Forum

Uplift of Oahu, Hawaii, during the past 500 k.y. as recorded by elevated reef deposits: COMMENT

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McMurtry et al.'s (2010) uplift rate of 0.06 mm/yr (= m/ka) places marine isotope stage (MIS) 7 at +16 ± 2 m, MIS 9 at +23 m, and MIS 13 and 15 at +30 m, but their age data are flawed and lack supportive field and proxy evidence. The amplitude of eustatic sea levels (ESLs) during interglacials is highly variable (Lisiecki and Raymo, 2005) but of critical importance for modeling potential ice and ocean responses to anthropogenic warming. As many fine sea-level records are derived from tectonic coastlines, uplift rates based on detailed shoreline geology and accurate dating are essential.

QUALITY OF CORAL SAMPLES

Of five coral samples from +22.8 m at Ko Olina (GSA Data Repository 2010005, Table DR1 [McMurty et al., 2010]), four are described as "rounded coral clast, *Porites* sp."; the last is "*Porites brighami* coral fragment." Three Ko Olina samples contain 2.29% calcite; two have 7.94% and 12.0%. These five samples have thorium (Th) concentrations of 16.79, 23.59, 29.91, 4.66, and 2.00 ppb. Not only could such allochthonous cobbles have been emplaced by younger transgressions or tsunami any time after coral growth, but screening protocols (e.g., Mortlock et al., 2005) should exclude all Ko Olina and Lualualei ages as incontrovertibly unreliable due to excessive recrystallization and detrital Th >1–2 ppb.

LINEAR UPLIFT AND CORRELATION OF SHORELINES

To determine the position of past sea levels on uplifted coastline, it is required that at least one benchmark (e.g., elevation/age of MIS 5e) and its original ESL position (± a constant), imported from stable locations, are known. Lacking reliable ages and ESLs, it is not possible to determine accurate uplift rates. An r = 0.999 correlation of shore levels, without mention of several other sources of uncertainty, has little significance. Indeed, *linear* uplift on Oahu for 500 k.y. is improbable because it is the result of a nonlinear process of migrating forebulge "waves" generated by crustal loading at multiple volcanic centers over time. Moreover, $\delta^{18}O$ records exhibit a range of peak ESLs up to 35 m (assumed 0.11‰ = 10 m of sea level) between MIS 5e and MIS 15—projecting them by constant uplift onto a straight line is thus an unlikely product.

EXTRAPOLATED VERSUS ACTUAL INTERGLACIAL SEA LEVELS

MIS 5e

McMurtry et al.'s uplift rate of 0.06 mm/yr (= m/ka) is based on a MIS 5e level of +7.6 ± 2.0 m as the average elevation of two notches at +6.7 and +8.2 m (Ku et al., 1974, their reference 4). In contrast, Hearty et al. (2007, their figure 8) surveyed and dated broad reef terraces at Kahe and Makua Valley (west coast), and Mokapu (east coast) excluding island tilting and documenting an early, sustained position at +5 m (ca.127 ka). Subsequent erratic sea stands rapidly incised notches at and above +6.7 m. From the +5 m terrace on Oahu (minus an ESL of +2.5 m from stable platforms), Hearty (2002) calculated an uplift rate of ~0.020 m/ka (3× slower than McMurtry et al.), yielding a far different sea-level history when ESLs are factored in.

MIS 7

Sherman et al. (1999) defined MIS 7 sea level at −10 m to −24 m in west Oahu (not cited in McMurtry et al.). 57 stacked, $\delta^{18}O$ benthic records (Lisiecki and Raymo, 2005) yield compatible estimated ESLs from −10 to −20 m. Thus, the actual present position of MIS 7 on west Oahu is 20–30 m lower than the postulated levels at +12 (Waialae) and +17 m (Kahuku) of McMurtry et al.

MIS 9

McMurtry et al. argue that ages from recrystallized cobbles of unknown provenance, excessively enriched in Th, are sufficient to establish sea level for MIS 9. However, these data are unreliable. Hearty's (2002) uplift rate places MIS 9 at +9 m (not +23 m), given an ESL of +3 m at 300 ka.

MIS 11

McMurtry et al. (2010, p. 30) find "no physical evidence" for MIS 11, yet they offer neither reliable ages nor empirical field evidence to contradict Hearty's (2002) observed stratigraphic sequence showing the "stepping up" of sea levels from +5, to +13.5, and +28 m (Kaena Point and Waianae Health Center). When corrected with a small, nonlinear uplift rate (Hearty, 2002), the sequence is corroborated by parallel stratigraphic sequences from Bermuda, Bahamas, and elsewhere (see Hearty and Olson, 2008; Olson and Hearty, 2009). The matching physical stratigraphies are first-hand empirical data documenting sea-level changes during a middle-Pleistocene interglacial, preferentially correlated with MIS 11.

MIS 13 and 15

Like MIS 7, the ESLs indicated by the $\delta^{18}O$ record for MIS 13 and 15 are ~−15 to −20 m; to raise them to the Kaena level at +30 m, a rate nearly double that of McMurtry et al. is required.

CONCLUSIONS

Of the ages >130 ka discussed by McMurtry et al., none would be considered definitive of any interglacial. Altered coral cobbles, perhaps emplaced by tsunami, produce unreliable ages regardless of correlation or transformation. McMurtry et al. have disregarded relevant studies and used flawed data to derive a sea-level history that contradicts documented stable shoreline and deep-sea isotope sea-level records. Because MIS 11 was the longest (~30 k.y.) interglacial of the past 1 m.y., if it were absent, while at the same time deposits from the brief, lower-amplitude ESLs of MIS 7, 13, and 15 were elevated to high positions on Oahu as McMurtry et al. propose, this would constitute a true geological paradox. Unsupportable interpretations such as theirs should not become embedded in literature. Rather, the discussion of sea-level history and uplifted coastlines must be advanced by diligent fieldwork, the use of pristine, in-situ samples, and accurate age determinations.

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