MY BUBBLES RISE IN STEPS

(Free-diving adventures in the tropical Pacific)

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ILLUSTRATIONS

Chart showing the track of the Baird

Baird at Kwajalein
Air view of an atoll

Charging the bottles
Dressed to dive

Walter Munk over coral bowl at Alexa
Author at Falcon Island

Coral head in the Marshalls
Diver with shark

Divers examine bottom at Vava'u
Diving party in the skiff

Lion fish on native spear — Color
Serua village and island

Outrigger at Koralevu Bay — Color
Specimen from the bottom at Vava'u

Tahiti scene — Color
Pearl divers in water at Tuamotus

I INTRODUCTION

There are few greater thrills in store for a man than his first dive to a tropical coral reef and although I never tire of diving to look at the myriad shapes and colors of coral and the endless varieties of bright colored fishes, I sometimes wish I could still take my first look again---just for the thrill of discovering this wonderful world once more.

It was at Eniwetok in the northern Marshalls that I lost my heart to tropical diving. The water was warm and clear and shallow, not over five feet deep, and my outfit consisted of a face mask and a pair of tennis shoes---not even trunks. I swam out leisurely from shore for a hundred yards or so across brown dead coral, hard and flat and uninteresting, in the general direction of the next island. Suddenly the water lighted up, as the sun was reflected from a white sand bottom and I swam over my first cluster of growing corals. White and gold coral colonies branched gracefully upward and among the branches swam dozens of brilliant blue fishes only a few inches long; large clams pulsed their brown and blue mantles; hermit crabs dragged their shells along the rocks and the sand tumbled slowly along the bottom propelled by a gentle current. It was enchanting and I, spellbound, floated on the surface even forgetting to breathe. Periodically, like a sea-lion who has gone to sleep, I would be roused with a start and have to put my head out and gulp frantically for air, but I resented every second lost. A face

plate in the Marshalls is a ticket to paradise. I should have been content to drift and watch but the beauty was too much for me; I had to touch! Practically everything on a reef is sharp---and well fastened down to hold it against waves and currents. Even the most fragile looking coral branches have surprising strength and I imagine some of the firmly-rooted shells are sharp enough to shave with. So I learned my first lesson at once; not very well, for I still occasionally forget: don't try to collect specimens with bare hands. I returned to shore that evening with hundreds of tiny cuts on my hands, a sunburned back-side, and the firm resolve to return to the tropic seas with diving gear and underwater color cameras at the earliest possible moment.

Fortunately, I was able to participate before very long in a diving program which was one phase of the scientific work carried out by the University of California's "Capricorn" oceanographic expedition to the south seas. Capricorn was primarily a deep-water geological-geophysical expedition made to obtain information about nature of the Pacific Basin and the structure of the rocks that compose its floor. The diving was incidental to this work but on a few occasions proved to be an important geological tool. Most of the dives were made just for the fun of it by those who were interested; we wanted to see the reefs and the fish and collect shells and take pictures. Remember that water shallow enough for diving was available only when the ship was in port or close to land and it meant giving up sightseeing time ashore in strange exotic lands to do it at all. Ship time is expensive and it was not

possible to stop at the many islands we passed just for the fun of diving on their reefs.

Free diving is, nonetheless, a very important oceanographic technique. It allows scientists to go underwater conveniently and live there comfortably for an hour or so. They can sample the bottom, watch the sealife, take pictures, observe currents and waves, and examine the underwater topography. Although most of our dives had no immediate scientific purpose, I am sure that we inadvertently learned more about the nature of coral structures by constantly swimming among them than would have been possible by any other method.

With other divers from the University, I was able to make many sorties underwater and see and do far more than I had dared to dream. We dived where none had dived before--- or likely will again. We swam among sharks, barracuda, lionfish and poisonous sea urchins. We examined Falcon Island, now completely underwater but an active volcano in 1936. We dove for the Prince of Tonga and the Governor of Samoa. We saw sunken ships, played with native pearl divers, searched for a lost aircraft and many other things--- each one an adventure. This is the story of those dives which were spread over 3500 miles of equatorial Pacific and seven island groups.

II EXPEDITION CAPRICORN

A scientific expedition is born of ideas and bred in endless conferences; as the ideas grow they are shaped by the restless currents of finances, personalities, time to get ready, kinds of instruments, and transportation space and time. Basically, there must be a single idea and it must be backed by the will to follow it to completion or the venture is doomed before it starts, since knowledge comes not from blind groping but from careful systematic search for specific truths. Expedition Capricorn was founded on the belief that the place to advance man's knowledge of the nature of the structure of planet Earth is in the vastness of the ocean basins instead of on the continental platforms.

This was not a new idea but it was an undeveloped one for although many exploring ships had passed thru the Pacific before, the objectives of each were slightly different, the tools were different, and the routes were different. In planning Capricorn then, it was necessary to plan a route and program which would fill the ~~needs~~ VOIDS of knowledge left by previous expeditions and at the same time strike out into new fields, heretofore untapped. Painstakingly, the course of the ships was mapped to thread a way thru the island groups calling for fuel and supplies at the right time, crossing the geological boundaries at the optimum places, avoiding the areas where certain kinds of knowledge was abundant but picking up a check-point now and then to consolidate the gains.

In the end, after weeks of long nightly discussions, two thin pencil lines on a chart left San Diego, circled thru the Hawiians, Marshalls, Gilberts, Fijis, Tongas, Samoas, Societies, Tuamotos, Marquesas and returned to San Diego. On each side of the thin lines was a swath of eraser marks two hundred miles wide indicating routes discarded after many a scientific battle. So were the paths-to-be of the research vessels Horizon and Spencer F. Baird decided.

The emphasis of the research was to fall within the dominions of geology - geophysics and rest principally upon seismic study of the nature of the rocks underlying the bottom of the ocean. Here perhaps was the key to the thickness of the sediments and perhaps the age of the oceans for this was the first two-ship scientific exploration in the Pacific and the first opportunity for a large scale seismic refraction study of undersea strata.

In order to make sense out of the seismic results, many other measurements and samples were required, the principal one being a constant knowledge of the depth of the water so that the submarine topography could be worked out. To this purpose the most modern of echo sounding machines was installed, the EDO, a recording Sonar which draws a continuous detailed profile of the bottom over which the ship is passing. Furthermore it is necessary to take samples of the bottom material called cores--- a core being a rod-shaped specimen taken by punching a pipe vertically into the bottom. Where the bottom is too hard for coring, a heavy steel dredge with a net made of chain is used to break off and bring up chunks of rocks.

Other measurements were to be made of related phenomena; of the heat flow from the earth's interior thru the sediments, of the temperature of the sea water at all depths, of the earth's magnetic field and of the chemistry of the water and the bottom. Water samples were to be taken with the standard Nansen bottles, with special plastic bottles of the water just above the bottom, and with the "beanie bottle" or Cuan sampler of a great quantity of water for carbon - 14 measurements.

For biological studies there were pressure bombs for the storage of bottom bacteria, nets for trapping the near-surface plankton, and a mid-water trawl for catching fish a mile below the surface. Meteorologists were to study tropical weather far from land with radio-sonde balloons and a kytoon bearing special instruments. Underwater cameras, able to go to the deepest parts of the ocean, were planned.

The ships were to voyage over thousands of miles of deep ocean and cross and recross the Tonga Trench, a great canyon in the sea bottom 27,000 feet deep in places --- three miles deeper than the average 12,000 foot depth of the Pacific Ocean. In order to be able to reach bottom with the corers, and dredges and probes and water samplers, a special winch had to be built --- one of the largest in the world --- to support the six miles of tapered wire rope required to reach the bottom. Completed and installed, this winch and its cables cost nearly $140,000.

These things I have described have only the most casual relationship to the subject of the book. They are mentioned to show the tremendous complexity and expense of a modern scientific expedition and how small relatively, is any one kind of study, such as diving, in relation to the whole. Presiding over this mad scramble of people who were wrangling over places on the schedule, ship time, money for new instruments, and the design of the winch was Dr. Roger Revelle, the director of Scripps Institution of Oceanography, and coordinating the day-by-day progress with a froth of letters, directives, phone calls, requests, requisitions, and work orders was John Isaacs, his special assistant.

When the Horizon sailed from San Diego on September 25, 1952, the [illegible] grounds rumbled with a great sigh of relief and John and I relaxed with a fifth, for it was three weeks before we had to fly out and meet her in the Marshalls. Somewhere on board, buried in the mass of scientific gear which choked the laboratories and flooded the after deck, was a set of free-diving equipment. The battle to see the underside of the tropical seas was half won.

In the diving equipment on the Horizon were several major items. Most important, for it was hardest to locate and get installed, was a suitable air compressor --- for high pressure compressors capable of filling our air tanks to 2500 pounds per square inch are rare. But find one we did, and with a 5 HP motor and a suitable cover, it took its

station on the boat deck. For a reservoir, and an air cleaning and drying unit, we had two large steel bottles hooked into the system, one of which was filled with silica gel and thru which all air passed on its way to our lungs. This unit worked beautifully thruout the voyage and was capable of filling a single bottle tank in about five minutes.

Also along were the Aqualung regulators and bottles; four of each. (When the Baird joined the expedition, it brought several more). Each diver carried his own face plate, swim fins and small gear.

Then there were the cameras. For still shots there was the Rolleflex mounted in a water-tight case imported from France which, for depths to 50 feet was quite successful --- but we never cared to risk it much below that; judge by the pictures in this book. Last of all was my pride and joy --- the Fenjohn. For years people have been putting ordinary cameras in boxes to keep them dry and attempting underwater photography; but looking at the Fenjohn one feels that here, at last, is a machine which was designed purely for taking underwater motion pictures.

