ported northward by longshore currents (*13*) or landward by currents within the tidal wedge (*15, 16*). It is difficult to estimate the quantity of frustules deposited along the northern coast since they are effectively masked by the large terrigenous load accumulating in these nearshore areas (*13*). However, a large portion of the frustules apparently is transported landward into the estuary: marine diatoms are common in the lower reaches of the Amazon River (*15*), and banks and bars off Marajo Island contain prominent dunes and interbedded layers of diatomite (*17*). If similar processes occur in other major estuaries, the actual amount of dissolved silica reaching the ocean may be considerably less than previously estimated.

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6. Biological uptake of silica reported in the Scheldt estuary [R. Wollast and F. de Broeu, *Geochim. Cosmochim. Acta* **35**, 613 (1971)] may have actually been dilution by silica-poor coastal waters (*3*). More recently, silica uptake by diatoms in San Francisco Bay has been reported [T. J. Conomos and D. H. Peterson, *Mem. Inst. Geol. Bassin Aquitaine* **7**, 45 (1974)].
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9. Surface water samples were collected with plastic buckets and through tubing attached to a towed weight. Salinities were measured with an optical refractometer, accuracies being ± 0.3 per mil. Dissolved silica measurements were made by the method of J. D. Mullin and J. P. Riley [*Anal. Chim. Acta* **12**, 162 (1955)], using a salt correction factor, to an estimated precision of ± 3 percent. The scatter in the data plotted against salinity (Fig. 2A) is partly related to real variations within the estuary. Suspended matter samples were obtained by filtering seawater through paired, preweighed Millipore filters having nominal openings of 0.45 μm. Total and combustible concentrations were determined by standard methods [F. T. Manheim, R. H. Meade, G. C. Bond, *Science* **167**, 371 (1970)]. A portion of each filter was mounted on a glass slide and the quantity of terrigenous and noncombustible matter was estimated optically.
10. The Brazilian Directoria de Hidrografia e Navegação (personal communication) also reports two distinct areas of shoaling, just seaward of the Amazon River mouth and on the innermost shelf.
11. The rapid deposition of fine-grained particles at salinities lower than 3 per mil agrees with salt-flocculation experiments [for example, see U. G. Whitehouse, L. M. Jeffrey, J. D. Debbrecht, in *Proceedings of the 7th Conference on Clays and Clay Minerals*, A. Swineford, Ed. (Pergamon, New York, 1960), vol. 1] but available field data are inconclusive as to whether salt flocculation or organic agglomeration controls estuarine deposition of fluvial suspended sediments [R. H. Meade, *Geol. Soc. Am. Mem. 133* (1972), p. 91].
12. The paucity of samples precludes accurate calculation of diatom concentrations between 4 and 8 per mil, although in February 1973 diatom populations reached 4.5 mg/liter at 6 per mil (*7*).
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Skeletal Low-Magnesium Calcite in Living Scleractinian Corals

Abstract. *The skeletons of living specimens of the scleractinian coral* Porites lobata *have been found to contain up to 46 ± 5 percent low-magnesium calcite even though free of gross detrital inclusions and boring or encrusting organisms. The calcite crystals occur in the interior of skeletal structures, have dimensions of 20 micrometers or less, and are surrounded by typical aragonite needles. Biogenic deposition seems to be the most likely source of the calcite, although the evidence does not rule out diagenesis of metastable aragonite on a time scale of months.*

The mineralogy and elemental composition of carbonate skeletons deposited by scleractinian corals have been examined by many workers (*1, 2*). Aragonite has been the only primary skeletal mineral thus far reported.

The diagenesis of metastable aragonite to low-magnesium calcite has also received much attention (*2, 3*). The results of these investigations show that under normal conditions in seawater the recrystallization is extremely slow, and skeletal aragonites of Pleistocene and older ages are not uncommon. We report here the discovery of skeletal low-magnesium calcite in living scleractinian corals.

Table 1. Age, percentage of calcite, and magnesium/calcium ratio in samples from two coral specimens (see Figs. 1 and 2); NA, no analysis.

