EARLY DIAGENESIS IN A CORAL REEF FRAMEWORK

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

OCEANOGRAPHY

AUGUST 1990

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ABSTRACT

Nearshore marine systems are of interest because of their role in controlling the transfer of materials from the land to open ocean. From a human perspective, they are important areas for fisheries, recreation and waste disposal. In much of the tropical ocean, coral reefs form a significant component of the nearshore environment. In order to evaluate both anthropogenic impacts and natural perturbations on coral reef systems, it is necessary to understand how materials are delivered, processed, and transported. This study is the first in-depth investigation of biogeochemical activity within the framework of a coral reef. The goals of this dissertation were to: 1) determine the nature and extent of reactions within the framework of a coral reef; 2) clarify the relationship between organic diagenesis and carbonate mineral saturation state; 3) measure the rate of hydrologic exchange between the framework and surrounding surface seawater; and 4) evaluate the significance of reactions within the framework to the reef system as a whole.

A patch reef in Kaneohe Bay, Oahu, Hawaii, (Checker Reef) was chosen as a study site. A series of wells extending to depths of 1, 2 and 4 m was established along a windward to leeward transect. The chemistry of the interstitial waters of Checker Reef is strongly affected by the oxidation of organic material within the reef framework. Oxygen is nearly completely consumed in all wells, indicating that oxic respiration occurs relatively quickly. Although both nitrate reduction and methanogenesis contribute to anaerobic metabolism, sulfate reduction is the predominant

anaerobic pathway. Nutrient ratios suggest that the organic material undergoing oxidation has both a benthic and planktonic origin.

A simulation model was developed to evaluate the effect of organic diagenesis on the saturation state of the calcium carbonate mineral aragonite. The saturation state of seawater with respect to aragonite dropped quickly in response to the input of CO_2 during oxic respiration. After oxygen depletion, sulfate reduction continued to lower the saturation state below 1.0. As sulfate reduction continued, the saturation state started to rise and eventually become oversaturated with respect to aragonite. Oxidation of organic material with a larger C:N ratio caused the system to be more corrosive. In contrast, precipitation of metabolically produced sulfide created an environment more likely to be oversaturated. Waters from the Checker Reef framework were close to aragonite saturation. It appeared that solid phase reactions were involved in maintaining the system at saturation. In summary, the effect of organic oxidation on the saturation state of aragonite is dependent on: 1) the amount of oxidation occurring; 2) the C:N ratio of the material undergoing oxidation; and 3) the extent to which sulfide forms a iron mineral phase.

Two naturally occurring chemical tracers were used to measure the rate of exchange between surface seawater and framework waters. Dissolved radon, released from the decay of particle-bound radium, was substantially more concentrated in framework waters than in surface water. The degree of radon enrichment was quantitatively related to the time that reef framework water had been removed from atmospheric contact. Residence times were 1-40 days, with deeper wells having slower exchange. The average residence time for wells at 1 m was 1.7 days. A storm induced

dilution in the salinity of Kaneohe Bay was the second tracer. Modeling the recovery of surface and framework waters from this salinity perturbation yielded an average residence time of 2.6 days at a depth of 1 m.

Three types of physical forces thought to cause mixing were examined. High frequency pumping by surface gravity waves caused water to exchange with a residence time of 4.8 days. Tidal pumping did not appear to contribute to exchange. Semi-stable pressure gradients caused mixing to occur on a time scale of 1-30 days, with faster exchange at 1 m. The combined effect of wave pumping and semi-stable pressure gradients resulted in an average residence time of 1.9 days.

All three methods for determining residence time were completely independent. All indicated that exchange in the upper framework of Checker Reef was primarily through vertical mixing. The best estimate for the residence time of water at a depth of 1 m is 2.1 days.

Material fluxes were calculated by combining the measured chemical composition of framework waters and the residence time determinations into a simple linear mixing model. It appears that organic respiration in the upper meter of the reef framework consumes an amount of organic carbon approximately equal to 25% of the gross carbon production of a typical reef flat. Rates of denitrification, oxic respiration and sulfate reduction are similar to measurements made in coral reef sediments.