Table 2 presents a generalized stratigraphic comparison of the major rock units encountered in Africa and Antarctica if the continents are brought in juxtaposition in a continental drift reconstruction (*4*). Although additional total rock rubidium-strontium isochron data are clearly needed, it is postulated that the 3-billion-year geochronologic province of Swaziland, South Africa (*5*), may extend to the northeast beneath the Mesozoic and Cenozoic cover to join the Antarctic continent along the Princess Martha Coast (Fig. 1).

The rock specimen was collected by D. S. Soloviev "from a granitic massif which occurs among doleritic and basaltic rocks of unknown but possibly late Precambrian age, the contacts with the latter being concealed under ice cover" (*1*). The analyzed rock powder was taken from a 65-gram sample of the pinkish, medium-grained biotite (*1*), which consists of approximately 20 percent dark gray (smokey), slightly strained quartz, 40 percent deuterically (?) altered K-feldspar (orthoclase), 35 percent sericitized sodic plagioclase feldspar, and a minor amount of chloritized biotite. Rubidium and strontium isotopic compositions were measured on a 6-inch (15.24-cm) radius, 60° sector field, triple-filament mass spectrometer with a Faraday cage collector. The ion beams are amplified by vibrating reed electrometers; the mass peaks are displayed on an expanded scale recorder.

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3 June 1970

Scleractinian Coral Exoskeletons: Surface Microarchitecture and Attachment Scar Patterns

Abstract. *Scanning electron microscopic studies have revealed the configurations of the growth surfaces of scleractinian coral exoskeletons. Skeletal surfaces exhibit profuse growths of minute elongate aragonite crystals which, on basal and mural surfaces, are punctuated by scars. It is suggested that these scars are sites of attachment for the specialized processes that connect the living tissues of polyps to the nonliving skeleton. Patterns formed by the attachment scars are taxonomically significant.*

Although the internal skeletal structures of scleractinian corals are known from studies with light and transmission electron microscopes (*1*), information concerning the form and arrangement of aragonite crystals on developmental growth surfaces has been mostly speculative. However, current investigations with the scanning electron microscope show that developing crystals grow in the form of laths, blades, or needles as discrete individuals, in spherulitic arrays (*2*), or in clusters called fasciculi (*3*). Growths of crystals usually cover all skeletal surfaces uniformly. Those along the tabulae and walls of the corallite are interrupted only by circular or oval depressions which mark points at which the living polyp is attached to the exoskeleton. These attachment sites and the patterns they form on the wall of the corallite are now described for the first time.

Crystals on developmental surfaces are commonly arranged in fasciculi, which are units approximately 5 to 25 μm in diameter in which the long axes of the crystallites are essentially parallel to one another. Well-developed fasciculi have been observed on the septal surfaces of many scleractinian genera, including *Manicina areolata, Mycetophyllia* sp., *Agaricia agaricites, Eusmilia fastigiata, Diploria clivosa, Isophyllastrea rigida,* and *Acropora cervicornis*. These findings prove the validity of Bourne's (*4*) contention that the so-called "calcareous scales" described by Ogilvie (*5*) are actually bundles of crystals with a high degree of preferred orientation, growing on the surface of the skeleton.

In the hermatypic colonial coral *Pocillopora damicornis* (Linnaeus) (Recent: Pacific), fasciculi cover both the basal and mural surfaces of the cup-shaped corallite (see cover). On the basal surface, the profuse growths of fasciculi are interrupted infrequently by circular depressions (Fig. 1A) approximately 10 μm in diameter, which mark sites at which the polyp was attached to the exoskeleton by specialized tissue-like processes. Bourne (*4*) called these attachment processes "desmocytes"; however, Matthai (*6*) disagreed with Bourne's conception of "desmocytes," and preferred to call these structures "wedge-shaped mesoglaeal" or "column wall" processes. My study shows that whenever wedge-shaped processes are attached to the skeleton, fasciculi in the areas surrounding them continue to grow upward; thus depressions are left when the processes are removed. At the bottom of the depressions, the attachment surfaces are not smooth like the surfaces of muscle scars on mollusk and ostracod valves; instead, they exhibit vestiges of the rough surface formed by the fasciculi on which the processes are attached.