Sample	Estimated age (years)	Mg/Ca atom ratio (× 10^3) (± 8%)	Percentage of calcite (± 5%)
C1-1	0.3	NA	20
C1-2	0.7	4.3	17
C1-3	1.2	4.8	18
C1-4	1.8	4.2	22
C1-5	2.2	5.0	22
C1-6	2.8	5.1	27
C1-7	3.2	5.5	35
C1-8	3.8	5.5	39
C1-9	4.3	6.2	23
C1-10	4.8	6.2	46
C1-11	5.2	5.6	37
C1-12	5.8	4.8	26
C1-13	6.1	4.5	26
C1-14	6.3	3.6	6
C3-1	1.6	*	33
C3-2	4.8	*	26
C3-3	6.3	*	3
C3-4	?	†	4

*Calcite fraction Mg/Ca, $< 4 \times 10^{-2}$; no bulk analysis. †Calcite fraction Mg/Ca, 16×10^{-2}; no bulk analysis.

The primary study specimens were colonies of *Porites lobata* collected live from Waikiki reef off leeward Oahu, approximately 300 m offshore in 3 to 4 m of water. A variety of other archive specimens collected from various locations in the Pacific over the past 3 years were also surveyed.

X-radiography of slabs cut parallel to the axis of growth showed the usual seasonal density bands (*4*). Samples were taken from known locations in the alternating high- and low-density growth bands, from which the time of deposition of the carbonate could be estimated (see Fig. 1).

We carried out x-ray diffraction studies with an x-ray diffractometer (Norelco), using copper Kα radiation. All major aragonite and calcite peaks with *d*-values between 1.54 and 4.44 Å were identified. Samples were prepared, ground, and mounted by a variety of techniques (*5*), and control samples of known mineralogy were included in the study in order to eliminate the possibility of procedural artifacts. We calculated the percentage composition using the aragonite peaks with *d*-values of 3.27 and 3.40 Å and the calcite peak with a *d*-value of 3.03 Å. The calculated percentages agree with published calibrations (*6*).

Elemental analysis for strontium, calcium, and magnesium was carried out with an atomic absorption spectrophotometer (Perkin-Elmer model 303). In addition, the magnesium concentration in the calcite phase was estimated from the shift in the *d*-value of calcite parallel to its major cleavage (*7*).