First of all, it takes good 16mm pictures, fifty feet at a time, but besides that it is aesthetically pleasing to one who appreciates fine machinery and fingertip control. Moreover it is painted orange --- a color that is as irresistable to an adventurer as it is to a bull. (This is said to be a safety feature but I think it's pure salesmanship). An orange bullet with solid handles and black dials for the thumbs to turn --- one each, for film speed, shutter opening,

filter change, and focusing. The view-finder looks right thru the camera case and while watching the subject, the operator can also see how the camera is set and watch a little neon light flicker when the trigger is held down. In the back is a valve for pressurizing the case against possible leakage (easily done with a couple of little CO_2 bottles). Also an underwater lightmeter.

In my sales talk to the university powers I included all these features and more too --- and in glowing language --- until I was allowed to spend $2000 on its purchase. Never was money better spent for now I could not only go to the south sea bottom but I could bring some of the best moments back with me. Corals and bright fish into the lecture room.

SHALL MAKE YOU FREE-DIVING

III THE TRUTH [redacted]

This is an account of diving adventures in the south seas. However, there are so many misconceptions prevalent about diving that a general discussion of diving and of diver problems will probably make the remainder of the chapters more intelligible.

Man's natural habitat is on land but although he is a land mammal, he is also the most adaptable of all animals and can readily learn to exist under water for short periods of time. Many mammals, such as sea lions, whales and porpoises, have substantially the same body organs as man and happily spend their entire lives in the water; their principal advantage is that they can hold their breath longer.

Types of diving

The problem of staying underwater then becomes mostly a matter of air supply and there are two obvious solutions: Man can hold his breath or he can take some of the atmosphere with him. Many divers have become very successful at holding their breath and, as we shall see in a later chapter, dives to over 100 feet for two minutes and more are not exceptional. Diving without an external air supply is called skin diving.

The next simplest form of air supply is a bottle of compressed air* carried by the diver from which he obtains a breath "on demand". That is, he holds a flexible rubber tube in his

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*Some free-diving equipment uses a pure oxygen supply; this is known as the closed-circuit system for there are no escaping gases. The exhaled oxygen - CO_2 mixture is passed thru a lime cannister which removes the CO_2. Additional oxygen is added continuously to replace that consumed. Because of the danger from oxygen poisioning such apparatus can only be used at pressures of less than one atmosphere. (33 feet of seawater)

mouth and when he wants a breath he sucks in air; when he is thru with the air he forcibly expells it. The exhaled gas, high in CO_2, rises to the surface in large bubles. Divers who carry their own air are called free divers. They may or may not wear a suit for protection from the cold. The word "free" indicates that the diver is not tethered to a surface air supply and can move freely about without danger of fouling lines to the surface. Usually free divers move about by swimming in a more or less horizontal position since they have neutral buoyancy and are essentially weightless.

Underwater the swimmer propels himself mostly by using the flutter kick which, with swim fins, is quite efficient but occasionally the arms are used with a breast stroking motion for additional speed. To orient himself in the water he uses arms and hands in unaviodably graceful motions which often appear to be waves, signals, or meaningful gestures to the other divers. (When signals are necessary, they are best done with fingers accompanied by appropriate grunting sounds in which an occasional word can be distinguished.) As the swimmer moves along below the surface the bubbles of his past breaths rise behind him, each a little higher up and a little further back; a staircase of mirrored mushrooms rising from the never-never land of diffused light and quiet swaying water to the naked reality of the surface with its harsh bright lines and garish red colors.

Free-diving devices, both oxygen and compressed air, are known professionally as SCUBA (for self-contained underwater breathing apparatus); there have been a great many varieties built which have been successful in varying degrees. The real birthplace of this kind of diving is in the Mediterranean Sea where the water is warm, clear, and near population centers; here also the best equipment has been developed including the Aqualung which is becoming widely used thru-out the world.*

Personally, I am inclined to face in the general direction of France and bow my thanks to Capt. Jaques Yves Cousteau and M. Gagnan for their invention of the Aqualung which we used exclusively on this expedition. It has the simplicity achieved only by brillian designing.+

*By no means the only SCUBA that is available. Sweeden makes the Varbel, England the P-party suit, and the Italian Pirelli company makes several models. In the U S there have been available at various times the Lambertson lung, the Jack Brown.

+Capt. Cousteau's story of the designing is told in the October, 1952 issue of the National Geographic Magazine.

The remaining class of divers are called line divers; they are connected to the surface by a hose thru which they receive their air supply. On the surface is a man called a "tender" who sees that adequate air is being furnished to the diver either from a hand pump, compressed air bottle, or compressor. In addition he "feels" the diver by holding to his life-line and pays out or takes in the lines as requested by short jerks on the life-line from below. The basic feature is that the air is furnished from the surface.

There are two principal types of line:diving gear; the shallow water outfit and the deep-sea dress. The U.S. Navy's shallow water gear (good to 60 feet) consists, primarily, of a triangular face plate which covers eyes, nose, and mouth. This face plate has a little valve on one side by means of which the diver can regulate the flow of air into the mask and a simple flutter valve for releasing the excess air. Fresh air and exhaled air are mixed in the mask and the excess is forced out the flutter valve by the incoming fresh air. In addition to the mask, the navy version has a light-weight waterproof canvas suit which is worn over heavy underwear. The suit seals around the face under the edge of the mask but it is not essential to the system and in warm waters is rarely used. The diver wears weights to hold him down and usually walks or crawls on the bottom. The "standard" diving suit or "deep sea dress" is the type of diving equipment best known to the public since it is frequently cartooned. It too, is supplied by air from the surface but there are several notable differences from the shallow water gear. First, there is a large

brass helmet with several glass ports which is connected by means of a breastplate and bolts to a heavy canvas suit. Second: There is a free flow of air between the helmet and the suit and in the helmet is a valve which the diver can push with his chin to release air; this gives him weight control. Third: There is a telephone system so that the diver can talk with his tender on the surface; this is the great advantage of the deep-sea rig. Today, most salvage and harbor diving is done in such suits. They are bulky, heavy (in air they weigh as much as 200 pounds) and expensive. Worst of all, when used from a ship (the usual situation), the ship must make a two point mooring* so that it will not swing and foul the lines; however, most old-time divers consider the use of any other gear suicidal. One version of this suit intended for very deep diving has a special helmet and is made so that an artifical atmosphere which replaces nitrogen with helium can be used (this decreases the decompression time considerably).

Underwater the important senses are touch (how the water feels) and sight. Smells and tastes are those of the surface or bottled air and there is relatively little sound in the audible range (the noise of the diver's bubles is likely to drown out what there is). To listen, the diver stops breathing for a moment if he is using the demand-type air supply of the Aqualung; in the deep-sea rig it is customary for the diver to shut off his air temporarily while he listens on the telephone. Both methods effectively stop the noisy bubbling of the escaping air. Near the ship we could hear the ping of the echo sounder, the engine room noises and the explosions of the

* Put out anchors fore and aft.

T.N.T from the seismic surveying but for the most part the ocean seems quiet to a diver.

The water feels wet---but only at first. Once below the surface the experienced diver's mind becomes occupied with his current job and there is no deliberate thought given to the simple functions of breathing, of clearing the ears , or of feeling the water. It becomes a natural element and is noticed no more than the air about you now --- except at one point, the thermocline. The underwater swimmer somehow accepts the water temperature at the point that he enters the water as being normal and adjusts himself to it both mentally and physically, cold though it may be. As he decends the water becomes colder; not gradually but all at once. That is, there is an upper layer of water, all about the same temperature, which is separated by a definite boundary from a lower layer which may be from two to ten degrees colder. The boundary between layers is called the thermocline and it may be a distinct shock to pass thru it; one touches it and hesitates like a man considering a cold finale to a shower. The thermocline may be anywhere from ten to 300 feet below the surface and it varies from day to day at most places; sometimes the cold water lies in puddles on the sea bottom and sometimes it is closer to the surface near shore like waves running up a beach. Almost always it is present and distinctly reminds the diver that he is in a foreign element.

Things look very much the same underwater as they do in air except that they are enlarged to about half again as large as one is accustomed to seeing them; all objects do remain in correct proportion however. A fish seen and speared underwater becomes dissapointingly small on deck and abalones that have

looked as big as a basket on the bottom turn out to be barely legal. In fact this phenomena may account for the large discrepancy in sizes between fabled fishes that "got away" and those actually caught. Probably a diver coined the phrase "ham handed" when his hand first crossed in front of his faceplate and his fingers looked as big as frankfurters.

The underwater world is a tremendously colorful place and in the tropical Pacific the plants and animals make liberal use of all the colors of the spectrum.

~~of all the colors of the spectrum.~~ Fish are striped and spotted and banded and speckled with incredible colors. Why, I do not know. It could not conceivably be protective coloration for all of them; in fact they attract attention. The algae are a brilliant green, the corals white and gold, the shrimp red, and to be with them on a shallow, sun-splattered reef without a color camera is frustrating indeed. Unfortunately, these colors are only seen at their full value near the surface. Below about 15 feet they start to become dull; the red portion of the spectrum is absorbed by the water and goes first. At 60 feet only blues remain. This is the unkind paradox of diving, for the attraction that offers the strongest lure dissappears first as one dives. Of course the diver can carry his own light and see the colors as they really are at any depth but this has not yet been made a convenient thing to do. The ~~new~~ changed appearance of familiar subjects is most striking --- particularly the surface of the sea as seen from below. Instead of the familiar peaked-up appearance of the waves and wavelets one sees their convex undersides. Hereafter, when fishing, don't worry about fish you can't see seeing you and being scared; it is just as difficult to see out of the water from below as it is to see into it from above. Puddles exist underwater, too; puddles of air. Under flat or convex surfaces air becomes trapped and looks from below just like a clear puddle of water does on land; it slops around, has a smooth silvery surface and you can see your reflection in it.

