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THE GEOLOGY OF THE SUBMERGED REEFS IN THE MAUI-NUI COMPLEX, HAWAII

Thesis submitted by

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B.App.Sci M.App.Sci.

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For the degree of Doctor of Philosophy

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James Cook University

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STATEMENT OF CONTENT

The body of this thesis is presented as three separate, self-contained works, each of which have been submitted to journals of international significance in similar format. Due to the completeness of each section, a small amount of repetition is unavoidable. These three chapters are followed by a discussion of the findings of the research that places this work in reference to both the research aims outlined in the introduction, and its place in the broader scheme of the scientific body of knowledge.

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ABSTRACT

The volcanic islands of the Maui-Nui Complex (MNC) in Hawaii; Maui, Molokai, Lanai and Kahoolawe, are dated as forming throughout the Quaternary (~2.0 – 0.2 Ma). The tropical location of these islands has lead to their flanks providing a substrate for reef growth throughout this period. During the Late Pleistocene (700 – 0 ka), coralgal reefs have developed in response to large (up to 120+ m) eustatic sealevel fluctuations characterised by 100 ka cyclicity. In contrast, reefs growing during the Early Pleistocene (1.5 – 0.9 Ma) were subjected to eustatic sealevel variations on shorter ~ 41 kyr cycles with amplitudes of ~ 60 – 70 m. The period of transition between these two states is known as the Mid-Pleistocene Transition (MPT). Combined with this change in dominant sealevel amplitude and cyclicity, the MNC has experienced a slowing in rate of subsidence as the lithosphere has responded to the volcanic loading of both the MNC and the big island of Hawaii. As the mass of the seven volcanoes of the big island of Hawaii has grown, the plate has flexed in a forebulge of uplift surrounding the big island. Lithospheric modelling suggests that this zone of maximum uplift is currently situated between Oahu and the MNC.

The offshore regions of the MNC in Hawaii comprise 89 separate submerged terraces, most of which are drowned reefs that have developed over the past 2 MA. These reefs represent a unique archive of both reef development throughout the entire Quaternary and lithospheric plate response to an oceanic hotspot. This library has been analysed for changes in reef development across the MPT and examined to quantitatively constrain the magnitude and attitude of the plate's tilting.

High resolution multibeam bathymetry and backscatter data together with field observations from ROV and submersible dives and sedimentological and chronological analysis of reef samples provide evidence of a distinct change in reef development throughout the Pleistocene. Within the south-central region of the complex (the area of best reef development) the morphology of the reefs varies both geographically and temporally. The deeper, pre-MPT reefs exhibit barrier reef and pinnacle features on the substrate steepened by the Clarke Debris Avalanche, and thick in-situ coral reef faces on the non-steepened margins of the complex. One quantifiable measure of a reef's morphology, the Rim-Index, has been used as a measure of an active reef crest with abundant accommodation space, and shows the deeper terraces of the MNC as having active reef crests with high Rim-Indices. These morphological characteristics are supported by the sedimentological data that show dominance in shallow water coral reef facies within the deeper, pre-MPT reefs.

The shallower younger reefs of the MNC display very different morphological and sedimentological characteristics to the deeper reefs. These post-MPT reefs exhibit low Rim-Indices, broad terrace back-stepping and low relief, in contrast to the deeper reefs. Sedimentological data from samples of the post-MPT reefs are dominated by deep-water coralline algae. Additionally, the channels between the islands of the MNC also exhibit closely spaced reef and karst morphologies that indicate repeated subaerial exposure.

Collectively, these morphological and sedimentological data show that reef development has changed throughout the Pleistocene within the MNC. These data suggest that this variation in the morphology, structure and composition of the reefs within the MNC has been controlled by three main factors; the subsidence rate of the complex, the amplitude and period of eustatic sealevel cycles, and the slope and continuity of the basement substrate. The growth of stratigraphically thick coral reef units on the deep pre-MPT reefs was due to rapid subsidence of the substrate and shorter, smaller amplitude sealevel cycles allowing re-occupation and coral growth on successive low-stand phases of the sea level cycles. The dominance of deep water coralline algae growth on the reefs of the Late Pleistocene is consistent with the near vertical stability and longer, larger amplitude sealevel oscillations made during this time frame.

Data analysed during this study confirm that accommodation space is critical to the continual coral reef growth and emphasise how integral the subsidence rate of the MNC has been to reef development within the complex. The regional subsidence rate is controlled by lithospheric plate response to volcanic loading at the hotspot. The high resolution multibeam bathymetry data used in this study show significant discontinuities in terrace morphology or depth, that define the edges of regions which age data indicates were initiated at different times. The tilting data of these regions show that they also responded to lithospheric flexure independently. The shallowest identified terraces in the Oahu and Molokai regions tilt towards the north, away from the current zone of maximum subsidence, indicating that these regions have recently passed the zone of maximum uplift. These last data differentiates between two different numerical modelling studies.

By examining the reefs of the MNC, this study not only details factors controlling coral reef development throughout the different climate and sealevel states of the Quaternary, but also provides new constraints on the lithospheric plate response at an oceanic hotspot. This study provides new empirical data that can contribute to further dynamic modelling efforts aimed at understanding plate behaviour in this setting and possible other locations.

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