Fresh, untreated fracture surfaces of the

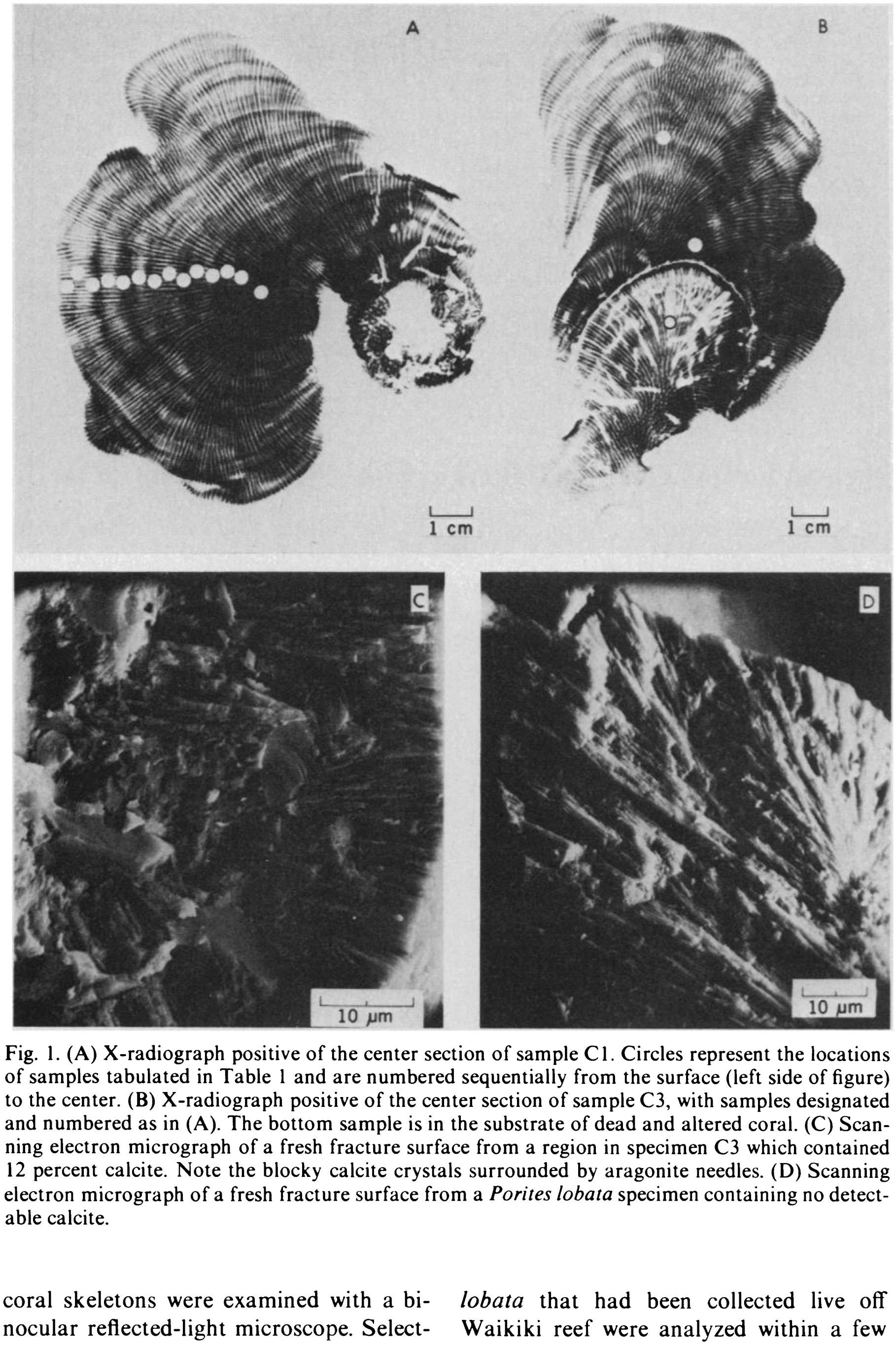

Fig. 1. (A) X-radiograph positive of the center section of sample C1. Circles represent the locations of samples tabulated in Table 1 and are numbered sequentially from the surface (left side of figure) to the center. (B) X-radiograph positive of the center section of sample C3, with samples designated and numbered as in (A). The bottom sample is in the substrate of dead and altered coral. (C) Scanning electron micrograph of a fresh fracture surface from a region in specimen C3 which contained 12 percent calcite. Note the blocky calcite crystals surrounded by aragonite needles. (D) Scanning electron micrograph of a fresh fracture surface from a *Porites lobata* specimen containing no detectable calcite.

coral skeletons were examined with a binocular reflected-light microscope. Selected samples of known bulk mineralogy were plated with a gold-palladium alloy and examined with a scanning electron microscope (Cambridge S-410).

A general survey of archived samples from various locations (Fiji and the Marshall Islands as well as Hawaii) showed that a significant minority of the colonies checked, primarily in the genera *Porites* and *Pocillopora*, contained detectable (> 2 percent) calcite. The six colonies of *Porites lobata* that had been collected live off Waikiki reef were analyzed within a few weeks of collection and studied intensively; all were found to contain detectable low-magnesium calcite at some locations in the skeletons. These specimens displayed some of the highest calcite contents found; analytical data for two of the samples are given in Table 1. Intraspecimen variation in composition was great; calcite contents ranged from 46 ± 5 percent (absolute error) to below the detection limit. We estimated the time of sample deposition by counting seasonal bands (Fig. 1) below the living surface; all samples were less than 10 years old, and those in the outer portions of the colonies were less than 1 year old (see Table 1 and Fig. 1). Scanning electron microscopy showed the calcite to be in the form of clean, solid, rather angular crystals with dimensions of 20 μm or less and surrounded by aragonite needles typical of normal coral skeletal structures (Fig. 1).

