# Dating sea level in caves

SIR—In their account of their dating of the calcite deposits (known as speleothem) from a cave in the Bahamas, Li *et al.*[1], refer in Table 1*b* to "equivalent samples" of the DWBAH speleothem. But inspection of Fig. 1 shows that some of the samples compared are not stratigraphically equivalent. For example, alpha-count-dated sample MB is coupled with mass-spectrometrically dated sample A1 in the table; yet, as is clear from Fig. 1, sample MB is at least twice as thick and contains younger material than sample A1. No wonder that it dates ~40 kyr younger than A1. Similarly, alpha-dated sample TT, which is coupled with mass-spectrometrically dated sample 18, contains flowstone stratigraphically older than in sample 18; and not surprisingly has a much older date. Where the mass-spectrometrically dated sample is from a stratigraphic interval near the middle of the thicker alpha-dated samples, comparable ages are obtained in two of three cases. The authors point out (Fig. 1 legend) that about ten times as much sample is needed for alpha-count as for mass-spectrometric dating. Nevertheless, a meaningful comparison of the alpha-count and mass-spectrometric ages requires samples from identical stratigraphic levels, a procedure not followed.

Li *et al.*[1] claim (their Fig. 3) that sea level was below about −12 m (the depth of speleothem DWBAH) between 135 and 215 kyr before present (BP), and that their record is generally "in agreement with the high-sea-stand chronology inferred from oxygen isotope stratigraphy of oceanic foraminiferal cores". Unfortunately, they fail to cite published evidence to the contrary. R. S. Harmon *et al.*[2] have used α-counting dates of submerged speleothem and emerged corals to show that sea level stood between the modern level and −6 m about 195–210 kyr ago. Moreover, the high stand shown in ref. 2 falls beneath the highest $\delta^{18}O$ peak of marine isotope stage 7 reproduced by Li *et al.* (their Fig. 3) at a time when they indicate sea level as below −12 m. Figure 6 of ref. 2 also shows a short-lived sea-level high (shallower than −7 m) at about 145–150 kyr BP, when Li *et al.* indicate that sea level stood below −12 m, and possibly[3] deeper than −40 m.

That sea level may have reached or exceeded modern levels by 145 kyr BP, in contradiction to the marine $\delta^{18}O$ chronology and to the data of ref. 1, is supported by other studies from the Bahamas, and from adjacent southern Florida. Alpha-count dating of corals and ooids from the Bahamas indicates that the sea-level history of this relatively stable platform is complex, with one or more high sea-level stands between 100 and 145 kyr BP[4,5]. For example, Neumann and Moore[4] dated two Bahamian corals at 146 ± 9 kyr BP and 140 ± 9 kyr BP; these corals were >95 per cent aragonite. And the Key Largo Limestone of south Florida was dated at 139 (+19/−14) kyr BP (an average taken from the data of 13 participating laboratories) during the first uranium-series intercomparison project[6]; the coral specimen used was 90 per cent aragonite. Recently, Szabo and Halley[7] obtained an age of 145 ± 10 kyr for the Key Largo Limestone using a coral containing >97 per cent aragonite.

Are we to assume that the dates in refs 2 and 4–7, indicating a high sea-level stand at around 140–150 kyr BP, are all 10–20 kyr too old? Or might there be an undetected hiatus in speleothem DWBAH between 145 and 165 kyr BP? No ages are provided by Li *et al.*[1] for this time interval, which corresponds to a 15 mm thickness of DWBAH (their Fig. 2). No other interval this thick is undated in DWBAH.

Speleothem DWBAH provides the authors with an excellent opportunity to address explicitly the decade-old debate of whether the last interglacial was marked by a single or a double rise in sea level, I urge them, therefore, to address these matters.

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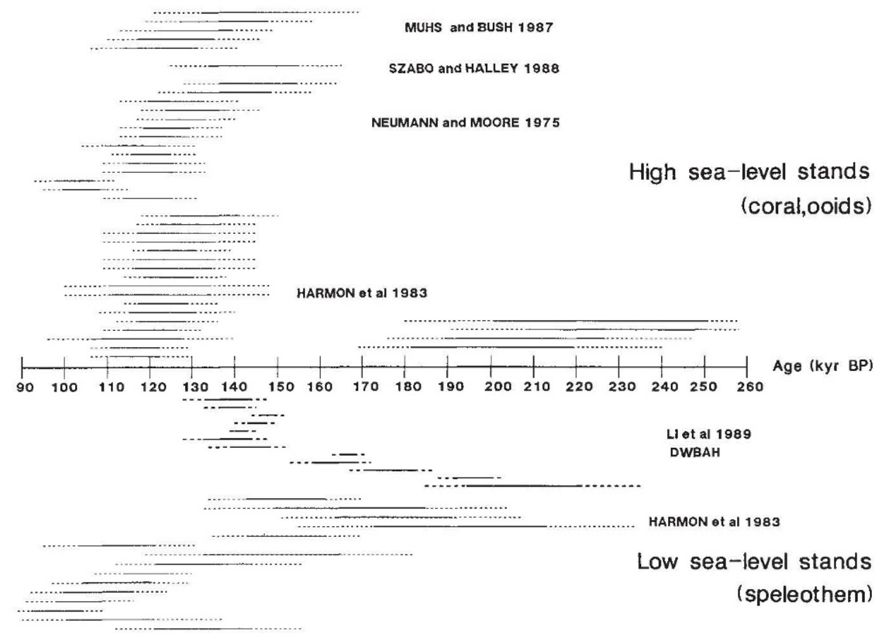
LUNDBERG *ET AL.* REPLY—Winograd is right in saying that the alpha-count and mass spectrometric dates in Table 1*b* are not directly comparable. They were not intended to be; they show the superior resolution obtainable by mass spectrometry in a time range where the resolution of alpha-count dates is poor (below Hiatus 1) and in pinpointing events (terminations). The alpha-count dates in question have high error because of low uranium contents (0.09 p.p.m. on average) and low yields (32–80% for U, and 8–65% for Th).

Winograd also questions the number and ages of high sea-level stands during isotope stages 7 and 5e. Although it is customary to quote α-counting dates with only 1σ error (the 68% confidence interval), there is a 32% probability that the true value is not in this range. If one looks instead at the 2σ errors (95% confidence interval), many apparent conflicts with the mass-spectrometry data disappear (see figure).




Dates on corals and ooids indicate high sea-level stands; those on drowned speleothem indicate low sea-level stands. ————, 1σ error; – – – – – –, 2σ error.

Harmon *et al.*[2] suggest that sea level rose to about +2 m between 210 and 190 kyr BP. In our DWBAH sample the first mass-spectrometric date after the stage 7a/7c recession (sample A1) is 237–186 kyr BP (2σ range). The equivalent stalagmite date in ref. 2 is 235–155 kyr (2σ range). Their four coral dates for the previous high sea-level stand range from 282 to 168 kyr; their coral and stalagmite dates overlap each other and both of the stage 7 hiatuses (1 and 2) resolved by mass spectrometry. Note that the date of isotope stage 7a itself has been only approximated (by orbital tuning), and that Chappell and Shackleton[8] modified their sea-level curve to fit this expected rise: their original (pre-tuned) dates at ~220 and 235 kyr BP coincide with hiatuses 2 and 1 (at around 220–212 and 235–230 kyr BP) from DWBAH.

The marine isotope record gives no reason to suspect a rise of sea level to modern heights at ~ 145 kyr BP, although