Although attachment scars on the basal surface of *P. damicornis* are infrequent, discrete, and isolated, those on the walls of the corallite are numerous and frequently coalesced to form large patches of scar surface (Fig. 1, B and C). Most striking is the alignment of scars in rows which extend up the walls of the corallite (area between arrows, Fig. 1B). These rows are spaced approximately ¼ mm apart around the corallite. It has been noted (*4, 6*) that the attachment processes are concentrated along the outside of the column wall of the polyp exactly opposite the junctions with the mesenteries (*7*). The scar patterns on the corallite, therefore, can be correlated with the positions of

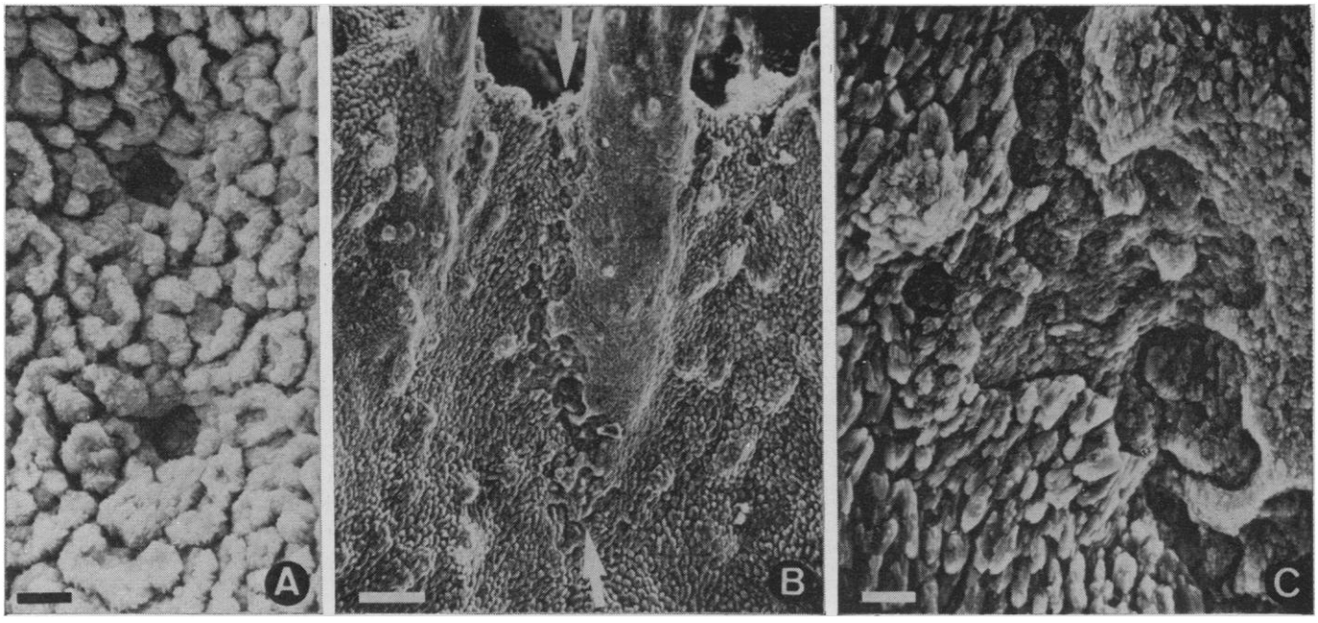

Fig. 1. Details of a corallite of *Pocillopora damicornis*. (A) Two circular depressions mark sites at which the polyp was attached to the basal surface of the corallum by specialized processes (scale, 10 μm). (B) Upper portion of the wall of the corallite showing the alignment of attachment scars in a vertical row (between the two arrows) (scale, 50 μm). (C) Detail of (B) showing a large, irregularly shaped scar surface formed by an attachment process consisting of many strands of tissue. Fasciculi surrounding the scar surface lie at a low angle to the skeletal surface (left side of figure) (scale, 10 μm).

mesenteries in the living organism. Because the arrangement of mesenteries varies among the different species of scleractinians, it would not be surprising to find different scar patterns developed on the thecal walls of different taxa.

