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THE STORY OF AN ATOLL

by

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Have you ever wondered how this little "rock" you are on came to be here in the center of this very deep ocean? Or have you ever thought about how secure you are from the elements of nature on a little earthen platform only 5 or 6 feet above the sea? Well, be assured that you aren't the first to hold such thoughts, for these problems have been uppermost in the minds of many scientists for over 200 years, and doubtless piqued early voyagers' curiosity since they were first seen by humans several centuries ago. I shall try to point out the most important facts discovered to date about this atoll, both from the standpoint of the origin of the limestone rock and from the geological processes that went on in the past to provide the foundations for atolls, particularly Enewetak.

Let's begin with a simple description of Enewetak Atoll. Approximately 30 small islands dot a broad reef platform which encircles a lagoon measuring about 20 by 25 miles in length and width. The total land area on these islets is only 2.5 square miles, or, if you come from the wide open spaces in the Midwest, a land area of about two and one-half sections, or 1,600 acres. The highest point of land is about 13 feet above mean sea level. The depth of the lagoon averages about 160 feet. Prior to turning the Atoll into the Pacific Proving Ground, it supported a population of 121 natives who scratched out a bare existence from coconuts, arrowroot, and pandanus supplemented with seafood from the reefs and lagoon.

All the limestone you see about you, and the entire atoll including islands and reefs is limestone down to a depth of several thousand feet, has been produced by animals and plants. You are already familiar with "corals." But, take a real close look at a piece of coral. You are gazing at the skeleton of this animal which, like our own skeleton, was inside the flesh of a colony of coral animals. And, like our own skeleton is produced, this piece of coral was secreted by living cells of the coral animal's body. You can see many small holes or depressions in the coral skeleton. In each of these holes a small coral animal (called a polyp) lived, joined by a thin skin to his fellow members of the colony. These coral polyps look like miniature sea anemones, and really are, except that they produce a hard, limy skeleton whereas a sea anemone doesn't. They have tentacles which are used to catch small animals as food. You may be wondering why the living coral is brightly colored, yet the skeleton appears perfectly white. This is because a tiny single-celled plant lives inside the cells of the coral pulp, and this plant is variously colored. We'll have more to say about these little plants later.

These coral polyps feed and grow like other animals, and reproduce often just by having new polyp "bud" off the connecting skin between two adjacent polyps. In this way very large colonies will develop and grow where each polyp is attached to its neighbor, and they continually lay more skeletons until some coral colonies (you will probably call them heads) may reach a diameter and height of several feet. In one way or another these coral colonies get broken up so that there is always a lot of coral rubble and coral sand being produced. This loose material would remain unconsolidated if it were not for the kinds of seaweeds which also secrete a limy skeleton.

At the edge of the seaward reef where the waves beat down with considerable force, you may have noticed a slightly elevated ridge of rock-like material. This really isn't rock at all, but a rather hardened type of seaweed which we call coralline algae. This algae secretes a limy covering to its tissues and in so doing incorporates sand and broken shell and coral fragments into it in such a way that it binds them together into a rock-like mass. Other types of plants assist in this process too. Thus, not only do plants help to build the limy reef-building material, they also serve the important role of binding together all the corals and shells into a solid mass.

We have seen then, that the limestone which makes up all the atoll substance we see is formed by corals, shelled animals and seaweeds, with the seaweeds playing the important role of binding these fragments into a solid rock.

These living organisms have certain needs to remain living just as we do. For example, they require warm, agitated water and strong sunlight. Moving water is especially important for corals, since they are attached and can only get food which drifts to them. Because of these needs coral reefs are only found at shallow depths to which light rays penetrate in sufficient density.

The depth to which reef-building corals grow is controlled by the light penetration into the water. Apparently most reef-builders grow best from the surface down to about 90 feet, but a few grow to a depth of 300 feet, still shallow in comparison to the ocean depth of some 20,000 to 25,000 feet.

Because corals and other reef-builders are continually producing their limy skeletons, the reefs must be growing upward. The rate of this growth has been one-half inch each year. Different species have different growth rates, and corals in different localities have different growth rates. One fact is universal, however, and that is, all growth upward stops when the coral is exposed at low tide. Thus the only way a coral head can grow once it reaches the surface is laterally or horizontally. If you observe shallow corals on the reef platform you will note that the top is dead, but the sides continue to grow outward.

