P. Mellars, personal communication). As with bone, important developments have taken place in the preparation of charcoal for radiocarbon dating. Advances in the pretreatment and graphitization of charcoal[3] have extended its dating range to at least 55,000 yr before present (BP) and make it probable that many of the original age determinations for charcoal are minima. Unfortunately, Mellars reconstructs routes and rates of modern human dispersal across Eurasia from published ages of samples that had not been pretreated using the new methods.

Mellars also erroneously refers to NotCal04 (ref. 4) as a 'calibration'; however, NotCal04 is a summary of data sets that extend beyond the 26,000 calibrated years BP limit of the internationally accepted radiocarbon curve, IntCal04, and is not a calibration curve (hence the name[4]). The records that contribute to the NotCal04 comparison curve deviate by up to several millennia from one another[5–8] (Fig. 1). Significant variability in atmospheric radiocarbon content is also indicated by a recently produced data set[9]. Some of this variability is due to uncertainties in the dating of individual records, but features common to all records will include, for example, short-lived excursions in the Earth's magnetic field[8].

Atmospheric ^{14}C variability has not followed a simple, smooth pattern, as suggested by Mellars[1]. Instead, smoothing took place during the statistical analysis of these data sets to develop the NotCal04 mean best-fit line. By using the mid-point of the mean best-fit line, Mellars artificially improves the apparent precision of calibrated ages in his Fig. 3; even 'infinitely' old ages are reported with improved precision, whereas calibration almost invariably results in age ranges that are significantly larger than the radiocarbon measurement error[10].

We appreciate that Mellars' review was restricted to radiocarbon dating, principally of bone, but it is recommended practice that multiple methods and materials should be investigated to avoid any possible pitfalls that might be associated with a single technique or sample type. Several numerical-age methods are now available for the dating of bone[11], sediments and artefacts[12] that complement one another and add much-needed rigour to radiocarbon chronologies. We recommend that the accepted nomenclature for ages should be strictly followed to avoid confusion[13]: radiocarbon ages should be reported as 'BP', time before present (where 'present' is AD 1950); calibrated ages as 'cal. yr BP'; and ages from alternative dating methods in calendar years.

Inevitably, researchers will need to compare finds older than 26,000 cal. yr BP to other records measured on calendar timescales. When ages are 'calibrated', it must be specified which curve has been used. Meanwhile, radiocarbon ages should be reported in their uncorrected form for recalculation when an accepted calibration curve is developed.

Only by taking these considerations into account can we hope to develop robust models for human dispersal.

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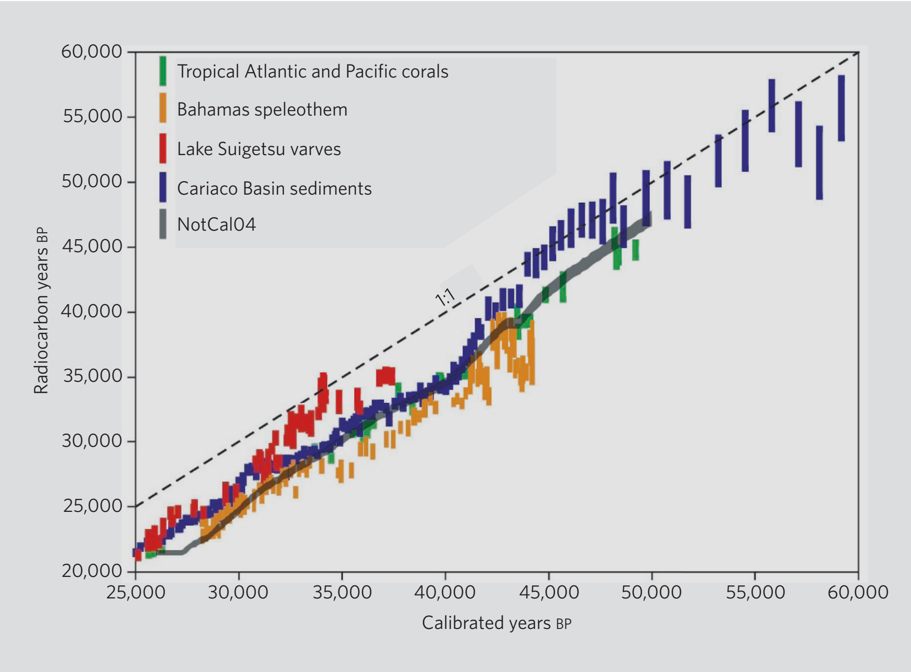