The underwater weightlessness of all objects is a new phenomenon for us air-dwellers--for all objects are buoyed up

by a force equal to the weight of the water they displace. If you have ever thought about what fun it would be to live on the moon which has one-sixth of the earth's gravitational pull and where you could jump six times as high as you can on earth, consider the things you can do underwater in a free diving outfit. There you can make the effective force gravity whatever you wish by carrying the proper weights; you can hover, float, or sink in a weightless ballet. Rocks fall slowly and bubbles rise slowly. Hair and seaweed stream under the influence of minute currents. Fish make zigzag courses while they swim straight ahead, for the water in which they are swimming moves with the waves.

Pressure

Most misconceptions about diving are caused by a lack of understanding of the effect of pressure on a diver. Many stories have been published about divers in which it is made to seem that the diver is in great danger or even pain because of the weight of the water above him. This is not an accurate picture; actually, the diver feels very much the same underwater as he does above it. It is true that the total pressure on a diver is very large but it is <u>not resisted by his body</u> --- <u>or by his diving suit</u>. Whether the diver wears a suit or not the pressure on his body is the same since the pressure of air inside the suit is exactly the same as the water pressure outside. It is simple to calculate the pressure on the diver's body. Seawater pressure increases about half a pound per square inch with each increasing foot of depth; at 20 feet the pressure is about 10 pounds per square inch (PSI), at 50 feet

about 25 psi, and at 100 feet about 50 psi. The average surface area of a man's body is roughly 18 square feet or 2600 square inches. Therefore the total* pressure* on a divers body at 20 feet is $\frac{2600 \times 10}{2000}$ or 13 tons; at 100 feet, 65 tons, etc.

These figures are huge but harmless since the human body is largely composed of solids and liquids---as incompressible as the seawater itself. Only air filled cavities such as the lungs, stomach, bronchial tubes and head passages (all interconnected) are subject to possible collapse since gases are compressible. As the diver decends and the pressure increases the volume of these organs will grow smaller unless he keeps taking in additional air. So the method of resisting pressure in a dive reduces to this: if the diver breathes in air which is at the same pressure as the water around him there will be no tendency for the air-filled cavities to collapse or expand since the pressure is equal inside and out and he will feel just the same as he did at the surface. The pressure due to the weight of the water is therefore resisted by taking additional air inside the body. For this same reason a diver must not hold his breath on the way to the surface. He must either breathe normally or exhale; otherwise the expansion of the air in the body cavities as the external pressure decreases may cause trouble known as air-embolism. This means that the small blood vessels in the lungs have ruptured allowing air bubbles to pass into the blood stream where they increase in size as the pressure drops and lodge at an arterial branching. The surface tension of the air bubble is usually sufficient to dam the blood stream cutting off the supply of blood and oxygen

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* In addition to atmospheric pressure of 15 psi.

to that part of the body often resulting in the feeling that an arm or leg has "gone to sleep" and more rarely in paralysis or even death. Damaging embolisms are said to have been caused by as little change in pressure as eight feet (four psi). That, theoretically, if a diver inhaled deeply from a SCUBA in the deep part of a swimming pool and then surfaced while holding his breath he would be apt to suffer serious internal damage. This situation is not to be confused with that in which the diver takes a breath at the surface, dives to any depth and then returns to the surface to breathe out again, for in the latter case the walls of the lung cavity remained in compression thruput the dive. In this respect the lungs act like a balloon and will stand a lot of compression (squeezing) but a very limited amount of tension (inflation) without bursting. In a standard deep-sea diving suit this changing pressure is taken care of by the fact that the flexible suit always maintains the same pressure as the water outside as long as it is recieving sufficient air from the surface and thus there is always a large reservior of air at exactly the right pressure from which normal breathing is easy. In the Aqualung, there is no large air reservoir comparable to the suit and the diver must suck his breath from a small air chamber whose pressure is intermediate between that of the bottles and that in his lungs; as he sucks in the differential pressure on a diaphragm opens a valve and high pressure air moves thru a tiny hole into the intake hose where it becomes the same pressure as the outside water and his lungs.

After the air is used it is expelled but this may have taken some time and if the diver has been rising rapidly he may have had the air in his lungs over rather a large change of depth. This is a dangerous situation and free-divers are particularly warned to exhale as they surface.

Temporarily the diver does feel pressure changes in his ears but he can quickly correct this discomfort. The human ear drum or tympanum is an elastic membrane that separates the visible part of the ear, which is open to the surrounding water, from an air-filled chamber called the middle ear. The middle ear in turn, is connected by a small soft tube (the eustachian tube) to the pharnyx or throat cavity. As we have seen, the pressure of the water must be resisted by air at equal pressure from within the body and although the other air-filled cavities are connected in such a manner that air flows easily between them, the smallness of the eustachian tube prevents rapid flow of air to the middle ear cavity. Nature has deliberately made this tube act like a small flutter valve so that we will not hear our every breath; at the same time the mechanism of swallowing or yawning has been provided so that the passage can be opened for short periods of time. As it opens a click or pop is heard and nearly everyone has experienced this in an aircraft or a fast elevator. When the diver decends water pressure causes the ear drum to bulge inward and a feeling of discomfort or even pain is experienced; in order to relieve this annoyance he must force air thru the eustachian tube into the middle ear cavity so that the eardrum will be supported by air pressure from the inside as are the walls of the body's other air-filled cavities. To move air into the middle ear the diver can swallow (but

this opens the tube only momentarily and must be repeated a number of times to be effective) or he can clamp his nose in some way, close his mouth and blow (snap his diaphram). This considerably increases the internal pressure and the air flows rapidly into the middle ear. Try it now and see. With a face plate on the diver usually finds it easiest to clamp his nose by holding the soft rubber bottom of the mask tightly against his nostrils with one hand. It is usually necessary to preform this maneuver about every fifteen feet in decending but because of the flutter valve action of the esutachian tube no difficulty is experienced in ordinary ascent. If an excessive pressure change comes too rapidly, the eardrum may burst and when it does a loud explosive sound is heard accompanied by pain and nausea. This is rarely a permanent injury and small breaks in the membrane heal within a few weeks; some divers have experienced this many times. This rupture of the tympanum is most likely to occur if the diver has a cold, sinus trouble or similiar infections; at this time the tube walls may be inflamed and unable to open thus making it impossible to balance the water pressure from within. Obviously it is unwise to dive with such an infection.

Diving ailments

There are certain ailments associated with diving in addition to the air-embolism difficulty already mentioned and although these have been highly publicized, they are fortunately quite rare. Best known is the "bends" or decompression sickness. When a diver decends to considerable depth and remains there for some time, nitrogen from the air in his lungs slowly goes into solution in the blood stream and thence is distributed thruout the body tissues. As long as the diver stays down, the nitrogen in the tissue causes no trouble and as he starts upward towards the surface and the pressure relaxes it returns thru the blood to the lungs and is exhaled---if the ascent (called decompression) is slow enough. If he returns to the surface too rapidly nitrogen bubbles may form---much in the same way that bubbles form in carbonated drinks when the bottle cap is removed. These minute bubbles form generally thruout the body and as the pressure continues to drop while the diver rises, they expand and distend the surrounding tissue. Most tissue is rather elastic and simply stretches a little so that the diver is not aware of the existence of the bubbles but particular tissues, such as scars and joint capsules, are inelastic and bubbles trapped there are restrained from expanding which results in the painful bends. The accepted treatment is to lower the diver back to where the pressure is high and then raise him again very slowly.

Many data have been collected and tabulated on the times that a diver may work at various depths and the times and depths of decompression necessary for the complete transport of nitrogen back into the blood and out the lungs. These data are known as the"diving tables" and all professional divers refer to them constantly and rise to the surface at rigidly prescribed rates. For shallow dives of less than one hundred feet and one hour like most of those described here, no decompression is necessary. In fact the limited air supply of most self-contained diving gear is likely to keep the free-diver

from getting into decompression trouble. Since he carries his entire air supply on his back, he must remember that when making deeper dives with larger tanks to time his stay below so that on the deliberately slow rise that is necessary for decompression, he will have enough air.

Occasionally divers get a very gay feeling like that of having had a few drinks too many. This is called nitrogen narcosis and is initself not harmful. A diver however, requires full possession of his facilitys to survive and is likely to do something foolish that will result in a serious accident when in this condition. Rigid physical examinations are used by the Navy to reject men who "get high on two beers"; experienced divers learn to recognise their own symptoms and return to the surface immediately.

A more serious problem of the free-diver is that he may be in danger of exhausting himself by overworking in the unusual element. Living in cold water, breathing against the resistance of the lung, swimming against strong currents or otherwise working hard, all contribute to fatigue and should be guarded against like any other physiological difficulty. The underwater swimmer must know his strength limitations and stay well within them.

