References and Notes

1. For reviews, see S. Appelle, *Psychol. Bull.* **78**, 266 (1971); M. M. Taylor, *J. Opt. Soc. Am.* **53**, 763 (1963).
2. Although the fact of orientation anisotropy is well established, its incidence has not been documented, as far as we are aware. Two earlier studies of anisotropy [H. Leibowitz, N. A. Myers, D. A. Grant, *J. Opt. Soc. Am.* **45**, 76 (1955); J. C. Ogilvie and M. M. Taylor, *ibid.* **49**, 898 (1955)] used a total of 11 subjects. Of these subjects, one showed no difference in performance for different orientations and two performed better for obliques.
3. M. H. Segall, D. T. Campbell, M. J. Herskovits, *The Influence of Culture on Visual Perception* (Bobbs-Merrill, Indianapolis, Indiana, 1966).
4. R. C. Annis and B. Frost, *Science* **182**, 729 (1973).
5. Titmus Optical Company, Petersburg, Virginia.
6. Subjects with prescribed corrective lenses were required to wear them during testing. If any subjects scored below normal values on the T-O vision tester or exhibited large differences in acuity for orthogonal gratings in the experimental situation, we attempted to improve their performance to normal with lenses. Those with obvious amblyopias were dropped from the sample. Since we did not refract our subjects to ensure a perfect optical correction, we were concerned that some cases of uncorrected astigmatism might have influenced our results. However, when we computed an astigmatism ratio by dividing the acuity for one axis by that for the orthogonal axis, the distribution for both Chinese and Caucasian samples approximated that reported for normal subjects by D. E. Mitchell *et al.* (*11*). Thus, we conclude that the differences between Chinese and Caucasian scores reported here were not produced by systematic differences in astigmatism.
7. Contrast is defined as
$$\frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}}$$
where L is luminance.
8. The anisotropy index (AI) was computed as follows:
$$AI = \frac{(V + H) - (OL + OR)}{(V + H)/2}$$
where V, H, OL, and OR are mean thresholds for vertical, horizontal, oblique left, and oblique right orientations, respectively. Subjects performing equally well on all orientations would have an index of 0.0, while those exhibiting a drop in acuity for obliques by a factor of 2 would have an index of 1.0.
9. Anisotropy indices were computed from Annis and Frost's published figure. For Euro-Canadians this was approximately 0.21 and for the Cree Indians it was 0.10. These values are somewhat smaller than we obtained, perhaps reflecting procedural differences, but the difference between the Euro-Canadians and Cree Indians is about the same as that between the present samples of Caucasians and Chinese.
10. F. W. Campbell, J. J. Kulikowski, J. Levinson, *J. Physiol. (London)* **187**, 427 (1966); D. E. Mitchell, R. D. Freeman, G. Westheimer, *J. Opt. Soc. Am.* **57**, 247 (1967).
11. D. E. Mitchell, R. D. Freeman, M. Millodot, G. Haegerstrom, *Vision Res.* **13**, 535 (1973).
12. S. C. Leehey, A. Moskowitz-Cook, S. Brill, and R. Held [*Science* **190**, 4217 (1975)] reported that 6-week-old infants preferred to look at horizontal or vertical gratings over oblique gratings at threshold spatial frequencies; however, it should be noted that D. Teller, R. Morse, R. Borton, and D. Regald [*Vision Res.* **14**, 1433 (1974)] failed to find orientation differences by using a similar technique, pairing gratings with blank fields.
13. Authorship order was determined by a coin toss. We thank B. Frost and D. J. K. Mewhort for constructive criticism, D. J. K. Mewhort for assistance in the data analysis, and S. Wong and A. Wong for help in recruiting Chinese subjects. Supported by National Research Council of Canada grants A0044 to P. C. Dodwell and A0353 to B. Frost and Defense Research Board of Canada grant 9425-12 to P. C. Dodwell and J. Z. Jacobson.

