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MODERN MARINE DOLOMITE CEMENT IN A NORTH JAMAICAN FRINGING REEF: CONTINUED STUDIES

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ABSTRACT

Ordered dolomite of Holocene age, which we believe has precipitated from near-normal seawater, is widespread in the fore-reef hardground at Discovery Bay, Jamaica (Mitchell et al. 1987. Geology 15:557-560). In the present study, eleven vertical cores as long as 137 cm were drilled into the hardground in water depths between 5 and 11 m, spanning a 7 km distance laterally along the shoreline on both sides of the bay. All contain dolomite which occurs primarily as isopachous syntaxial pore-lining cement, constituting no more than 1% of the whole rock volume. Extensive dissolution of both aragonite and Mg-calcite is present in many of the coral-algal boundstones. Water flows forcefully into most of the open core holes at all ranges of the tide and at times of no wave activity. Water which exhales from a few of the shallowest wells was analyzed during the winter wet season, immediately after 26 mm of local rain. Concentrations of all major components indicate at most 2% departure from normal surface seawater values, suggesting unmodified seawater to be the agent of dolomitization. The observed water flow patterns cannot logically be explained by tidal pumping, wave pumping, or meteoric discharge, based on available data.

INTRODUCTION

Unmodified marine water has conventionally not been thought to be responsible for precipitating dolomite in shallow, warm subtidal environments. Considering that seawater is approximately 20 times supersaturated with respect to dolomite (Bathurst 1975), and that ample time exists for dolomitization to take place, why are extensive quantities of dolomite not formed as a shallow normal-marine precipitate? Although the dolomite present in the hardground at Discovery Bay is admittedly not volumetrically abundant, it is significant as it seems to be derived by direct precipitation from modern marine water. Other examples of subtidal Holocene dolomite precipitation rely on heat-sourced convective cells circulating deep, cold marine dolomitizing fluids through carbonate sediments (Saller 1984), restricted hypersaline environments (Behrens & Land 1972), and tidal pumping of marine water through carbonate sediments (Carballo et al. 1987) as mechanisms of dolomitization.

Using a submersible coring drill, we penetrated the exposed hardground at Discovery Bay, located on the north coast of Jamaica. The entire northeast coastline was subjected to the wrath of Hurricane Allen in 1980, during which the diversely populated, shallow fringing reef was destroyed and the sediment that previously covered the fore-reef hardground was swept away (Woodley et al. 1981), baring the nearly featureless hardground surface. The eleven 75 mm diameter cores up to 137 cm in length were drilled in water depths ranging from 5 m to 11 m, both east and west of Discovery Bay. Historically, submarine coring operations have been less than optimally productive in terms of core recovery. In this study, a 12-horsepower surface hydraulic power supply turned a diver-operated submersible drill of custom design (courtesy Dr. Fred Taylor, Institute for Geophysics, University of Texas at Austin). Core recoveries averaged 80%, using 75 mm diameter thin-wall diamond bits designed for coring concrete. Maximum possible penetration with the bits used was just under 140 cm, but modifications to the drill will allow increased depth of investigation during the upcoming field season.

The cores obtained range from extremely well lithified to very friable and rubbly coral-algal boundstones. These exhibit a wide variety of megascopic features, including peloidal crusts and "mud drapes" which are also abundant in the onshore, Pleistocene (dolomitized) Hope Gate formation (Land 1973). For documentation of the microscopic cement varieties of the hardground observed in this study as well as previous studies, the reader is referred to Mitchell (1988). Only a brief summary of the textural observations will be presented here. Mg-calcite cement is more abundant than aragonite cement, calcite cement has not been identified, and very irregular patterns of pore-filling cements were observed; i.e. some coral pores are filled (partially or completely) by only aragonite, some by only Mg-calcite, some by internal sediment, and some by a combination of fabrics.

The cores were washed, dried in the sun, and slabbed. To date, samples have been analyzed using binocular and petrographic microscopes, x-ray diffractometer (XRD), scanning electron microscope (SEM), and electron microprobe.

HOLOCENE DOLOMITE

Calcian dolomite ($Ca_{1.22}Mg_{0.78}(CO_3)_2$) in peloidal pore-filling mud in skeletal cavities of corals was discovered by Mitchell et al. (1987) in hand samples taken near the seawater-sediment interface from both walls of an artificially deepened ship channel passing through the reef at Discovery Bay. Electron microprobe analyses have documented dolomite in all eleven cores of this study, indicating that the dolomite is not restricted to the pass through the reef. Petrographic, SEM, XRD, and electron microprobe analyses of the cores, together with data from transmission electron microscopic analysis of Mitchell's study, indicate that dolomite is indeed a Holocene feature, and confirm its syntaxial relationship to underlying

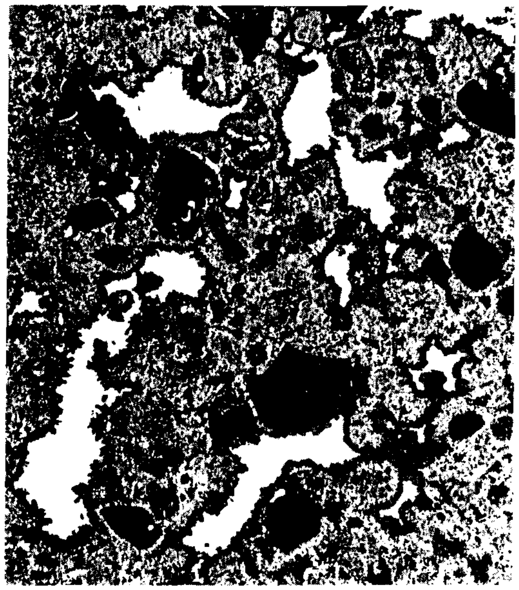

Figure 1. Backscattered electron image showing isopachous dolomite lining epoxy-filled pores which are white in this inverted image. Because of signal inversion, coral fragments are darkest. Long dimension is ~285μ.