THE MARSHALL ISLANDS

The first leg of expedition Capricorn took us to the coral atolls of the Marshall Islands where tropical diving is at its best. This is no coincidence either, for the waters where coral grows so well are the ones in which a diver is the happiest, and of the two, the coral is most exacting in its requirements. This greatest builder of all time must have conditions just right before he can do his best work. Water must be sunny and shallow; temperature must be between 75° and 85° F; and there must be a constant supply of clear water moving past. In short, a coral reef by its mere existence indicates that diving conditions are ideal. Consider for a moment these fascinating animals which, like the rose, have combined fragility and beauty with an occasional warning thorn which says to the diver, "Tread lightly and touch gently". Their tale has been told many times before but never, I believe, by a fellow dweller of the reefs.

Great atolls from little polyps grow

The coral, polyp is a strange little animal rarely larger than the eraser on a pencil; it feeds, mostly at night, by extending small tentacles and catching even smaller animals called plankton which float past. Most important from our point of view, the coral extracts calcium carbonate from the sea water and with it builds a hard lime sheltering skeleton which it attaches firmly to something solid---usually another coral but originally to volcanic rocks. These coral polyps reproduce by budding new polyps from the margins of the older ones and the new and old animals remain together adding additional lime to fill the spaces between their skeletons. A coral then, in the usual sense, is a colony of these polyps all living as a single solid unit that takes on all sorts of weird and wonderful shapes which are popularly called by the things they resemble. There are brain corals, antler corals, fan corals and many others; each a colony consisting of many thousands of animals which somehow resemble plants and have been poetically called the "frozen gardens of the deep". The shape of each colony depends on the manner of the budding and the amount of crowding of the polyps; it seeks the sun and leans with the current. No two are alike.

With the corals and partly dependant upon them for food and carbon di oxide live plants called calcareous algae which also secrete lime to form a sort of skeleton. As the reef grows the older corals and plants die off as the newer higher ones stop the water circulation and cut out the sunlight; wave action breaks off and grinds up the skeletons; fish eat the living

corals dropping a trail of sand; algae die and their calcareous plates settle to the bottom. Little by little the spaces between the roots of the coral garden become filled with calcareous debris and passing solutions dissolve and redeposit enough of the lime to cement the particles together. This newly-formed limestone offers a place for more corals to start and the process goes on and on. Over half a million square miles of the earth's surface has been so created. As the sea level has gradually risen thru the geologic ages, the corals have builded ever upwards from the volcanic basement rock, climbing over each other to stay in the sunny shallows they like so well. In this way coral rock a mile thick has been formed [redacted] and herin lies the story of the atoll.

The visible ring of breaking reefs and palm covered islands that we call the atoll is only the surface showing of a great mountain that rises two and a half miles from the ocean depths; a mountain that if placed on the Colorado plains would tower three thousand feet above Pike's Peak. Of this structure the bottom portion is a hard dark rock which once rose as a volcano in its own right but now is merely a basaltic pedestal for the ever-rising limestone reef that caps it

Millions of years ago when the ocean was 5000 feet [redacted] shallower than it is now and part of this volcano broke the surface, a tiny coral drifting freely on the surface of the vast ocean encountered a rock in the shallow water near shore and attached itself; it grew and multiplied and with it [redacted] thrived calcareous algae. First the corals spread sidewise until the

island was encircled by a fringing reef which lay right against the original cone itself. As the ocean level rose, this reef built straight up upon itself while the part of the volcano that showed above water became smaller and smaller. In time the corals, needing the nutrients of the freely-moving waters of the surf, refused to grow far from it and left a quiet lagoon around the original island which was protected from the great ocean waves by this outlying coral ring, now called a barrier reef. Eventually as this slow process continued, the tip of the volcano dissappeared below the surface and only the coral ring remained. So the reef became a full-fleged atoll with a great circular lagoon over the drowned volcano--- the great granddaddy of the atoll of today.

Great storm waves break off pieces of the limestone rock from the outside edge of the reef and fling them into the lagoon; constant currents driven by winds and tides sweep over the shallow reef moving coral and algal fragments with them and these settle to the bottom in the quiet lagoon. So grows the great structure; the coral building upwards on the reefs and the lagoon filling with sediment.

On the storm-flung boulders and on other hard spots in the lagoon bottom, more corals take root and grow becoming coral heads or knolls; massive coral fingers reaching up thru the clear calm water. A coral head may be as small as a suitcase or as large as an apartment house; some reach nearly to the dark blue lagoon surface where they show as light milky-green spots and the lagoon navigator must be on constant watch for them or he will soon loose his craft. Around these knolls the fish congregate in great swarms, hiding in the grottoes and under the flat coral branches or deliberately flaunting their gay costumes and then dodging into a coral thicket. Surely coral heads are among the world's most beautiful natural objects and the man who

could bring one back for exhibit, intact with its bright fish and shifting sands and swaying water would have a priceless attraction. Today one sees the geological processes of atoll building in each of its stages; in cruising about the islands, there are new and naked volcanoes whose waters are still too muddied by volcanic dust to allow the corals to grow; others are hugged by the fringing reef and still others, like Tahiti, have an offshore barrier reef which encloses a quiet narrow waterway around the island where light canoes can travel in safety. The echo-sounder shows still another stage deep below the surface; the volcanic mountain on which, for some reason we do not understand, corals never grew; it tells us where the sea level was when the atolls were begun and the corals started their climb.

The rings of small islands that break the surface are thus but a diadem of palm-covered coralline mounds that rise from the shallow encircling reefs of the huge unseen submarine structure. They are low, rarely reaching ever fifteen feet above the low water mark, and sandy, shifting their positions at the will of the passing waves and currents so that old charts often show more or fewer islands than now exist—and in strange shapes and positions. In the main, the solid reef remains unchanged although large semicircular notches in its outer rim give evidence that pre-historic earthquakes have shaken the earth so that large pieces of the reef and perhaps the islands on them, have broken off and slid down the steep outer slope into the abyss. On the leeward sides of the atoll an occasional channel or pass cuts thru the reef and connects the lagoon with the ocean. Thru these passes the tidal waters move in and out of the lagoon and the excess water thrown across the reefs by the breakers on the windward side is drained off. The number of passes thru the reef is related to size of the atoll and smaller lagoons rarely have a pass. Since these deep passes are the only means by which ships can reach the comparatively calm lagoon, the economy of the

islands and their military value depends to a considerable extent on the size of the lagoon and whether it is accessible by a pass.

The small lagoons may be no more than a half a mile across and are sometimes almost completely encircled by a single island; this is the idyllic situation usually pictured by the public's mind. There are tall palm forests which grew right to the waters' edge so that at high tide one must wade to pass them and there are shell and coral beaches so white in the sun they hurt the eyes which fringe the glassy lagoon. But there is a price on such beauty, for islands where the palms are so thick they stop the wind are invariably hot, and closed lagoons are comparatively stagnant. Such small lagoons are found in the Ellice islands and the Fijis but In the Marshalls the lagoons are large and quite different in character and at times frightening. Bikini lagoon for example, is over 10 miles across at its narrowest part, Eniwetok, fifteen; the islands around their edges are relatively small and from a small boat near the middle one cannot see land or even the tops of the palm trees in any direction. When storm winds blow, the down-wind side of the lagoon is scarcely less rough than the ocean and although there are no great swells, the waves generated within the lagoon itself are short and steep and sometimes as much as five feet high.

Navy landing craft, built to operate in the surf, have been trapped by squalls on the downwind shores of the larger lagoons and battered to pieces with the loss of their crews, so that present regulations call for the cessation of small craft operations when high winds are expected.

To the underwater swimmer the atoll appears as a series of fizzy-edged bluish worlds each with different and readily recognizable characteristics limited at any moment by the range of vision. Above water he sees things below not known to ordinary mortals in the same way that a mechanic looks at the outside of an engine and sees it operate as though the moving parts were exposed . With X-ray eyes the diver's mind penetrates the waves to recognize five distinct environments; the outer face of the reef, the surface of the reef between the islands; the

passes; the beaches inside the islands which slope away to form the lagoon bottom; and the coral knolls. Once he has examined a particular crevasse in the reef, a special clump of coral or an unusual knoll, it becomes a scene as recognizable to him as a blazed tree to a woodsman.

The outer face of the reef below the churning surf is the most dangerous and in some ways the most fascinating of these regimens; here there are surge channels in the limestone, steep-walled dark canyons that offer a serrated edge to the waves. Their bottoms are paved with cobbles and their upper surfaces and outer points studded with spiny echinoids and coral colonies. There are more and larger fish here, including some varieties which do not seem to enter the lagoons, and the deep-reaching water movement of the ocean swell.

The surface of the reef between the islands is another of the atoll's worlds. Here, in waters rarely over a man's head at high tide, the corals seem to grow the best and show the most color. Waves and winds sweep the outer waters across these shallows where the bright sunshine warms it and the lucky corals here get the first chance at the incoming food supply and grow fat and healthy as a result.

The deepest parts of the passes into the lagoon are usually about the same depth as the nearby lagoon bottom itself and towards the sides of this coral-hemmed channel the sands of the bottom slope gently upward until they finally end abruptly against a vertical wall which reaches the last fifty or sixty feet to the surface. Small corals encrust the channel walls and large gorgonian fans branch from them; thru these the reef fishes rise to forage in the shallow coral gardens atop the reef.