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Skeletal Calcite in Living Scleractinian Corals: Microboring Fillings, Not Primary Skeletal Deposits

As far as is known, modern scleractinian corals construct their skeletons entirely of calcium carbonate in the form of aragonite. Houck, Buddemeier, and Chave (*1*) recently challenged this concept by reporting as much as 46 percent primary skeletal calcite in certain tropical reef corals. Further examination of their samples of *Porites lobata* (*2*) indicates that the calcite is not a primary deposit of the coral but is associated with microborings.

Petrographic thin sections revealed these samples of *P. lobata* to be extensively altered by a branching network of fine (≃ 3 μm in diameter) calcite-filled tubules (Fig. 1A) extending to the living coral polyp layers. The tubules are probably fungal or algal in origin. Endolithic plant borings are a prominent characteristic of tropical reef corals (*3*, *4*), but microborings or exposed filaments of these plants to date have been associated only with the precipitation of aragonite and magnesium calcite (*4*, *5*). Although Houck *et al.* identified algal borings, they concluded that most of the calcite is "not associated with any evidence of boring" and, more importantly, suggested that the calcite is skeletal calcite "deposited by the coral as an alternate form of calcification."

Our study of the samples does not support these conclusions. Etching of the polished coral surfaces with ethylenediaminetetraacetic acid (EDTA) at *p*H 8 caused the calcite to stand out in relief from the finer, more soluble aragonite. Figure 1B shows the filamentous nature of the more resistant calcite which when completely dissolved leaves a branching, tubular organic network (Fig. 1C). We observed enough calcite-filled microborings in thin sections and scan-

