Radiocarbon profile of Hanauma Reef, Oahu, Hawaii: Discussion and reply

Discussion

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Easton and Olson (1976) have offered evidence to prove that the ocean at Hanauma Bay has not stood higher than at present during the past 7,000 yrs. They ignore an important outcrop of beachrock clinging to a basaltic dike on the east shore of the bay 5 to 8 ft (1.5 to 2.4 m) above sea level, coincidental with the elevation of the "2-m" bench so well developed around the east side of the bay and shown in their Figure 1.

Fossil coral from this beachrock outcrop has a C^{14} age of 3,485 ± 160 yr (Geochron Laboratory sample GX-2673; Stearns, 1974). Easton and I examined the outcrop together. The specimen taken as a sample for dating had been transported, but the 2-m bench is ubiquitous in Hawaii and the Pacific and cannot be omitted from their study. The 2-m bench and notches occur only in weak tuff and limestone in the Pacific and are believed to indicate only a short eustatic stand of the sea lasting about 1,000 yr and ending about 3,000 yr ago. There is no way the hard beachrock at Hanauma Bay could have been cemented at this level from storm-tossed sand and gravel, because it adheres to the face of the basaltic dike and shows bedding typical of a beach held at the 2-m level by a higher ocean.

The 2-m emerged reef at Midway Island described by me (Stearns, 1941) has been C^{14} dated at 2,420 ± 1,230 B.P. (Gross and others, 1969, p. 22). The Midway date was obtained from fossil corals in the position of growth and confirms that the ocean stood higher in the Hawaiian Islands 3,500 yr ago. A notch 5-ft (1.5 m) above mean sea level was found on Guam (Stearns, 1941, p. 779), and coral dated from this stand has a C^{14} age of 3,400 ± 250 yr (Tracey and others, 1964). In Japan, Fujii and Fuji (1967) found that the sea stood several metres above the present level from 6000 to 3000 B.P. To account for the decadence of the reef on Eniwetak, I proposed (Stearns, 1945) that sea level had dropped about 1 m in late Holocene time. Tracey and Ladd (1974) found a C^{14} age for emerged coral in situ on Eniwetak atoll of 2,200 to 3,300 yr. Buddemeier and others (1975) stated that rapid reef growth occurred in Eniwetak until 3,500 to 3,000 yr ago and that the ocean was significantly more than 1 m above present height from about 3500 to 2000 B.P. Curray and others (1970) found samples in the reef flat pavements in the Caroline and Marshall Islands which seem to indicate that sea level stood higher 3,200 to 3,700 yr ago. I described (Stearns, 1971) a wide, emerged fringing reef limestone 2 ft (0.6 m) above mean sea level on the island of Ewa in the Tongan group, which indicates a very late eustatic drop in sea level. The evidence is abundant that the Pacific stood higher about 3500 B.P. (Tracey, 1972). The level submerged shorelines of Pleistocene time on Oahu and Kauai do not support the suggestion of uplift of Oahu in Holocene time (Easton and Olson, 1976, p. 717).

Easton and Olson described a fine black volcanic ash underlying the reef in Hanauma Bay and suggested that it came from nearby Koko Crater, possibly about 7000 B.P.: however, the ash they described could not have come from Koko Crater, which is blanketed with a similarly textured ash. All vents producing such ash would be surrounded by cinders and spatter. All fine black volcanic ash is blown by the wind and deposited some distance from the vents. A black ash — known as the Black Point Ash (Stearns, 1966) — of similar age to that at Hanauma Bay and possibly from the same vent, mantles much of Black Point 6 mi. (9.6 km) west of Hanauma Bay. The location of the vent for the Black Point eruption, the last on Oahu, is unknown. It may have erupted offshore when the sea was lower.

Reply

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Stearns expresses views different than those presented by Easton and Olson (1976) on the interpretation and significance of an outcrop of beachrock at Hanauma Bay, the possibility of a former stand of sea level at about 2 m approximately 3000 B.P., and the origin of the black ash under Hanauma reef. Olson has agreed that this reply should be written by me.