A coral reef is something like an oasis in the desert too. That is, the life on it and over it in the water is much more abundant than the life in the open sea or open lagoon bordering the reef. Because of the many marine organisms have shells and skeletons, we find that the deposit of these skeleton remains from dead organisms is far greater on the reef than in the ocean or lagoon on either side. As a matter of fact, it is in the order of 1,000 times greater. Thus this sediment tends to build up the reefs upward much faster than the adjacent lagoon or ocean floor.

We have now learned something about the nature of reef-builders, but have not mentioned the various kinds of reefs in the world. Three types are recognized. First, the "fringing" reef which borders a high island forming an apron of limestone around its edge. This is the kind of reef found in the Hawaiian Islands. Second, the barrier reef which is a reef separated from its high island foundation by a more or less broad lagoon. This is the type found off Northeastern Australia and known as the Great Barrier Reef. Third, is the coral atoll, which we have just been describing.

Before we undertake the geological aspects of atolls, let's review the known fact about limestone producing organisms.

1. Limestone is produced by corals, coralline algae, and many shelled animals.

2. The algae are also important in binding coral and shell fragments into solid rock.

3. Corals and most coralline algae grow best in shallow, warm, clear water which is somewhat agitated.

4. All reef-building corals contain tiny plants within their cells. This fact may be very important in limiting reef-building corals to shallow water, because these plants must have sunlight to live. Whether or not they promote more vigorous growth of corals is problematical.

In 1837 Charles Darwin, one of the most famous naturalists, proposed a theory to explain the origin of the three kinds of coral reef structures. He thought that volcanic mountains which rose above sea level in areas where coral would grow would soon have a fringing reef around them extending to about 200 to 300 feet. With the cessation of volcanic activity, he assumed that the mountain would settle downward, along with a general substance of the sea bottom in the area. If the substance of the mountain were slow enough, it would enable the upward growth of the coral fringe, particularly at its seaward edge where the water is agitated, to maintain the reef at the sea surface while the mountain slowly settled downward. In such cases the outermost edge of the reef would grow rapidly enough to keep up with the settling, but the inshore part, where the water was too quiet for the corals to flourish, would not grow upward rapidly enough to keep up with the rate of settling and would be submerged, thus forming a deep channel between the shore and the off-shore reef edge. This explained how a barrier reef could be formed. With further subsidence of the sea bottom, the mountain top would be submerged completely and the barrier reef, still keeping pace with the settling mountain by growing upward, would be all that remained of the original structure. In time the mountain top would be covered by sediment, coral algae growth, but would never grow upward as fast as the outer reef edge. This would explain the formation of the shallow lagoons.

Darwin's theory, based on widespread subsidence of the sea bottom, was subsequently attacked by several other persons who had different interpretations of reef formation. One of these was the geologist Daly, who suggested that the same sort of coral growth on mountain sides as did Darwin, except that he felt the rise and fall of the sea level was more important than subsidence of the bottom. Certainly the sea level did rise and fall with the formation and subsequent melting of the ice sheets during past geological periods. However, few believed that the great depth of the limestone caps which characterize atolls could have resulted solely from fluctuations in sea level.

Other ideas came forth also, but in fairness to all, it must be emphasized that these scientists had very little evidence on which to base their theories, particularly compared to what we know now. Let us see what the current geological facts are.

An important key to the origin of atolls is the thickness of the limestone cap over the volcanic mountain foundation. This has been studied in several ways, particularly by measuring the speed of sound waves through the limestone, sediments and underlying lava rock by seismic refraction, and by actually drilling cores in seven places throughout the Pacific, including Bikini, and Enewetak. The limestone cap is apparently 3,000 to 4,000 feet deep on these atolls. Thus, on the basis of these figures it would appear that Darwin's subsidence hypothesis was more reasonable than Daly's sea-level fluctuation idea. However, we have recently discovered additional facts based on studies of submarine mountains called sea mounts.