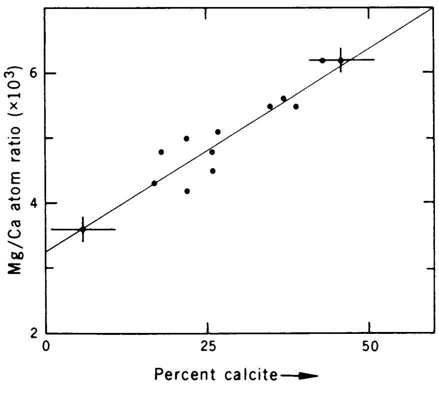

Fig. 2. Plot of the magnesium/calcium ratio (× 10³) versus the percentage of calcite for the corals examined (see Table 1), and a least-squares fitted line. For visual clarity error bars have been omitted from all but two of the points. The 0 percent calcite intercept is 3.2×10^{-3}; the 100 percent calcite intercept is 9.5×10^{-3}.

The atomic ratio of magnesium to calcium in the calcite fraction was determined by the *d*-spacing shift method to be less than 4 percent (*7*). The ratio was also determined in both the calcite and aragonite fractions by a least-squares plot of the magnesium/calcium ratio calculated from atomic absorption analyses versus the percentage of calcite in the sample. The limiting ratios thus obtained were 9.5×10^{-3} for pure calcite and 3.2×10^{-3} for pure aragonite (Fig. 2). Atomic ratios of strontium to calcium obtained in a similar fashion were $(3 \pm 1) \times 10^{-3}$ in the calcite fraction and $(9 \pm 1) \times 10^{-3}$ for the aragonite.

The strontium/calcium and magnesium/calcium ratios in the aragonite skeletal component are typical of those reported for normal aragonitic coral skeletons (*1, 2*) and are consistent with values from other Hawaiian corals (*8*). The strontium/calcium ratio in the calcite fraction is within the normal range reported for marine skeletal calcites. The magnesium/calcium ratio in the calcite, although not uncommon in skeletal calcites (for example, pelecypod and gastropod shells), is much lower than that of organisms known to bore or encrust coral heads, and also lower than the average magnesium content of coral reef calcites (*1, 2*) in general.

Sample C3-4 (Table 1 and Fig. 1), taken from the substrate of the living coral head, is an example of the high-magnesium calcite. Although originally coral, this substrate was noticeably altered by boring and encrusting organisms. Although the total calcite content in this sample is lower than in some parts of the apparently unaltered coral, it is high-magnesium calcite clearly distinguishable from what we have designated skeletal calcite.

In summary, the skeletal calcite consists of clean, blocky, rather angular crystals possessing no internal structure. They occur internally within the skeletal structures, show no evidence of occupying preexisting skeletal cavities, are surrounded by normal aragonite needles, and have a very low and consistent (Fig. 2) magnesium/calcium ratio. In addition, other massive *Porites* specimens from the same area have been found to be pure aragonite. We believe these data are inconsistent with a detrital origin for the calcite.

The possibility of a diagenetic origin is not eliminated a priori but would require that extensive recrystallization occur on a time scale of months in the interior of an intact aragonitic structure in a normal marine environment. If true, this would necessitate a reevaluation of rates and mechanisms of carbonate diagenesis. Wise (*9*) has discussed the possibility of early diagenesis triggered by boring algae. Although algal bores, both with and without recrystallization, can be identified in some of our specimens, most of the atypical crystal formations (Fig. 1) are not associated with any evidence of boring. As noted above, the low-magnesium content argues against direct algal deposition.