Islands contact the lagoon via coral sand beaches thru which an occasional pitted piece of reef rock shows; these sands slope away steeply, then gradually, then steeply again until they reach the ultimate depths of the lagoon. In the deeper areas of the lagoon the bottom is fine white coral dust, easily stirred by a passing fin into a fog of suspended particles. Most important is the fact that divers can reach the bottom anywhere in the atoll lagoon, for depths over 200 feet are rarely encountered. Usually however, the sandy slope and the deep bottom environments are less interesting to the diver than the living reefs and dives there are more often made to see the works of man than those of nature.

Last of the atoll's little worlds is that of the coral knolls on which I have already expended many superlatives. From a ship they appear as dark shapes in the light green water for which the navigator must be ever watchful but below the surface they are seen as intricate living towers where there is no wave motion or other disturbing influence. Here free from danger and annoyance were taken the best of our motion pictures.

Corals and Cables

The oceanographer is the blind man of science; with his long cable for a white cane he lowers instruments far down into the lightless depths of the ocean, tap, tap, tapping at the unknown, groping for bits of truth. Never does he see these instruments operate and frequently there is some doubt about exactly what they did, and when, a nd how. Perhaps it would seem obvious to test these submarine measuring and sampling devices in shallow water with a diver looking on but this is a difficult thing to do in the cold and murky coastal waters of the United States and very few underwater instruments have actually been seen in operation.

On a dozen occasions, the Capricorn scientists would have given their last cocoanut to have known exactly what happened to the coring tools, or the temperature probe, or the dredges, while these were on the bottom over two miles below —— and in frustration the most far-fetched explanations were considered for inexplicable records and reactions, but the security of the whole truth was missing. Not all measurements of the ocean's strange whims and changes need be made from a ship in deep water however; waves, for example, are best measured by instruments resting on solid bottom where the water is shallow.

On an island in the Marshall group we wanted to measure the ocean waves of the Western Pacific so that we could compare the data with records of waves arriving on the California coast. In the instrument that was devised, a pressure-sensitive box or head is firmly mounted on the ocean bottom in water about 60 feet deep and from it an armored cable containing insulated electrical conductors leads ashore to the graphical recorder and power supply. The weight of the waves passing over the pressure head compresses an elastic bellows and an electrical impulse is transmitted thru the cable to the recording device on the beach where a pen neatly draws the shape of the sea surface on an ever-moving roll of paper. From this record the height and frequency of the waves can be

worked out if the relationship between the pressure on the bottom and the movement of the pen has once been established.

Time for building the complex wave meters was short; time for collecting data with a ship standing expensively by was even shorter. How to improve our efficiency?

We knew from past experience that the underwater working conditions would be good, so here was a chance to try something new which would save valuable time. Underwater swimmers would help install the instruments and work with them on the bottom. This was a new use of the free-diver and the first halting step forward in a program of, "see the wheels go 'round underwater".

Somewhere along the fifty-mile perimeter of the atoll we would measure waves and the first problem was the selection of a suitable site. After narrowing down the possibilities a great deal on the basis of exposure, bottom topography, and nearness to an island, (convenient for a recording station) the ultimate choice would be made by underwater swimmers.

Warren Beckwith, Todd Carey and I shared the work, and although we were all experienced working underwater off Southern California there were many new unknowns. The foremost thought in our minds was, "What will the sharks do?" for we knew them to be abundant thruout these seas. We knew little or nothing about which animals and fishes were poisonous, whether there were dangerous eels and groupers about, or if the waves and currents would drag us over the sharp corals. Would we need protective clothing? Is it better to try to wade across the reef with a lung or risk taking a small boat outside the lagoon? These questions we asked ourselves but they were comparatively academic; it was the sharks we were concerned about and every time we mentioned that we were going to dive in these waters we heard another shark story. (It may be that there was originally only one story but in the telling and

retelling it divided and changed color until there were many). At any rate we took some precautions. Divers were to carry knives or a short wooden spear with a dull iron point; there was to be a shark lookout on the boat who would warn the men below by pounding on the bottom of the boat; and the lookout was to carry a gun to shoot at any sharks he might see. This

latter item was really intended to occupy the time of the men in the boat so they would not become too bored or worried for we all knew well that a bullet will not penetrate water over a few inches and the chance of damaging a shark at any distance was infinitessimal. The gun however was very handy for sinking passing cocoanuts and had the effect of making the swimmers very careful not to break the surface anyplace except alongside of the boat. Whether or not the lookout would have even seen a shark or not is doubtful, for although I have often read that one notices sharks when their black dorsal fins are seen cutting the water, this turned out to be a very rare sight even when sharks were all about; almost always we would find sharks below of which the lookouts were unaware. If the lookout ever fired a shot in anger I do not remember it and although shooting at sharks from the ship became a pastime later on, none ever seemed to be hurt.

Our first reconaissance of the southern islands and reefs of the atoll answered many questions —— both about cable sites and sharks. Using a borrowed DUKW (the Army's amphibious truck) which makes an admirable diving barge, our party was able to land on various islands, cross the less rugged reefs and inspect the unknown waterways free of the usual small boat problems. For the DUKW is a wonderful hybrid having the best features of the Army truck and the Navy landing craft. It has six wheels with heavy ribbed tires and when power is flowing to all of them the DUKW is hard to stop ashore; in the water with wheels either turning or disengaged, a large propeller drives it as a boat at nearly six miles per hour. The wheels hang down on their springs acting as excellent underwater bumpers and although this causes considerable drag which slows the craft down somewhat, it also gives stability achieved by no other small boat so that they ride easily thru the roughest surf. They're wonderful machines; I love 'em.

The first dive was made off a large island on the south rim with a long difficult name where a narrow channel of white sand bounded by ragged living reef sloped abruptly from the island into deep water. This channel looked like it might be an excellent place to lay a submarine cable where it would free from sharp coral edges which might chafe and damage it; at least it was one of the most promising possibilities. We

eased the DUKW out across the shoal sands until its wheels were just touching bottom, and Todd and I in Aqualungs dropped off into the shallow water and swam slowly seaward along the bottom. Almost at once we saw a large turtle only a short distance to one side making frantic and erratic flipper motions to get away and, since it was the first I had seen, I was tempted to follow it but with great resolution continued the survey. The sand bottom had been formed by currents into giant ripple marks or waves of sand as much as two feet high and five feet from crest to crest, and in the hollows of the troughs were fascinating shells and coral fragments. Here too there was a temptation to dawdle but this time the sight of an approaching shark changed my mind.

Now was the time to find out if shark stories were fact or fiction; if we were going to continue to dive in shark-infested waters it was absolutely necessary that we know how we stood. The fellow who was approaching was a grey shark about five or six feet long and perhaps weighing 180 pounds——roughly my own size. I got out my small pocket knife, opened its largest blade and headed for the critter; as I did the picture of Peter facing the wolf with a pop-gun flashed thru my mind. He, or she, looked a little surprised and turned away; I followed him from the sandy area thru a little valley in the coral swimming faster all the time but without the slightest intention of overtaking him. Finally, with an exasperated air and one swift flick of the tail, he instantly tripled his speed and dissappeared from sight. The issue was decided, for the moment anyway, and I turned back. Just what I would have done with a beligerent shark is hard to say, for the little knife blade (not over three inches long) would have inflicted a more infuriating than damaging wound.

We continued along the sandy river and the endless blue of deep water (I always think of it as the color of infinity); appeared ahead. The bottom curved gently downwards, then steeper and steeper until it must have sloped sixty degrees or more. The sand waves lengthened out and somehow changed into a staircase-like succession of narrow rock ledges with sand falling in waterfalls the dozen or so vertical feet between them. Steps descending ever more steeply into the abyss. Here the sandy channel had widened to over fifty feet and on each side the reefs stood vertically; clean-cut black buttresses that rose from the deep past us almost to the surface. At about sixty feet there was a school of fishes with three small sharks (three or four feet long) circling them, but they gave no sign of seeing us although we approached within fifteen feet or so. A pressure head could probably be installed on one of the ledges but it would be hard to do----and if it slid off it would be gone for good. We would have to inspect other sites before making a decision and turning, started back up the slope. On the return we found we were bucking quite a current; this should have been no surprize because it was evident that the sand river was maintained by some special force, but it was a little discouraging to swim at maximum speed and barely make any headway. We knew we could not keep up the effort long enough to get back to the DUKW in the channel so we swam to one side and worked our way along over the shallow reef rocks where the current was slower and where we could grasp the corals and pull ourselves along the bottom. It was work, but we made it back all right, climbed aboard the floating truck and moved on.

The next prospective location was in one of the deep passes leading into the great lagoon between two small islands. From each island a table-flat reef covered with growing coral extended a hundred yards or so before it dropped away into the quarter-mile wide passage where the tidal waters of the lagoon flowed; because the pass was short, deep and well exposed to the ocean, it

was possible to measure waves near its entrance. Near the sides of the passage where the water was from thirty to seventy feet deep, it was possible to see bottom from the surface and I clung to the side of the DUKW with my head under water as it plowed slowly along, looking for a likely spot. John Isaacs rode the forward deck with the rifle at "ready" and a fierce bandolier of cartridges around his middle---he fired occasionally at "suspicious objects" and told long sad tales about how great sharks of twenty or more feet long were likely to be cruising about in such passes. He didn't really convince anyone but the conversation kept the kibitzers busy so that the divers could work in peace.

Warren and Todd dove to make the next examination. They had hardly gotten into the water when both surfaced, spluttered something about a lot of sharks around and disappeared again brandishing knives. I put my head under for a moment but could not see anything and so climbed back on deck and stood nervously awaiting developments. The current was fairly strong and by watching the bubbles break the surface we could see that the divers were being carried along out to sea. I was really as much worried about the current as about the sharks. In a few minutes Warren surfaced nearby and said,"There's a big one circling Todd", (it later turned out to be only about six feet but that's big enough in some circumstances) and a moment later Todd broke the surface about fifty yards away apparently to see where he was. "Come back", I ordered.

