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A pulse of ooid formation in Maui Nui (Hawaiian Islands) during Termination I ☆

Paul J. Hearty [a,*], Jody M. Webster [b], David A. Clague [c], Darrell S. Kaufman [d], Jordon Bright [d], John Southon [e], Willem Renema [f]

[a] Department of Environmental Studies, University of North Carolina at Wilmington, Wilmington, NC 28403-5949, USA
[b] School of Geosciences, The University of Sydney, NSW 2006, Australia
[c] Monterey Bay Aquarium Research Institution, Moss Landing, CA 95039, USA
[d] School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ 86011-4099, USA
[e] Earth System Science Department, B321 Croul Hall, University of California, Irvine, CA 92697-3100, USA
[f] Nationaal Natuurhistorisch Museum, Leiden, The Netherlands

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ABSTRACT

We describe the first recorded occurrence of oolite in the main Hawaiian Islands. Well-cemented oolite was recovered at several locations at −140 to −150 m depth south of Lana'i. The ooids contain foraminiferal, skeletal, and peloidal nuclei, coated by thin to moderately thick (20–50% of ooid radius) tangential cortices, and are cemented by fibrous aragonite needles. The extent of amino acid racemization (AAR) analysed on 127 ooid grains and 55 pristine foraminifera in the same deposits confirm that the particles formed during a brief interval estimated at 1900 yr duration. A single, large benthic foraminiferan (*Amphisorus* sp.) intermixed with the ooid grains yielded a calibrated ^{14}C age of 12.2 ± 0.3 ka. In contrast, a series of progressive leaches on two splits of ooid grains yielded a sequence of ^{14}C ages ranging from ~27 ka for the nuclei to <15 ka from the outermost cortices, similar to recently reported results of deeply submerged ooids from the Great Barrier Reef (GBR), Australia. In contrast, a similar leach experiment using AAR showed no evidence for this 12,000-year range of apparent ages within the ooids. Based on modern analogues, individual ooids are unlikely to have formed continuously during 12 ka of deep submergence without leaving evidence of corrosion or bioerosion. At this time, we have no definitive explanation for the range ^{14}C leach ages, and further research is needed. However, assuming that the age of the ooids lies between the ^{14}C ages of the youngest cortex (14.9 ka) and the *Amphisorus* (12.2 ka), then eustatic sea-level history records suggest two intervals of slowing sea-level history rise that could accommodate ooid formation. These occurred immediately preceding MWP1A (~15 ka) and MWP1B (~12.5 ka). In the area of the oolite deposit, there is no terrace or hardground morphology that coincides with a −100 m sea stand preceding MWP1A. Thus, we suggest that conditions required for ooid formation converged when a flat carbonate hardground in the broad Au'au Channel was initially flooded with energetic shallow water as sea level rose to and slowed at −60 to −55 m during the onset of the Younger Dryas (YD) interval around 12.7 ka. Ooid formation ensued for a short period (~1900 yr) and then abruptly ceased; most reasonably as a result of a 7.5 m deepening of the sea during MWP1B around 11.5 ka. The oolitic sediments were subsequently transported longshore and offshore to southern Lana'i.

1. Introduction

Webster et al. (2006) recorded the first occurrence of fossil oolites from the main Hawaiian Islands. Oolites are extremely rare throughout the Pacific and Indian Oceans but emergent oolites of Quaternary age have been reported from Malden Island (Schlanger, 1987), Rodrigues Island (Braithwaite, 1994), northwestern Western Australia (WA) (Hearty et al., 2006), and Lizard Island in the GBR (Davies and Martin, 1976). There are several additional reports of ooids collected from submerged shelf locations on the Kōko Seamount (Eocene; Matter and Gardner, 2007), along the outer Bengal Shelf (Wiedicke et al., 1999), northwest WA shelf (James et al., 2004), at −123 m in the GBR (Marshall and Davies, 1975; Yokoyama et al., 2006). This limited number of Indo-Pacific sites may be explained in part by the high-relief volcanic land- and seascapes, with fringing and barrier marginal reef formation among tropical and subtropical islands. Further, the aggressive growth of the marine biota in tropical zones appears to rapidly colonize hardgrounds, inhibiting the growth parameters required for ooid formation.

1.1. Conditions requisite for ooid formation — relationship between ocean chemistry, sea level and substrate

Tangential ooids, which we investigate here, are characterized by concentrically layered crystals oriented tangential to the nucleus.

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* Corresponding author.
E-mail address: heartyp@uncw.edu (P.J. Hearty).

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They form in less than 3–5 m of agitated, normal marine water (Simone, 1981), and are generally composed of marine aragonite. Ooids in the fossil and modern records are well documented for the Persian Gulf (Loreau and Purser, 1973) and the Bahamas (Kindler and Hearty, 1996). “Bahamian ooids” generally form across broad, shallow, high-energy platforms, and in tidal passes (Ball, 1967; Hine, 1977; Kindler, 1995). Upwelling of deep, cool, $CaCO_3$-supersaturated water from adjacent deep margins promotes and sustains the precipitation of aragonite.