It is our opinion that this skeletal calcite is of biogenic origin, deposited by the coral as an alternate form of calcification. The production of calcite in larval skeletons of normally aragonitic corals has already been reported (*10*). The data presently on hand do not suggest any clear-cut species or environmental control over the occurrence of the calcite in mature, living coral colonies. However, this discovery opens up a number of exciting avenues for research in the areas of coral genetics, calcification mechanisms, and the use of coral growth and skeletal chemistry as environmental indicators.

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New Flow-Through Centrifuge Without Rotating Seals Applied to Plasmapheresis

Abstract. *The flow-through centrifuge eliminates complications arising from rotating seals. Preliminary studies on plasmapheresis demonstrated negligible platelet injury and no evidence of hemolysis during 12 hours of operation. Thus the system may provide a broad application to cell washing and elutriation, zonal centrifugation, and countercurrent chromatography.*

The conventional flow-through centrifuge utilizes rotating seals which can become a source of leaks between the inflow and outflow lines; these rotating seals represent a weak point in the machinery in terms of the performance life, complexity, and fragility of the pieces and the necessity for a continuous and comparable degree of lubrication. When these continuous-flow centrifuges are adapted for an on-line blood separation—as applied to the collection of blood cells—rotating seals become critical in terms of platelet injury, red cell hemolysis, and obstruction of the channels by aggregates and impaired lubrication of the rotating seals. To overcome these problems we have developed a flow-through centrifuge which functions efficiently without rotating seals.

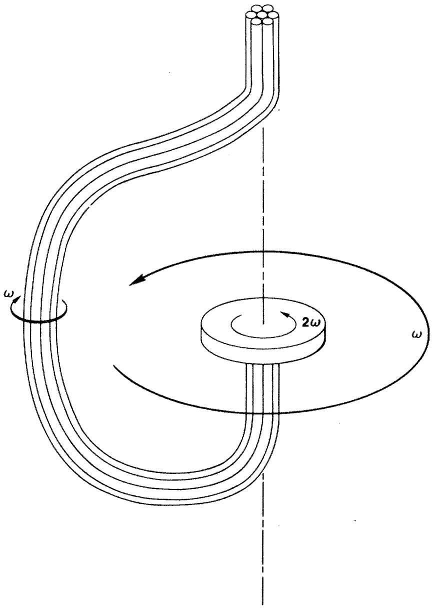

Fig. 1. Principle of the centrifuge: a bundle of tubes is connected to a bowl at one end and tightly supported at the other end, forming a loop. The bowl rotates around the central axis at an angular velocity of 2ω while the loop simultaneously revolves around the same axis at ω. This operation can be performed without twisting the bundle.

The principle of the system has been introduced by Adams (*1*) and is illustrated in Fig. 1. A bundle of flexible tubes is connected to a bowl at one end while remaining stationary at the other end, forming a loop as shown. When the bowl rotates at an angular velocity of 2ω around the vertical axis and the loop simultaneously revolves around the same axis at ω, the tube bundle remains free from twisting. In so doing, the tube bundle counterrotates around its own axis at – ω.

The design of the flow-through centrifuge based on this principle is shown in Fig. 2. The frame of the centrifuge head consists of three parallel horizontal plates rigidly linked and driven by the motor shaft as a unit. The frame holds a centrifuge bowl (center), a countershaft (right), and a tube-supporting hollow shaft (left), all mounted in ball bearings. A stationary pulley mounted on the motor housing is coupled through a toothed belt to an identical pulley mounted at the bottom of the countershaft to counterrotate this shaft with respect to the rotating frame. This motion is further conveyed to the centrifuge bowl by 1 : 1 gearing between the countershaft and the centrifuge bowl. This arrangement doubles the angular velocity of the centrifuge bowl. To support the heavy counterrotating flow tubes, the hollow shaft is actively counterrotated at – ω by means of a pair of toothed pulleys (1 : 1 ratio) coupled to the hollow shaft and the countershaft.

A doughnut-shaped silicone rubber bag (800-ml capacity) equipped with three flow lines is fitted inside the centrifuge bowl. A transparent Lucite cover makes it possible for one to observe the contents under stro-