Todd removed his mouthpiece long enough to holler, "I'm more afraid of the shark than I am of you" and was gone again. Apparently by this time the shark had gotten dizzy or otherwise discouraged and left and soon the two divers were back aboard. "A very good location", they confirmed, and it was decided to make use of this site. We dropped a marker-buoy and called it a day

The cable which was to be used to connect the pressure-sensitive element underwater to the recording devices on the beach was stored on a large spool on the after-deck of the Horizon. Because of the danger in operating the ship close to the reefs in the swift and changing currents of the pass, we elected to use the old reliable DUKW for cable laying. Solid in the water, slow but powerful and able to take the shoreward end of the cable across the reef and up the steep beach to the ultimate destination, the DUKW was remakably suited to this purpose. As always, cable laying was hard work, right from the beginning, and many hands were required to unspool the steel and jute covered cable, pass it into the DUKW, and neatly coil it there in large figure-eights.

After that the anchor, made from an old railroad wheel and weighing about 300 pounds, had to be loaded aboard (in place of the spare tire) and the pressure instrument spliced to the cable. We were lucky on the weather for although it was never really bad, on some days it was better than others and on this day the lagoon surface was unrippled so that the reflections of clouds and cocoanut palms waved at us from below. Just right for this kind of a job, and with half a dozen not-too-eager beavers aboard, the DUKW headed for the instrument site in the channel leaving the Horizon anchored in the lagoon.

On approaching the selected location the first difficulty became apparent; whereas we had surveyed the cable path at high tide, the cable would have to be laid at low tide. This was not exactly a surprize for we had calculated what the tides would be, but the reef turned out to be too rough for the DUKW to traverse with much weight on the wheels; partly waterborne it could have readily crossed the deep holes in the live coral reef surface. Pressed for time as we were, there was no waiting for the afternoon high tide; the cable would have to be laid now at a nearby break in the reef and moved to its final site by hand later on.

The plan was to drop the anchor and instrument alongside of the marker-buey and then run the DUKW in slowly along the selected course allowing the resistance of the anchored end to drag loops of cable from the cargo hold as we went. "Stay out

of the bight!" was the oft-shouted watchword (meaning don't get a leg caught in a loop going over the side or it will drag you over with it). This scheme worked beautifully and in half an hour the job was done; as a truck, our craft climbed up the beach and with less than 100 feet to spare, dropped the shoreward end of the cable alongside of a tent that another work-party had set up to hold our shore station. Hushed and sweating in the still hot air, our breath sounded noisy as we huddled over the ohmmeter to check the resistance of the cable. Infinite to ground! (no leaks) And we gave a sort of gasping cheer and relaxed; we were over the hump —— but there was still a lot to do.

Inside the tent there was a heap of batteries, instruments, tools, C-rations, extra chart paper, and momentarily unidentifiable boxes. By lunch time these had been organized and assembled, our wave recorder was working and the situation looked pretty good but two major items remained to be done: the cable had to be secured to the reef surface so that it would not wash about or chafe when the waves were large, and the instrument had to be calibrated.

After a quick lunch and a quicker siesta we went back to work, for ironically time was our scarcest commodity at this timeless atoll. By now the tide was several feet higher and we could swim above the surface of the rough reef, stand on the highest corals, and skin-dive to the deepest holes. Since the reef was over a hundred yards wide, it was necessary to move this much cable sidewise for nearly fifty yards. Five of us, spread along its length, tugged, dived and freed the loops, and tugged in a new spot. Since we could only carry a few feet of the stiff and heavy cable at a time there was always a loop dragging bottom. The blasted thing hung up like a comb in a sheep dog, but little by little we worked it along and on the verge of utter frustration, finally suceeded in placing it safely in a meandering slot in the coral where I hope it stays forever.

Then on to the final step which required diving to the pressure head at the end of the cable some sixty feet below. For this we piled the diving gear in a

small skiff, rowed out to the marker buoy, and tied up, and descended to work with an instrument on the bottom. As I went down the buoy line, it was necessary to make one stop to clear my ears and as I hung there for a moment gazing vacantly out thru the clear water, four miniature space ships appeared moving slowly towards me. Polished aluminum bodies with perfect streamlining and control windows like large unblinking eyes; as they glided slowly towards me I could see the long row of windows along the side and the jet propuls —— No! they were fish; but automatic non-living fish. Unbending except for the tail, they did not move like a fish; no scales were visible, only their dull metal hulls; and as they approached, passed and dissappeared again in perfect formation on an unswerving course, I had a strange feeling of unreality; Buck Rogers himself would have been scared out of his space helmet by such a sight. Dog-tooth tuna, each about four feet long and any one of which would have been a wonderful meal for the entire ship's company. So the diver sees at unexpected times and places the endless wonders of the deep.

Calibration is a commonly used technical word which means that the response of an instrument is related by a precise test to the actual physical changes that it is supposed to be measuring. Almost everyone has calibrated the speedometer on his car by running it over the "measured miles" marked along many roadsides; from this one can find out if it reads too fast or too slow: Perhaps at the end of the mile the milometer will read a tenth more than it should; when it reads 50,000 miles this calibration is recalled and mentally one calculates that the car has actually gone only a little over 45,000 miles. Scientific measuring instruments are usually calibrated very carefully before and after every use so that there is absolutely no doubt about the quantities that they measured and our wave meters were no exception —— but the problem at first seemed a tough one. Now the time-honored method of making calibrations would have involved, in our case, the creation of an even set of ocean waves of known height (a very difficult

thing to do); we would then have set the pen to move six divisions on the record paper for a six-foot high wave, four divisions for a four-foot wave and so on. It is of course, possible to simulate such pressure conditions in special tanks ashore but we had no time for that; moreover our instrument acted differently in every depth of water.

The calibration procedure we used this day was unique, but straightforward and it showed us beyond all doubt exactly what the instrument would do on a day when there were waves. The only equipment used was a folding rule.

The bottom was light and pleasant with flecks of dancing sun on the irregular slope, and a hundred feet to one side, the dark reef rose steeply without its usual ominous appearance. The railroad wheel on which the instrument was mounted was surprizingly easy to move and I dragged it down the slope to a more level location where it would not be moved by the sometimes strong currents. Walter Munk arrived on the bottom and we set about the calibration.

This wave meter really measured pressure---any pressure, so that any change in the height of the water above the pressure head was picked up --- and presumed by those who watched the record ashore, to be a wave. Thus, in order to make a record that looked exactly like a series of five-foot waves it was only necessary to raise and lower the pressure-sensitive element five feet a few times. This is exactly what we did. Walter held the rule vertically and I stood, legs apart, stomach braced against the half-axle until, by carefully adjusting my leg-span, I was able to make the top of my head exactly five feet above the bracket on the anchor wheel. Then I hoisted the pressure pick-up to the top of my head and held it there for a few minutes remaining motionless, then lowered it to its bracket for a while and raised it once more. On the shore a five foot wave was recorded. As I stood immobile, crowned by the brass instrument case, I was a little embarrassed by a number of fish which circled about staring at the strange sight and my eyes would follow them as they passed before the face-mask in their

silly merry-go-round. Maybe it was a bit crazy but this was science in action undersea —— and scientists are entitled to be a bit crazy.

The work of the day was done and now we could spend a little time looking at the bottom of the pass; Walter prowled off into the distance looking at new coral varieties, and I returned to the surface to get a camera. It was getting late but pictures were still possible and I worked down the slope to a depth of about 80 feet where the bottom leveled off, becoming coarse white sand; a great gorgonian fan grew out from a solid projection of reef rock. This fan must have been eight feet in diameter and no thicker than a few inches; between the stout branches was the most delicate tracery of webbing not unlike the carved screens of the Taj Mahal. I sat on the bottom nearby with the sun behind me, and waited for some fish to cross in front of it. Soon several did and the camera flickered away; then back up to the instrument for some portraits of it working.

As I was finishing a long pan of the cable weaving its way between the corals, a shark appeared in the viewfinder. Wonderful! and I moved slowly towards him until he filled the entire frame. At that point he moved away and I followed, intent on getting my first shark scenes. The shark circled and as I cut across to meet him head first, I encountered Walter prying away at a coral colony. He looked up and seemed pleased that I was taking his picture. Then, plain as plain could be, the little wheels in his head started to go around. Why had I suddenly selected him for a photo subject? Turning he saw the shark coming up behind him and there was doubt no longer. Walter did a very neat upwards and backwards motion like a somersault and the shark passed beneath him. By comparing their sizes later we decided the animal must have been about eight feet long. I continued the chase and eventually got as close as about five feet but he never really cared for my company and soon left.

We followed suit for the sun was getting low and so was our air supply. In an hour and a half below we had seen and done a lot of new things and the grip on our new scientific tool was getting firmer.

Beyond the reef

As I have already indicated, coral reefs take many forms being shaped and moulded by the seas currents, the light, the food supply and the waves. The most difficult for a diver to attain, and the most curious of its many regimens is that of the outer edge of the outer reef where, just beyond the breakers, is a world of steep cliffs, cobble-filled gulleys, sea castles and fabulous fishes. This is the land of the surge channel where the seaward edge of the flat surfaced outer reef is dissected by parallel gulleys, caves, and crevasses which point outward from the atoll towards the abyssal depths of ocean. Overhead, on the surface, the great waves roar and break up, spending their energy in passing this ruggedly serrate edge and crashing hopelessly on the lithothamnion ridge just beyond --- tamed to ripples. In comparison with the thousands of men who have swum in the lagoon and on the inter-island reefs, perhaps a dozen have seen the bottom outside the atoll and very few, if any, have dived there. Todd and I are lucky to be among these few.