The beachrock consists mostly of a veneer of coarse-grained calcarenite a few millimetres thick on the side of a basalt outcrop that lies across the Hanauma shore bench. The beachrock extends from 0.7 to 2.7 m above sea level. Crude bedding is indicated by parallel ridges dipping 5° landward. The beachrock is several centimetres thick in a few pockets near the base of the outcrop. Small fragments of coral and calcareous algae are embedded in the beachrock here and there. One of these was dated at 3,485 B.P. (Stearns, 1974). Stearns interprets this occurrence of beachrock and dated coral as proving a former high stand of sea level.

Field observations led me to develop an alternative explanation, which I think is more persuasive than the other. A re-entrant 2 or 3 m wide and about 5 m long has been eroded through the tuff of the shore on the north side of the basalt outcrop, and it terminates in a niche about 30 cm wide at the contact between the tuff and the basalt. Waves constantly rush into the re-entrant and impinge

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against its inner end and the niche with exceptional force. Spume, spray, and drenching splashes bathe the side of the basalt, carrying suspended sand and small fragments of reef debris. One can always pick up fragments of coral and algae on top of the basalt outcrop and in cracks and depressions on its flank.

This same locality is noteworthy for the remarkable rapidity with which calcium carbonate is precipitated. In April 1968, I first observed a mass of white, very fine-grained limestone essentially spanning the head of the niche. Fragments of reef debris were solidly entombed in the plasterlike matrix, and the neck of a brown bottle protruded from it. By June 1974, all of the original mass, together with the bottle and debris were gone, but in their place other fragments of glass and cobbles were firmly cemented in the niche and nearby cracks, although not completely entombed in matrix as before. It is apparent that calcium carbonate is precipitated and dissolved or abraded quite readily at the head of this surge channel. This being the case, calcium carbonate also could be precipitated higher up on the basalt outcrop, thus cementing sand and coral fragments that had lodged there.

Stearns states in his discussion that, "there is no way the hard beachrock at Hanauma Bay could have been cemented at this level from storm-tossed sand and gravel, because it adheres to the face of the basaltic dike and shows bedding typical of a beach held at the 2-m level by a higher ocean." His objection is overcome if one will accept the possibility that during the past 3,000 yr cracks may have existed near the margin of the basalt and that the dike has been exhumed from the tuff of the country rock. If debris had accumulated in these cracks and was cemented, it is visible now because of removal of part of the outcrop. Moreover, the suggested bedding resembles solution ridges as much as it resembles successive strata separated by bedding planes, such as one sees in typical beachrock.

An example of calcarenite occurs nearby that can be classified pseudo-beachrock. It bears on the subject at hand. The sea cliff above the Hanauma shore bench is cut by systems of joints along which the cliff collapses from time to time. As the joints open, calcareous sand grains may accumulate in the cracks and become cemented into a kind of limestone resembling beachrock in every physical aspect. In April 1968, Ralph Moberly and I observed this pseudo-beachrock a few millimetres thick encrusting joint planes on blocks of tuff that had fallen from the cliff recently. Corresponding encrustations were visible on the newly exposed face of the cliff at distances estimated to be from 5 to 10 m above the shore bench. This pseudo-beachrock surely was not a deposit laid down during a high stand of the ocean.

Finally, the transported coral fragment from which the radiocarbon date was obtained could have been derived from the present central area of Hanauma reef. Material about 3,000 yr old occurs in the upper 1 m of the reef (Easton and Olson, 1976, Fig. 3). Neither the occurrence of the beachrock nor the date of the transported coral are conclusive evidence for a former high stand of sea level. For this reason we included the sentence, "No samples of datable coral-algal material in growth position are found above present sea level on the shores of Hanauma Bay" (Easton and Olson, 1976, p. 717).

Stearns' second point relates to the widespread belief that sea level was about 2 m higher 3,000 yr ago than it is now. It is true that we stated in our conclusions that sea level was not higher then than now, but that statement should be read in context with the purpose and scope of the report. Our study was confined to the evidence gathered by an intensive study of one locality. We did not expand our remarks to cover any other part of the Pacific Ocean, and we intended our conclusions to be narrowly confined to the evidence at hand. On the basis of the evidence as we interpret it, Hanauma Bay should not be used as an example to support a former high stand of sea level. Furthermore, in my opinion the time has come for critical evaluation of the other examples that are cited as evidence for the high stand. The most that can be said for some examples is that they indicate a *relative* change of sea level. The basic problem that has to be solved is whether sea level changes are due to eustatic, tectonic, or combined causes. As of now, the underlying causes of relative changes that have been recognized remain generally unclear.