An examination of *Pectinia lactuca* (Pallas) (Recent: Indo-Pacific) supports this hypothesis and reveals some interesting differences in relation to the first scar pattern examined. The scars of *P. lactuca* (Fig. 2A) are strictly aligned in parallel rows ¼ to ½ mm apart which run toward the top of the wall of the corallite (direction of arrow, Fig. 2A). The scars have irregular circular or elongate outlines (Fig. 2B), with the longest dimension parallel to the rows. All of the impressions are quite large (about 50 μm wide) and can even be seen with a binocular microscope with reflected light. The uniformly large size of the scars and their arrangement in single file distinguish this pattern from the one observed in *P. damicornis*.

A limited amount of knowledge concerning the gross morphology of the attachment processes can be deduced from the general size and shape of the scars and from small impressions on the surfaces of larger scars. The small circular impressions on the scar surfaces of *Pectinia* and similar-sized impressions outlined against the fasciculi adjacent to the scars (arrow, Fig. 2B) indicate that the largest structural elements forming the processes are strands approximately 5 to 15 μm in diameter. Because the scars on the basal surface of *Pocillopora* (Fig. 1A) are about this same size, it appears that those scars were formed by single strands of tissue. A detailed analysis of the morphology of the attachment processes and a precise definition of the type of tissue they actually represent can only be rendered by a modern histological study. Such an investigation would also be helpful in resolving the conflicting reports (*4, 6*) concerning their origin.

Patterns of muscle scars are important in reconstructing the probable arrangement of soft parts in organisms now extinct (for example, see *8*). They

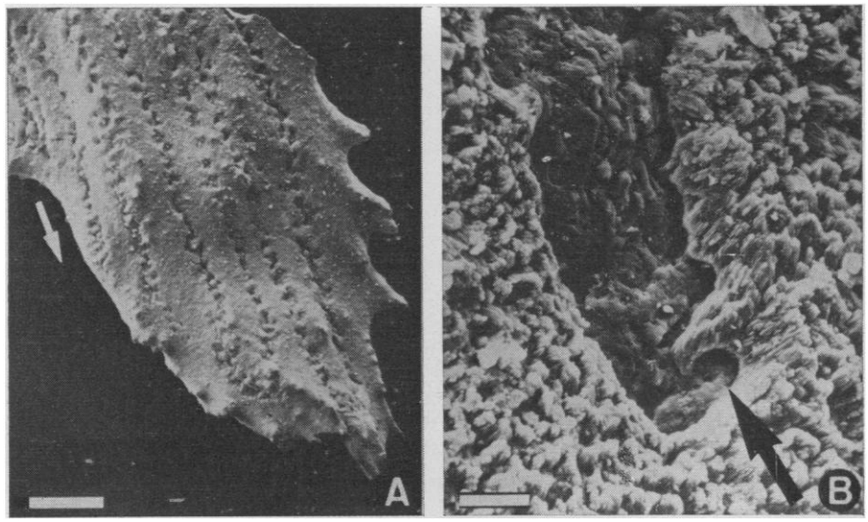

Fig. 2. (A) Fragment broken from the top of the wall of a corallite of the colonial coral *Pectinia lactuca*. Attachment scars on the fragment are large and strictly aligned in rows which run toward the top of the wall (direction of arrow) (scale, 0.5 mm). (B) Detail of (A) showing a single attachment scar. Arrow points to a circular depression which presumably was formed by a single strand of the attachment tissue (scale, 20 μm).

are also used by taxonomists and paleontologists to distinguish species of living and extinct representatives of several different phyla of invertebrate organisms (for example, mollusks, brachiopods, ostracods). Similar uses for patterns of attachment scars should now be considered by specialists dealing with scleractinian corals (*9*).