In the Marshalls one can depend on winds and seas from the northeast, for this is the belt of the trade winds. Day after day there is a white line of breaking waves five to eight feet high along the northeast rim; between each wave the atoll bares its coral teeth in sullen defiance. Only a very few days of the year is the edge of the reef calm enough to attain with reasonable safety and even then

an occasional large wave makes the crossing adventurous. It was on such a day that we made this dive.

We waded out across the reef wearing the usual tennis shoes, Aqualungs, and face plates and I carried the Fenjon camera. The flat dead reef had a slippery surface full of solution pockets with an occasional live coral stalk --- enough so that it was dangerous to fall to one hand without inspecting the bottom first. We crossed, half kneeling and half crawling to keep our face plates below the surface so we could see where we were stepping. In the holes were spiny sea urchins, brittle stars, and sea slugs; in one was a rectangular-trigger fish which I half-heartedly tried to remove but gave up when he flattened against the rock like a de-cal on a kitchen cabinet. As we approached the reef edge which was about 50 yards from shore (the closest we could find) the water deepened a little and small unbroken waves moved past us. We swayed but stood fast, for the real wave energy is in the breakers. By now the water was up to our waists --- at least three feet --- and it was evident that a slightly larger wave would down us, especially with the heavy air bottles still out of water. Between the wave crests, the trough left (only) water to our knees and it was, of course, accompanied by a swift seaward rush of water around the increasing numbers of sharp, live coral.

Then we caught it; three big ones in a row. I had fortunately just tightened my faceplate and taken the mouthpiece in my teeth when the first breaker hit me. It was less then four feet high but it knocked me to my hands and knees on the sharp coral and the foam of bubbles it churned up made it impossible to see; after the crest passed I tried to right myself but the trough rushing into the next wave held me down. Whether the camera was a hindrance because of its drag or a help because of its weight I do not know, but there was no releasing it and I remember floundering and washing about in two more waves and taking a lot of small cuts before I could half stand. It was now or never, and I flung myself seaward and struck out.

Within 15 feet, the bottom dropped away sheer and I found myself descending into a natural room with an irregular plan but sheer rock walls; its floor was paved with grey coral cobbles. Here there was little water motion but I could look up and see the waves passing overhead and turning white at the crest just as they passed from sight on the landward side. The seaward wall was missing and I saw Todd disappearing in the blue; soon he turned a boulder and only his bubbles were left, temporarily, behind. I sat on the bottom and pondered, first my cuts and scratches, then my surroundings. The room was a large surge channel roughly 20 feet wide and having a floor that much below the water surface. The walls were of dead brown coral and

absolutely vertical; to the landward side, the room divided into three crevasses separated by buttresses of coral extending up to the level of the reef. It must have been at the extremity of these cracks that the waves had knocked me down and walked over me.

Although I had flown over these surge channels many times and thought I had a pretty good idea of what they were like in advance, the appearance of one from the inside somehow surprised me. Mostly because it was a lot larger than I had expected, partly because there was a strange and indefinable air about the place; cool like a vault. Close to the cobbles there were a few small fishes and some ragged bits of weed wich swayed gently in the wave currents.

I half crawled, half swam out to the open end turned a nose of coral and headed back into the next room. Ahead of me several boulders rose with live coral growing profusely and looking over the top, I saw the most fantastic collection of fish I have ever seen in one place; there were dozens of species, hundreds of fish. Although I never cease to be amazed and delighted by the fish which abound thruout the tropics this was, I think, the zenith of my experience. There were blue coral fish, blue-green parrot fish, wrasses , butterfly fish, tongs and a great many more which I could not identify. They cruised back and forth just below the surface over a strangely formed group of coral heads. The camera went to work at once and I was able to obtain a fine sequence of

16mm color movies for later study. Of course, the passing waves swayed me and the camera too, for we were only about 10 feet below the surface but I grimly clung to a jagged coral cluster with one arm and cinched the camera against it with the other so it held relatively still while my body and legs swayed back and forth with each wave. When the film was used up, I set the camera down and looked more closely at the fish.

There was quite a school of parrot fish, a dozen or so packed tightly together and I concentrated on them, having heard of but never having observed their unique feeding. These fish were adults, each about a foot long and colored a changeable blue-green. Their shape is not unlike the bass of American waters except that the mouth bears a considerable resemblance to a parrot's beak. They live on live coral and it is strange indeed to see and hear them taking bites out of the rock-like coral clusters. They nibble away, grind up the chunks and digest them; their stomach and intestines must sort the animal flesh from the calcium carbonate casing, for the fish excretes little white dots of matter. I swam after one and allowed the material to settle onto my open palm; it was clean white coral sand. There are great numbers of the fish which, in a lifetime must consume a tremendous amount of coral; it seems likely that they are a very effective geological agent in creating sand.

Now I decided to return to the beach for more film and although the prospect of traversing the breakers again was not pleasing, I worked my

way into shallow water and after being rolled over a few more times, got to my feet and staggered ashore. Looking about for Todd I saw a head showing off shore. It was Ned snorkling over Todd. He excitedly called, "We've got another Clam".

The camera loaded, I dragged myself across the reef again and thru the breakers, submerging in the midst of the swarm of fishes who paid not the slightest attention. I swam thru them, grinding away with the camera and sat on a rock to watch some more. In the distant blue I could make out a shark and feeling that some good shark footage would be nice I rechecked the lightmeter reading and the camera settings. Finally, the great fish turned and swam directly for me; he was about eight feet long and had a large remora clinging to his under side. With elation, I leveled the camera and pulled the trigger. Nothing happened; the magazine had jammed. (or did the equivalent for a fish, whatever it is called) He paced up and down thru the smaller fish who paid no attention. At pacing, sharks are often as bad as polar bears, going back and forth over the same ground in exactly the same way time after time.

Already the situation appeared in a different light. As a photo-subject the shark was superb but if no pictures were possible, he was only a nuisance. A large nuisance too, for I felt it was necessary to watch him respectfully and continually. Moreover, my air supply was probably getting low and the thought of crossing the shallow reef with the shark snapping at my heels was not pleasant --- for he could

operate very nicely in the waters where I was blindest and most awkward. But there was no other possibility so I waited until he started off on the outward leg of his pacing and dashed for the reef. With one flick of his great tail he could have overtaken me and I knew it, but it seemed better to try this plan than to edge across the reef edge and maybe be smashed up by the breakers. As it was I was lucky and neither breakers or shark bothered me although some huge waves broke just after I passed the critical zone and their foam lines helped carry me ashore.

Ned and Todd somehow got the clam to the beach although it weighed 150 lbs, and carried it across the island to our waiting boats on the lagoon side.

This trip marked the beginning of our underwater geological field work. I felt particularly pleased because here was a place where only free diving equipment could be used. To have tried diving using air lines run across the jagged reef or to have attempted to anchor a diving boat in the open sea just outside the surf among the coral patches would have been sheer suicide. This test of our free-diving gear in a new and difficult location gave us a mental boost and added confidence which we were to need in the dives ahead.

Search for an aircraft

In some devious way which I do not now remember, we became involved in the search for a military aircraft lost in Eniwetok lagoon. The plane had run out of fuel and was trying to make the field in a glide; it didn't --- by over a mile.

The Navy wished to retrieve the plane for examination and bury the pilot, and knowing that we were engaged in diving in the lagoon anyway --- wouldn't it be nice if we spent a little while locating the plane and putting a line on it for them. A number of people had seen it go down and had good "fixes" on the position; it wouldn't take long to find and would be easy --- for us. That officer was a real salesman.

Naturally, there was no compulsion to make the effort, but curiosity about ways and means of search diving and eagerness to explore the possibilities of free-diving gear led us to accept the job. No pay, long hours, adventure.

First we got a chart and plotted the point where the plane was seen to go down; this "point" became a triangle of error nearly a mile on a side in water from 60 to 130 feet deep. This was staggering; I had anticipated searching an area not larger in size than a couple of football fields but this vastness --- well, it might take weeks, and we could spare four days. So it was decided to search around each of the possible points in the order of their apparent reliability.

The Navy's contribution to the search was Lt. Roy Clymer, a small landing craft, and about eight men; we contributed Warren, Ned Barr, me, and the diving equipment.

Successful search diving depends on system; a plan must be thought thru and followed or the diver will loose all track of where he has been and search some areas over and over while missing others completely. It was particularly important that we keep track of exactly where we had searched because of the large distances involved.

On the first day we made a rather superficial examination of the most promising areas with the fond hope that we would be lucky and spot the wreckage at once. We weren't, of course, but it was a good opportunity to see what the place was like and try out some ideas. Conditions were excellent. There was lots of light and we could see the bottom, 60 feet below, or at least make out vague colors and shapes there, from the surface. By descending two-thirds of the way to the bottom however, we found that a diver could see about 120 feet in each direction; a little less if a cloud passed in front of the sun. Water temperature was 80° and there were lots of interesting things to see: coral heads, sleeping sharks, submarine cables, the bottom of our own boat with its puddles of air, old oil drums and a sunken landing craft. "What a wonderful job we thought this is."