Certain physical constraints, related to the timing and elevation of sea level and antecedent topography are also imposed on the formation of ooids. To sustain ooid formation, shallow, agitated water (<3–5 m), supersaturated with $CaCO_3$, warming, degassing, and flowing over low-relief (carbonate) hardgrounds or platforms appear to be the most critical environmental factors (Dravis, 1979; Simone, 1981). If the elevation of a slowing of sea-level history event and terrace morphology are coincident for hundreds or a thousand years, and the essential energetic hydrological conditions are operative, then a significant volume of oolitic sediments may be produced. In contrast, if the rate of sea-level history rise is too rapid (5–20 m/ka; e.g., Hanebuth et al., 2000), as was experienced during several periods of the last deglaciation then sea level passed through the “critical zone” interacting with the low-angle platform too quickly, then abundant ooids do not form. At extreme rates of sea-level history rise, of up to 30–50 mm/yr (Fairbanks, 1989; Bard et al., 1996) the critical zone of ooid formation of 3–5 m water depth will be bypassed in less than 100 yr.

The goals of this study are: (1) to document a new occurrence (site, setting, microstructure) of late Pleistocene ooids in the Indo-Pacific, specifically Maui Nui (Molokai, Lana'i, Maui, and Kahoolawe; Figs. 1 and 2); (2) to compare geochronological information from radiocarbon and amino acid analyses; and (3) to explore the origin, age, and environmental conditions (sea-level history position, terraces or hardground morphology, oceanography, etc.) leading to ooid formation, within the uncertainties of the available geochronology. There is no attempt to reconstruct deglacial sea-level history, but instead focus on the most likely position of sea level at the time of ooid formation.

2. Materials and methods

2.1. Chronostratigraphic setting of samples and previously published work

Oolite was collected 3.5 km from the southern coast of Lana'i using the ROV *Tiburon* at the southern opening of Au'au Channel (Fig. 2). The oolite was recovered from a 20- to 30-cm-thick, moderately sorted grainstone deposit exposed at several sites between −142 and −150 m (see Fig. 3 and Fig. 9A/B in Webster et al., 2006). Video and still images show that the deposit forms a 2- to 3-m-wide pavement that overlies and fills crevices in an *in situ* coralgal nodule deposit.

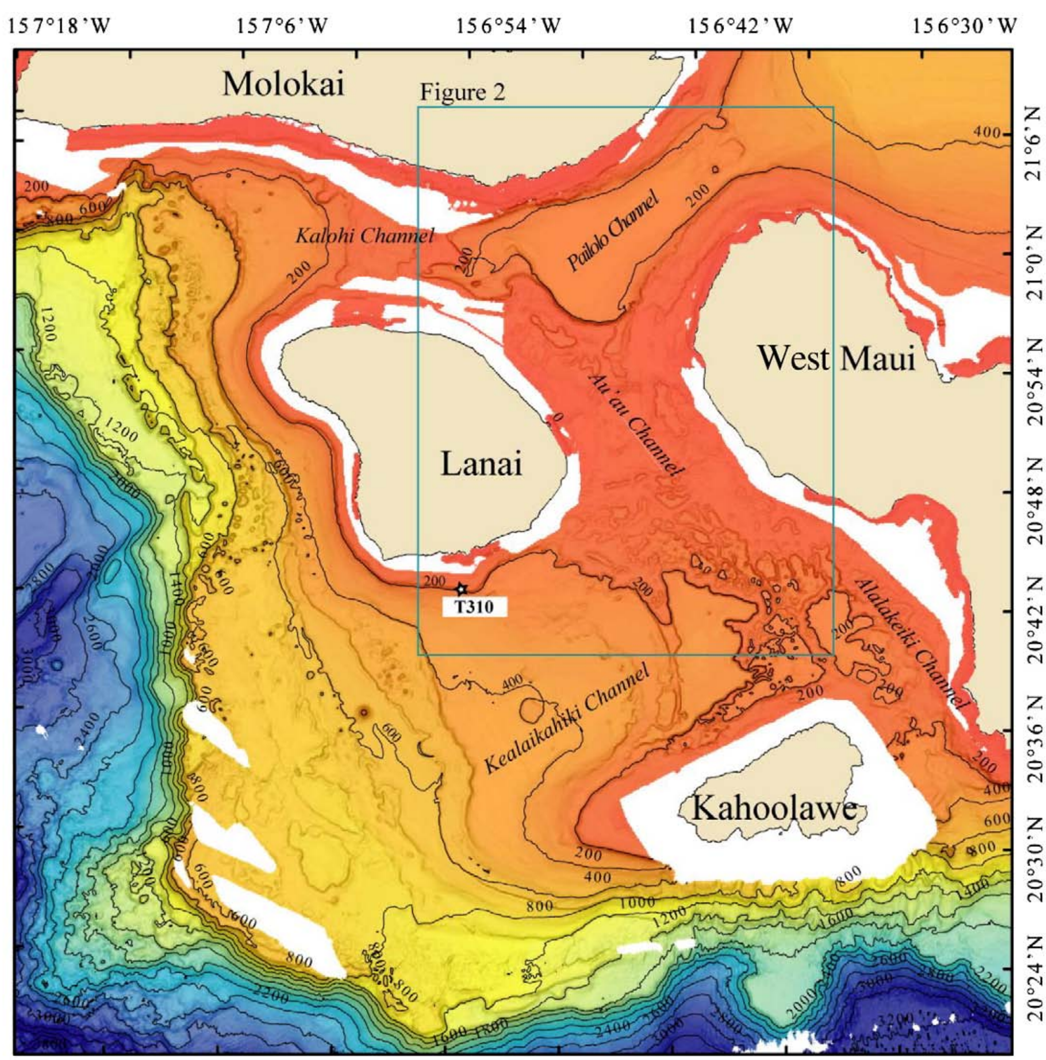

Fig. 1. Map of Maui Nui showing the regional bathymetry and collection site during dive T310 on the southern coast of Lana'i, and the study area in Au'au Channel.