Figure 1 | Selected radiocarbon comparison curves for the period 25,000–60,000 calibrated years before present (BP). The graph shows the NotCal04 best-fit curve[4], and Cariaco Basin sediments[5], Lake Suigetsu varves[6], the Bahamas speleothem[7], and tropical Atlantic and Pacific corals[9] radiocarbon data sets. Age ranges at 1σ uncertainty (including those for the NotCal04 curve) are plotted only on the 'radiocarbon years BP' axis.

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Mellars replies

Replying to: C. S. M. Turney, R. G. Roberts & Z. Jacobs *Nature* 443, doi:10.1038/nature05214 (2006)

Turney *et al.*[1] offer a useful summary of their own observations on new developments in the dating of charcoal samples. There are, however, several errors or misunderstandings in their reading of my review[2].

I was careful to describe the NotCal04 calibration study[3] explicitly as a "best-estimation" curve (as the authors[3] also describe it). But, even if there were an accepted calibration curve for the period before 26,000 cal. yr BP (calibrated years before present), there are still problems with any 'authorized' calibration curve because these can soon become out of date. As I pointed out in the last sentence of my review[2], the implications of such studies for the interpretation of the human archaeological and evolutionary record need to be kept under active and vigilant review.

Contrary to the assertion by Turney *et al.*[1], I did not suggest that atmospheric ^{14}C variability has followed a simple, smooth pattern, but noted instead that the new calibration curves (from the Cariaco Basin, Atlantic and Pacific coral samples, the Socotra island speleothem, and so on) follow a "relatively" smooth pattern, "apparently" without any of the sudden and aberrant oscillations in the atmospheric ^{14}C content that had been claimed in some earlier studies. Important revisions[4,5] have now been made to the latest calibration curves for both the Bahamas speleothem record[6] and for the Cariaco Basin calibration curve[7], which now show significantly smaller deviations from other calibration curves[8] and render out of date the data plotted in Fig. 1 by Turney *et al.*[1]. If all these revisions[4,5] in the different calibration curves were incorporated into a new best-estimation curve, this curve would now be even tighter and would conform closely to the already published NotCal04 curve. I made a point of stressing[2] the potential impact of geomagnetic events, such as the Lake Mono and Laschamp excursions, for which the full impact on the terrestrial (as opposed to marine) radiocarbon records have still to be clearly elucidated.

I emphasized (Fig. 3 of ref. 2) that all radiocarbon dates (whether determined on bone or charcoal) should be regarded essentially as minimum figures, owing to the potential effects of contamination by recent, intrusive carbon. And I also made a point of presenting both the calibrated and uncalibrated versions of the dates I used. (If I had plotted dates only for charcoal samples that had been processed by newly developed methods, such as the ABOX technique, there would have been almost no dates to plot.) I did not claim to improve the precision of 'greater than' age estimates, although I noted that calibration increases the minimum age of such estimates.

The implications of regarding all of these dates as essentially minimum age estimates must be kept clearly in mind in any applications of ^{14}C dating to modern human dispersals, as I took pains to stress[2]. Even so, the very marked geographical patterns visible in my Fig. 3 of the combined, best-available charcoal and bone dates should not be dismissed, even by the most pessimistic critics of the present state of radiocarbon dating in prehistory.

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