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Inorganic Liquid Photovoltaic Cell: Tetravalent Molybdenum in Water

Abstract. *An inorganic liquid photovoltaic cell is described. The cell is based on the reaction* $2Mo^{4+} \leftrightarrows Mo^{5+} + Mo^{3+}$, *with pentavalent molybdenum formed in the illuminated half-cell and trivalent molybdenum formed in the dark half-cell. In the photochemical reaction pentavalent molybdenum precipitates. Consequently, the cell has the capability of storing energy.*

We report a new liquid photovoltaic cell based on the disproportionation of excited Mo^{4+} to Mo^{3+} and Mo^{5+}. The sequence of reactions in the illuminated side of the cell is

$$Mo^{4+} \xrightarrow{h\nu} (Mo^{4+})^*$$

$$(Mo^{4+})^* \rightarrow Mo^{5+} + e$$

The reaction in the dark side is

$$Mo^{4+} + e \rightarrow Mo^{3+}$$

The net reaction is

$$2Mo^{4+} + h\nu \rightarrow Mo^{3+} + Mo^{5+}$$

The photovoltaic effect is due to the accumulation of Mo^{5+} in the illuminated side and the simultaneous accumulation of Mo^{3+} in the dark side.

The experimental cell is shown in Fig. 1. The cell is made of two Pyrex test tubes 25 mm in inside diameter connected by glass tubing 6 mm in inside diameter with a very fine glass frit. The two sidearms are used to flush the solutions with nitrogen, the stream of which also stirs the solution. The platinum electrodes have an area of 0.5 cm^2. The thermometers in the two sides are necessary so that the temperature in the illuminated side does not exceed the temperature in the dark side.

To ensure temperature uniformity and to rule out thermal potential differences, the whole cell is immersed in a thermostated water bath (25.0° ± 0.5°C). The light source used is a tungsten halogen lamp (General Electric "quartzline," model FAL). The 420-watt lamp is kept at a distance of 15.3 cm from the cell. To exclude light from the dark side, one of the test tubes is wrapped with aluminum foil.

The materials used were colorless hydrated ammonium molybdate $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$, and red "$(NH_4)_2MoCl_5\cdot H_2O$." In the first compound, which is commercially available, molybdenum is hexavalent. The second compound, in which molybdenum is trivalent, was prepared as described by Palmer (*1*, pp. 413–415), except that we used nitrogen rather than carbon dioxide as our oxygen-free atmosphere. We obtained Mo^{4+}, also as described by Palmer (*1*, pp. 410–413), upon mixing a solution containing one equivalent of the Mo^{6+} compound with two equivalents of the Mo^{3+} compound. The formation of Mo^{4+} requires about 5 minutes. By mixing equal amounts of an 0.05*M* Mo^{3+} solution and an 0.025*M* Mo^{6+} solution, we obtained an Mo^{4+} concentration of 0.0375*M*. The Mo^{4+} solution, which has a deep green-black color, was used to fill both sides of the photovoltaic cell.

Figure 2 shows the voltage development after the light is switched on. A plateau of 88 mv is reached in about 15 minutes. The cell is capable of storing electrical energy. When the light is switched off, the drop in the cell's voltage is very slow unless a current is drawn (there is no substantial drop in potential in 2 hours). As the voltage develops, the color of the solution changes from dark green to light brown in the illuminated side and from dark green to brown-green in the dark side. We assign, by polarographic experiments, the yellow-brown solution and the crystals precipitated in the illuminated side to Mo^{5+}, and the brown-green solution in the dark side to Mo^{3+}. The color changes are consistent with the formation of Mo^{5+} and Mo^{3+}. On the illuminated side the Mo^{5+} precipitates as the light brown "$MoO(OH)_3$," which dissolves in concentrated hydrochloric acid to give the dark green Mo^{5+} solution (*1*, pp. 406–407). If ammonium carbonate is added to the solution in the dark side, a red compound, characteristic of Mo^{3+}, precipitates (*2*).

To prove the nature of the light-induced reaction, we subjected the starting solution and its photoproducts to a polarographic study. The solvent and supporting electrolyte for the polarography in all cases was 3*N* HCl. All of the reactions described below were carried out in a nitrogen atmosphere.

To establish that the molybdenum was indeed in the tetravalent state prior to irradiation, the molybdenum in the solution was precipitated as "$py_2H_2Mo(CNS)_6$" (where py represents pyridine), and then converted to "Cd_2Mo-