Stearns does not believe that the black ash that we discovered under Hanauma reef could have come from Koko Crater because there are no cinders or spatter around that vent. This is a strong point in support of his belief. He thinks that the fine ash may have come from a vent near Black Point, west of Koko Crater, that is no longer exposed.

The ash seems to be thickest near Koko Crater and in a band to the west, which would be downwind, given the present flow of the trade winds. In this I was in agreement with Wentworth (1926, p. 81), who, using the same evidence, concluded that the ash came from Koko Crater. In addition, I mapped ash in 1963 during the extensive site development of Hawaii Kai that seemed to be correlative with ash on the flanks of Koko Crater, under Hanauma reef, and in boreholes beneath Kaupa Pond. If these occurrences of ash all were derived from a vent somewhere close to Black Point, then the ash had to spread several kilometres in the probable upwind direction and for some reason fall most thickly in a pattern somewhat oblique to the usual patterns of wind circulation. Although some preliminary studies have been made of the geochemical and optical properties of ash from outcrops between Diamond Head and Koko Crater, the discrimination of the ash into separate falls has not yet been fully documented.

COMBINED REFERENCES CITED

Buddemeier, R. W., Smith, S. V., and Kinzie, R. A., 1975, Holocene windward reef-flat history, Eniwetok Atoll: Geol. Soc. America Bull., v. 86, p. 1581–1584.

Curray, J. R., Shepard, F. P., and Veeh, H. Y., 1970, Late Quaternary sea level studies in Micronesia: Carmasel Expedition: Geol. Soc. America Bull., v. 81, p. 1865–1880.

Easton, W. H., and Olson, E. A., 1976, Radiocarbon profile of Hanauma Reef, Oahu, Hawaii: Geol. Soc. America Bull., v. 87, p. 711–719.

Fujii, S., and Fuji, N., 1967, Postglacial sea level in Japanese islands: Jour. Geoscience, v. 10, p. 43–51.

Gross, M. G., Milliman, T. D., Tracey, J. I., Jr., and Ladd, H. S., 1969, Marine geology of Kure and Midway Atolls, Hawaii: A preliminary report: Pacific Sci., v. 23, p. 17–25.

Stearns, H. T., 1941, Shore benches on North Pacific islands: Geol. Soc. America Bull., v. 52, p. 773–780.

——1945, Decadent coral reef on Eniwetok Island, Marshall Group: Geol. Soc. America Bull., v. 56, p. 783–786.

——1966, Geology of the State of Hawaii: Palo Alto, Calif., Pacific Books, 266 p.

——1971, Geologic setting of an Eocene fossil deposit on Eua Island, Tonga: Geol. Soc. America Bull., v. 82, p. 2541–2552.

——1974, Submerged shorelines and shelves in the Hawaiian Islands and a revision of some of the eustatic emerged shorelines: Geol. Soc. America Bull., v. 85, p. 795–804.

Tracey, J. I., Jr., 1972, Holocene emergent reefs in the central Pacific: [abs.] Am. Quarternary Assoc., natl. conf., 2nd, p. 51–52.

Tracey, J. I., Jr., and Ladd, H. S., 1974, Quaternary history of Eniwetok and Bikini Atolls, Marshall Islands: Internat. Coral Reef Symp. 2nd, Great Barrier Reef Committee, Brisbane, Australia, Proc., p. 537–550.

Tracey, J. I., Jr., Schlanger, S. O., Stark, J. T., Doan, D. B., and May, H. G., 1964, General geology of Guam, Mariana Islands: U.S. Geol. Survey Prof. Paper 403A, p. A1–A104.

Wentworth, C. K., 1926, Pyroclastic geology of Oahu: Bernice P. Bishop Mus. Bull. 30, 121 p.

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