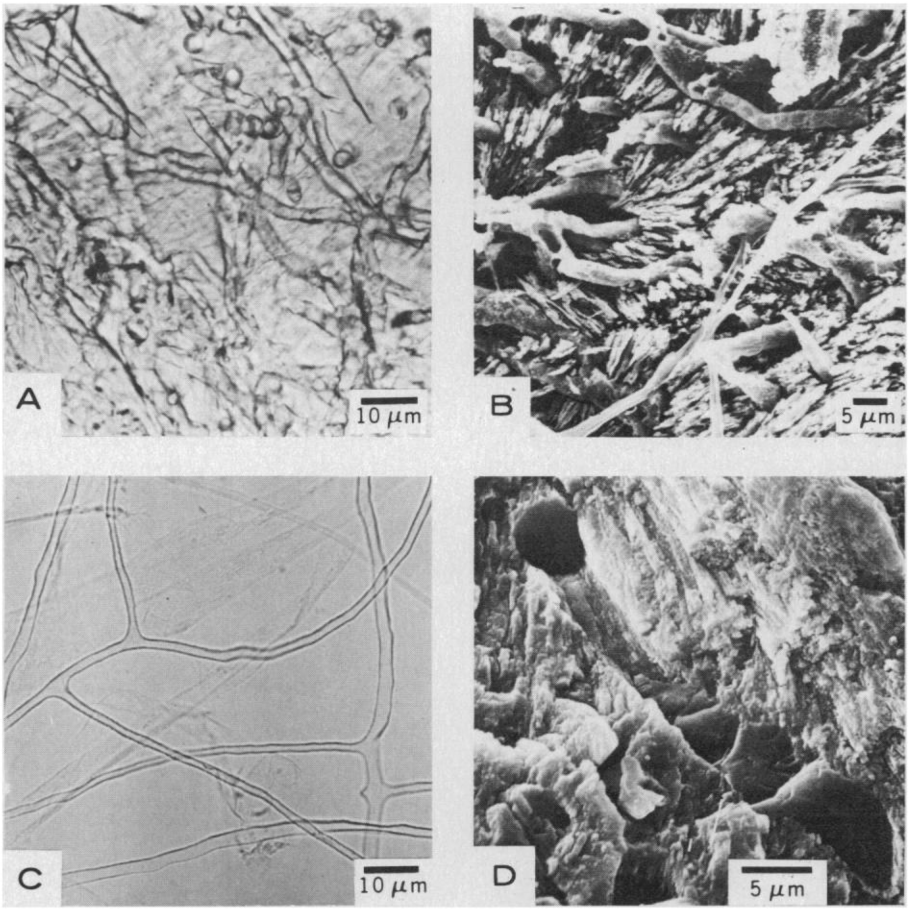

Fig. 1. (A) Photomicrograph of *Porites lobata* from Waikiki reef showing extensive alteration of skeletal aragonite by microborings. (B) Scanning electron micrograph of a polished surface from *P. lobata* etched with EDTA. Less soluble calcite in the microborings projects from the finer aragonite crystals of the coral skeleton. (C) Photomicrograph of organic sheaths from microborings which remain after the carbonate has been removed by EDTA. (D) Scanning electron micrograph of the fractured surface across a calcite-filled microboring.

ning electron micrographs of etched samples to account for the calcite reported by Houck *et al.* We did not find any evidence in the etched samples of calcite outside the microborings. Houck *et al.* (*1*) also reported "angular crystals" presumed to be calcite which are too large to be accommodated into the microborings. Our scanning electron stereomicrographs of freshly fractured coral surfaces exposing "angular crystals" reveal well-developed cleavage in coarse crystals, both along microborings (Fig. 1D) and across wider areas where they branch or coalesce.

If Feigl's solution (*6*) is applied to the etched surface, the skeletal aragonite is stained black, leaving the protruding calcite filaments comparatively unaffected. Resolution limitations of our electron microprobe prevented us from obtaining completely isolated analyses of the material in microborings; however, filamentous areas show lower strontium/calcium ratios and higher magnesium/calcium ratios than the skeletal aragonites—a feature consistent with the calcite mineralogy.

Houck *et al.* (*1*) reported that other samples of *Porites* from the same area at Waikiki consisted entirely of pure aragonite. This finding detracts from their contention that the calcite is a biogenic deposit of the coral itself. This atypical occurrence of calcite may represent a unique example in modern corals of "low-magnesium" calcite precipitation in association with boring activity of endolithic plants.

The origin of the calcite within the microborings remains unknown. Nevertheless, the data clearly indicate that the calcite is not the primary biogenic skeletal deposit of the coral.

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2. Samples of the study specimens of Houck *et al.* (*1*) were given to us by R. W. Buddemeier for further detailed analyses.
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7. We thank W. T. Boykins for assistance with the photography and W. R. Brown who operated the scanning electron microscope. We thank R. W. Buddemeier for making available to us study specimens. We appreciate the complete cooperation of J. E. Houck, R. W. Buddemeier, and K. E. Chave with this interesting problem.

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The findings of Macintyre and Towe are certainly relevant to our observations (*1*) and will help to focus further research on this interesting problem. Although we accept the validity of their observations, some comments on points of interpretation seem in order.

First, the differential etching and staining experiments could be interpreted as showing the effects on carbonate reaction rates of the refractory organic coatings rather than of differences in mineralogy. Although persuasive, these results do not prove that the calcite occurs only in the microborings or that the contents of the borings are exclusively low-magnesium calcite. Second, we have investigated further a number of presumed calcite crystals with dimensions of several tens of a micrometer in at least two directions. The tubules shown by Macintyre and Towe do not appear capable of containing crystals of these dimensions, and we remain somewhat skeptical that all of the large calcite blocks are situated in junctions of 3-μm tubules. Finally, neither group of workers has carried out a quantitative correlation between microscopic observations and the composition as determined by bulk analysis, and so it is still not possible to show conclusively that microborings account for all of the calcite present.

We certainly agree that the additional data suggest that it is less likely that the calcite is "primary" skeletal deposition by the coral, but we do not agree that the observation necessarily rules out the possibility that it is biogenic deposition by the coral. A secondary calcification in which the coral deposits calcite or makes possible its precipitation in the borings left by another organism seems to us a real possibility. Deposition by endolithic plants, either primary boring organisms or their successors, is also possible. In either case the frequent occurrence of borings of micrometer size (*2*) without calcite and the fact that the calcite in question has a low magnesium content complicate any simple explanation. It is this sporadic occurrence of low-magnesium calcite in scleractinian corals which remains the central phenomenon to be explained.

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