Figure 2. Backscattered electron image showing rhombic dolomite filling primary intergranular pore space. Some rhombs (arrow) are zoned. Considerable dissolution within the Mg-calcite micrite is evident (now filled with epoxy - black), and some dolomite may be precipitating in these "secondary" pores. Long dimension is ~75μ.

Figure 3. Skeletal pores in this coral fragment are partly filled with peloidal micrite and isopachous marine cements. The coral skeleton is being dissolved, and the secondary pores are now filled with elogate casts of epoxy (dark in this plane light micrograph). Long dimension is 1 mm.

Figure 4. Fluorescein dye from the syringe at upper left streams into one of the open holes (lowermost right), demonstrating the active hydrologic system of the hardground.

substrates, documenting the dolomite as a primary shallow-water marine precipitate.

Backscattered electron (BSE) imaging of epoxy-impregnated, polished thin sections shows varying shades of gray corresponding to substances of different atomic numbers (Figs. 1 and 2); the higher the atomic number, the brighter the image. Aragonite generates the brightest image and epoxy the darkest (Figure 1 is a reverse image). Mg-calcite and dolomite are intermediate in backscattered intensity, and Mg-composition can be measured directly on crystals greater than 10μ in diameter by wavelength dispersive x-ray analysis.

Calcian dolomite in the cores occurs in several modes. The most spectacular is euhedral rhombs lining both inner and other skeletal pore walls (mainly forams and red algae) as syntaxial isopachous cement. Maximum size of each of the crystals comprising the one-crystal-deep layer of euhedral rhombs is 5μ. The dolomite of this variety is localized, such that within a single field of view of approximately 360x it may constitute up to 10% of that volume (Fig. 1). However, dolomite is estimated to constitute at most 1% of the whole rock.

Areas of Mg-calcite mud, both as interparticle matrix and intraparticle pore-fill, host dolomite of several morphologies. Individual peloids in pore-filling mud are sometimes encased by isopachous 5μ rhombs. Diffuse clouds of submicron-size dolomite are present in some areas of very dense Mg-calcite mud, although quite sparsely. Even more rare are "giant" (as large as 24μ diameter) dolomite euhedra suspended within the dense Mg-calcite mud. Faint zonation in the euhedral dolomite is marked by alternating bands of lighter and darker gray (faintly visible in Fig. 2).

DISSOLUTION FEATURES AND HYDROLOGY

Cores showing evidence of dissolution of aragonite and Mg-calcite are randomly located throughout the study area. Halimeda and red algae fragments seem to be most readily attacked, and obvious coral dissolution (Fig. 3) is present in several samples. This is probably due to the more robust nature of the coral grains, as opposed to the high surface area structure of the other allochems. Fibrous aragonite and Mg-calcite scalenohedral pore-lining cement crystals have also undergone dissolution, however less extensively.

The extent of dissolution of allochems is apparently not directly related to the degree of encasing cements present (micrite or Mg-calcite), as examples of locally extensive Mg-calcite envelopes directly adjacent to dissolved red algae fragments were observed. In other areas, the fragments most attacked by dissolution were exposed in cement-free regions.

Because dolomite is present in all cores, and dissolution is variable but also present in all cores, at this time no obvious correlation can be made between dolomitizing fluids and destructively interactive fluids with respect to depth below the hardground surface, geography, or degree of marine cementation. The possible explanations for causes of the dissolution have not yet been thoroughly explored. Proximity of each specific core to meteoric water boiling up through fractures and natural permeability tracts in the hardground may prove to be plausible.

The lithology which comprises the hardground is, by nature, very porous and sometimes quite permeable. Fresh water schlieren are present in several places in the back-reef lagoon near the Discovery Bay Marine Laboratory, and have been noted by J.D. Woodley (pers. comm.) on the deep fore-reef at one location at 50 m depth. However, measured chloride, alkalinity, and pH values (in Jamaica), and sodium, calcium, magnesium, strontium, and sulfur concentrations (by ICP-AES in Austin) of samples taken during the winter wet season the day following a local rain of 26 mm, documented at most a 2% meteoric water component in the wells. In contrast, Pigott & Land (1986) found chlorinities as low as 12.3‰ 65 cm below the reef-water interface at one locality.

Strikingly forceful flow of water into the majority of the drill holes was observed at all ranges of the tides and during "glassy calm" conditions in the early morning when wave action is nonexistent. As wind-driven waves build up during the day, active flow occurs throughout both the landward and seaward surges of the waves, with inflow dominating outflow, primarily on the landward surge. A few of the shallowest holes persistently exhale water (samples for chemical analyses were from these wells). In order to document the flow of seawater in and out of the drill holes, fluorescein dye was released from a syringe at the orifice of the holes and photographed (Fig. 4). Flow meters to measure net movement of water will provide more information on the specifics of this hydrological phenomenon during 1988 field work.

We conclude, on the basis of current data, that the dolomite present in the fore-reef hardground at Discovery Bay, Jamaica, is extensive and is not necessarily a product of a mixing zone of meteoric and marine waters; rather, it may have precipitated from unmodified seawater.

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