Geology

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

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Notes

Forum

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Herein, we rebut Hearty's (2011) claims about our data and interpretations, which hopefully will help bring some clarity to the issue of Oahu's uplift over the past 500 k.y.

QUALITY OF CORAL SAMPLES

A plot of $^{230}Th/^{238}U$ versus $^{234}U/^{238}U$ showing the trend of ideal closed-system behavior over time is often used to evaluate the quality of U-series dates of coral samples. Reasonable dates fall within the 5% band of uncertainty in the initial seawater $^{234}U/^{238}U$ ratio at their respective times. Of the Kahe Point and older Ko Olina coral samples, only two of the five dates for each group fall above this band, suggesting some open-system behavior. Of these four samples, only one shows excessively high calcite of 12% and Th of 30 ppb. The rest contain <2.5% calcite and <5 ppb Th. Open-system corrections previously made for these dates reduce their apparent ages by a few thousand years for most samples reported in our Table DR1 in GSA Data Repository item 2010005.

We agree with the comment "such allochthonous cobbles may have been emplaced by younger transgressions or tsunami," and that possibility, plus the anomalously high elevations of these deposits, were used to reject them from our original linear regression analysis of reef uplift. Therefore, concerns about the poor quality of these dates, with which we disagree, are rendered moot.

LINEAR UPLIFT AND CORRELATIONS OF SHORELINES

The regression coefficient of $r = 0.999$ simply expresses that the mean or single ages of the coral samples from each elevated reef, and their maximum estimated elevations, are highly linearly correlated, which extends for over 500 k.y. This linear uplift for Oahu is no more improbable than the previously determined linear subsidence rates over the same period for islands southeast of Oahu (Campbell, 1986; Ludwig et al., 1991). Comments about "nonlinear processes of migrating forebulge 'waves' generated by crustal loading at multiple volcanic centers over time" have no reference to evaluate. Over the past 500 k.y., loading of the lithosphere beneath Hawaii has been mainly from the massive Hawaii Island volcanoes that abut each other, and have been modeled as a single point source (Watts and ten Brink, 1989).

EXTRAPOLATED VERSUS ACTUAL INTERGLACIAL SEA LEVELS

We are interested in the maximum elevation of each elevated reef, not other, lower stands of the sea. Therefore, we do not see the relevance of "an early, sustained position at +5 m at ca. 127 ka" for MIS 5 reefs measured by Hearty et al. (2007). Stearns (1978) measured the maximum height of the MIS 5 reef on Oahu from two wave-cut notches at +8.2 and +6.7 m asl, and used +7.6 m asl as the most representative maximum height found elsewhere amongst this extensive reef exposure, where the two notches were often not observed. Dismissing maximum reef elevations and using lower ones obviously leads to slower uplift rates, even without resort to dubious corrections based upon claims of eustatic sea level from "stable platforms" elsewhere, e.g., see commentary by Bowen (2010).

MIS 7

Sherman et al. (1999) found reef corals dated to MIS 7 at water depths of −10 m. Deeper reef corals at −13 m date to 280 ± 2 ka (MIS 8?), and those at −27 to −30 m date to 97 ± 6 and 83 ± 5 ka (MIS 5.3 and 5.1, respectively). The deeper coral reefs are not relevant to this Reply.

MIS 7 has been resolved into three main peaks of sea level lower than present: MIS 7.1, 7.3, and 7.5, separated by rapid drops in sea level (Dutton et al., 2009). The Sherman et al. (1999) coral dates for MIS 7 fit within these periods of lower sea level (MIS 7.4 and prior to MIS 7.5 peak), and in fact better fit the eustatic sea-level curve (Lisiecki and Raymo, 2005) when corrected for linear uplift. We were concerned with maximum interglacial reef positions, so inclusion of the Sherman et al. (1999) lower reef elevations was not considered relevant.

MIS 9

If the Ko Olina deposits result from storms or tsunami, as we previously suggested, then they would represent a maximum elevation for Stage 9 on Oahu. Stearns (1978) originally described these deposits as "bedded beach conglomerates." We suspect that the single coral date of 334 ± 17 ka (closed) from the nearby, extensive Lualualei reef at +21 m asl is correct, but the coral is altered, and yields an older, open-system date of 372 ± 17 ka.

MIS 11

We consider the uplift rates derived from the mostly undated stratigraphic sequence at Waianae Health Center (Hearty, 2002) to be circular. A more reliable approach would produce accurate dates of highstand reefs in situ at their apex elevations.

MIS 13 AND 15

Hearty ironically uses proxy data ($\delta^{18}O$ records) to argue for lower MIS 13–15 reef elevations. At present, corals dated from the Kaena Stand at +29–30 m asl on Oahu have mean ages from 468 to 547 ka (McMurtry et al., 2010). These ages have large analytical uncertainties, but appear to best coincide with MIS 13, and their measured elevations are consistent with linear uplift for Oahu, based upon the other elevated reefs there used in our analysis.

CONCLUSIONS

Hearty dismisses all U-series ages of corals >130 ka reported for Oahu as being definitive of any interglacial period, including his own TIMS data for the Kaena Stand (Hearty, 2002). Older U-series coral dates have larger uncertainties, because of the increased chance of exposure to weathering and open-system behavior over time. However, when plotted with means of coral dates <130 ka, most of these older dates continue to define a linear trend in age elevation. The rest of Hearty's conclusions are opinions, among them that MIS 11 should not be missing from the geologic record on Oahu, and suggesting a paradox if it is missing when other highstands of lesser duration are represented there. Beyond stating the obvious *Est quod est,* perhaps the best approach would indeed be "diligent fieldwork, the use of pristine, in-situ samples, and accurate age determinations." We agree with this ideal.

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