By using recording fathometers, the same device used on all ships for determining the depth of water below the ship's hull, vast areas of the sea bottom have been mapped. It is not all smooth, but rather it is as rough in topography as the mountains, valleys, and plains of our land areas. Among the submarine mountains, however, are some peculiar, flat-topped areas, especially common in the vicinity of the Marshall Islands, and presumably near all other coral atoll concentrations. These so-called sea mounts rise from the sea floor toward the surface, ranging in depth from the surface from 3,000 to 6,000 feet. They are volcanic in origin and flat topped as though they have been sheared off by a gigantic plane.

Volcanic rock dredged from their tops indicates that it was produced as lava when the mountain was much nearer the surface than it is now. This can only mean that the mountain has sunk several thousand feet. This subsidence is in line with what Darwin presumed and is in line with what is indicated by the great depth of the limestone caps on atolls. However, the sea level could have risen greatly too, due to the accumulation of volcanic material of the type which produced these sea mounts and such submergered land masses as the Hawaiian Islands.

The flattened tops can only be explained logically by wave action, beveling the mountain tops off when they are at the surface of the sea. As evidence for this, rounded cobbles have been dredged from the tops of sea mounts and photographs of ripple patterns in the sediment rather clearly indicate wave action. This wave action is an excellent clue to the mystery of atoll formation, for it aids in interpreting such occurrences as subsidence of the sea bottom, fluctuations in the sea level, different depths of flat-topped sea mounts, and the presence or absence of atolls.

We can get at our mystery of atoll formation by delving into the question of possible explanations for the varying depths of sea mounts. There are three possibilities for explaining the depth of sea mounts. First, the sea level could have risen; second, the entire ocean floor could have subsided; and third, individual sea mounts could have subsided at different rates. If the tops result from beveling by the waves, then we must assume that at one time all sea mounts must have been at the same height. Moreover, if widespread subsidence of the sea bottom were the sole occurrence, then all of them would be submergered to about the same depth, coupled of course with a certain amount of simultaneous subsidence of the sea bottom over wide areas. On this basis various factors would account for different rates of sinking.

Evidently many sea mounts sank too rapidly for coral growth to keep pace and they dropped below the depth at which reef-building corals could exist. This would account for no coral growth on some sea mounts and very little on others. However, those which sank slowly apparently were the sites for vigorous coral growth which kept pace in growing upward as the sea mounts sank, and became our present day atolls.

The lagoons represent the interior area of the reef circle where the water is less agitated and coral growth is less vigorous, resulting in this region slowly becoming deeper as the sea mount sinks. The rim, where the water is agitated and the coral growth is more vigorous, still keeps pace with settling rate of the sea mount.

During the last glacial period the sea level certainly lowered, with the inevitable beveling by wave action, the coral reefs which had grown up to that time. However, as the ice sheet melted, the sea level rose slightly, so slowly that the corals at the edge of the reef platform could keep pace with it, while the ones toward the interior could not. In this way the present configuration of Enewetak and other atolls may be accounted for. Our present information thus gives credit to both Darwin and Daly; for Darwin's theory of great subsidence explains the great thickness of the limestone mass atop a sea mount, such as is below us here at Enewetak, and Daly's sea-level fluctuation theory, based on the formation and melting of polar ice during the ice ages, explains the flattened floor of the lagoons which, in the Marshalls, are all about the same depth.

So much for the volcanic foundation and limestone cap of Enewetak; but are the islands here to stay? As a matter of fact, the islands, which are just accumulations of loose limestone fragments on top of the basic reef platform (the basic reef platform is the reef you see between the islands around the rim), are here only because we have had a recent 6-foot lowering of the sea level in the last few thousand years. If the sea level were to rise again, the islands would be swept off. Actually, this sort of disaster happens rather frequently on atolls during typhoons when the storm waves rise higher than normal. Hardly a generation goes by that some changes don't occur in the land area of atolls. Formerly, long islets were divided by channels during the typhoons, and in other cases the land areas changed their shape, or were even built up.

There is little cause for alarm, however, because the Micronesian people have resided on these atolls for at least 1000 years. The chances are therefore very good you will be able to serve out your assignment here! While doing so, I trust that this information will make your stay more meaningful, and possibly lead you into the path of an amateur naturalist.