That night we talked the problem over and decided upon the method of search. There would be range lines marked by a small flag buoy and a distant hangar which reflected the

sun; as long as the two points were aligned we were searching in a straight line. By using two flag buoys we could make (nearly) parallel ranges and search out along one and back along the other; then buoys would be moved over, thirty yards and sixty yards, and we would repeat the procedure; in this way we could be sure of covering the area thoroughly. The distant hangar was always one of the range markers.

For the diving we divided into two parties, each composed of a surface swimmer using a snorkle and a diver using an Aqua lung. Ned and I were one party; Warren and St. Clymer were the other. The plan was this: the boat would move slowly along the marked ranges towing two lines thru the water; one trailing on the surface for the snorkler, the other, heavily weighted, about 60 feet below the surface with the diver on it. In this way the diver could observe an area 200 feet wide while moving at about a knot and a half; he was not in danger because he was under constant surveillance by the surface swimmer directly above. Hand signals were evolved so that the boat could be stopped or speeded up, the line shortened or lowered, and the direction altered to avoid a coral head or pass over some unusual object. The diver signalled the swimmer who signalled the boat and he received almost instant obedience.

This system worked beautifully and I recommend it to anyone with a similar problem; using it we eventually covered a great area of bottom seeing new objects all the time.

Each range line was followed for 500 to 800 yards so that the time required for the boat to travel out one

line and back the other one was about half an hour. This was also about the limit of diver endurance so that at the end of each run we reset the buoys and traded divers. In this manner we worked a half hour and rested a half hour; twice in the morning and twice in the afternoon. Although we only spent two hours each in the water we were exhausted by night. What bothered us most was the cold.

It may be hard to believe that in water over 80 degrees a diver can get cold to the point of chattering, shivering and gooseflesh in 30 minutes; nevertheless it is true for as we were towed along, the water flowing past us drained our body heat away like air rushing thru a car radiator. Heat always "flows downhill" from warm bodies to cooler bodies and even though the water was warm by usual standards it was well below body temperature. At times we would kick violently or otherwise work our muscles to try and generate additional warmth but this did not seem to help much; it was just about as satisfying to dream of finishing the run and lying in the sun on deck.

So we searched a part of Eniwetok lagoon. We saw fish by the thousands: tuna, sharks, rays and grouper; coral heads by the hundred; and torpedo net panels by the dozen, their grommets slowly rotting away. one pass took us along the line of an old minefield, methodically placed to guard the entrance in the last war. The old mine anchors were neatly spaced about 100 feet apart; one of the mines had never released to take its depth; another had been released but had subsequently sunk and was still attached to its anchor by a length of cable. These we left strictly alone. The missing mines, I suppose, had been swept up after the war or perhaps they had broken loose and drifted away, being carried west by the equatorial current.

Soon after seeing the minefield, while I still had mines on my mind, I got quite a scare. Ahead a dark shape loomed which at first seemed to be a coral head but as we approached appeared ever more like a mine floating directly ahead of me, 80 feet below the surface. Frantic signals caused the boat to turn just in time so that the weight on my tow line narrowly missed the object. Stopping the boat I swam cautiously over to X look more closely; half shrouded by a maze of cables floated a torpedo-net buoy , just about the same size and shape as a mine but without the horns or deadly contents. I felt a moment of relief and started to step on the starnge pile of floating junk when another thought struck me. What if a small jar caused the rusty sphere to suddenly collapse (which it certainly will do some day) The resulting implosion would kill me just as dead as the explosion of a mine. Quietly I returned th the line and motioned the boat to go on.

There were pieces of paper with legible printing, one of which we identified as an old Navy operations order, and there were cardboard cartons. Also there were quite a few tin cans which, with the paper labels missing, looked like bits of aluminum wreckage, so each one was inspected.

We alternately lolled on the cable , 60 feet below the surface, holding with one hand and then with the other, trailing out behind like a monstrous live bait, our eyes probing the bottom where it vanished into the blue haze on all sides. Once Warren attracted a shark who followed along just behind his toes, and unable to let go or signal at the moment, he "sweated it out " until the animal became discouraged and left voluntarily. Sometimes we would stand on the weight and ride upright and sometimed sit on it with our legs crossed around the tow line like a child on a swing. I remember feeling very much alone in the cold quiet, so much so that I whimsically indulged in some ballet poses as I looked from side to side. Next time up Ned kidded me about it and after that I remembered he was there and looked up more often. He rode sprawled out on the surface with a tail of rope behind him like a man hanging over the edge of a glass precpice.

Ahead of me the tow line rose in a graceful catenary and passed into the wake of the boat and I could see even slight variations in the speed of the screw and the set of the rudder as she changed course and speed at my hand signal. Behind, the bubbles of my past breaths rose in steps; I could count back six or eight sets of bubbles each a little further back and a little higher up. It became a game, releasing breaths at exactly equal time intervals so that the steps would be perfectly even. Each breath was composed of two or three large mushroom-shaped bubbles, perfectly smooth and with an upper mirrored surface; these were trailed a little by a number of lesser bubbles, all getting larger as they approached the surface. On one occasion two of us descended the line together, Warren below,. His every outward breath released these bubbles under me which tickled my body and legs as champagne tickles the nose --- a strange sensation.

On one occasion he tapped my foot and pointed, all the while making very garbled noises into his mouthpiece. I thought he was pointing at my aqualung regulator and I felt cautiously over my shoulder to see if anything serious was about to happen for with mouthpiece and face plate his face was held too rigidly to make meaningful expression and I couldn't tell whether this was funny or serious. Finally, I caught on; under my right armpit swam two small fish, bright orange-yellow

were possibly blushing in confusion for thinking I was a shark. On another occasion a foot-long remora, which usually attaches to the belly of a shark by means of a suction cup on the top of his head, made a similar mistake . Warren had to nick it with his knife to discourage it from fastening to his under side.

What had seemed great fun at first got to be tedious work by the end of the fourth day and our morale was not improved by the lack of success. our view had changed to, "How did we get mixed up in this?"

We never found the plane but we certainly tried. Our only reward was the education we got in search diving. I pass it on to you, gratis.

The Wreckage of War

On the lagoon side of one of the small islands of Eniwetok atoll lies the crumpled wreck of a ship. Bow to the beach, it huddles between two large coral knolls as though it's dying act had been to frantically seek shelter from a rain of death --- any kind of shelter. It appears at first to have been a small cargo vessel although there is pityfully little remaining evidence. The well-defined bow with its hawse pipes and anchor windlass is above water, fairly intact; towards the stern, the shapelessness increases. The well-deck is awash at low tide and its two open hatches, their black bowels open for inspection seem to be sightlessly staring upward. Beyond is a great piece of amorphous metal jaggedly piercing the water surface. The stern? At first I thought so, but the great chunks of twisted plate ending in ragged edges were incoherent. No masts or superstructure of any sort remained as a clue.

Seen from sea or air this stubby black and tan gash in the milky green shallows of the great lagoon seemed an offensive blemish. Perhaps there was a story in this jumble of metal that closer look would reveal. From the first, I regarded the spot as a "target of opportunity" for a dive. When the opportunity presented itself, by careful arrangement, lungs and cameras were in the ship's boat and there were two wonderfully unscheduled hours.

It is hard to believe that a more complete wreck could exist. For from below, it was at once evident that the portion just described was only the forward half of the vessel. The entire after end was strewn as plates, bolts, girders, pipes and unrecognizable chunks of iron over an area fifty yards square. Some of the pieces must have weighed over twenty tons but none were identifiable as elements of a ship and where they should have been organized in the form of a stern there was only flat sand and detached bits of junk.

One of the king-posts, a tube of steel 24 inches in diameter had been wrenched away at both ends and bent nearly double like a discarded soda straw, its ladder rungs making a crazy pattern. Between the rusting fragments swam a school of Ulua and groping for a handhold to steady myself for a picture of them, I fell backward over a piece of pipe doing a slow somersault and stirring up great quantities of soft white silt. There was an implied smell of death about and I swam towards the bow to escape the snowstorm of particles. The water was only 30 feet deep and the straight black side rose vertically, extending into the bottom below and thru the surface above.

The scuppers were a string of bright lights with the sun behind them and I peered thru the openings, one after another, trying to make out the shapes on the well deck. I was so intent at this that my head brought up smartly against a

rusted piece of pipe drooping over the rail. I looked more closely at the odd looking machine from which it projected and found it strangely familiar. A 30mm gun. Then I recognized others, barrels warped and skewed, blocks shorn of aiming wheels; only the massive parts had survived Green algae grew brightly on the rusty deck and fish darted from the shadows of the guns to the shelter of the holds. The Fenjon recorded this scene, thru the dark frame of a scuppers port.

The tangle of iron which I had at first thought to be the stern now was resolved as the midships section; a platform on which the superstructure, cabins, and bridge had once stood. Of these, not an identifiable trace remained; not a stump, not a railing. From near the bottom I looked back and the blackness of the ships side now resembled a starry night for thru the side leaked hundreds of pieces of sky. The hull plates were a giant cheese grater and every hole was ringed by jagged-outward-pointing iron fingers.

Finally, I understood; this had been an ammunition ship. Probably it had been strafed or bombed until it caught fire and was deliberately beached here by its crew. The ammunition in its forward hold had heated up and gone off like firecrackers sending hundreds of rounds of shells thru the sides of the cargo hold from the inside. Perhaps some of these, or perhaps the fire, set off whatever was in

the after holds --- high explosive of some kind --- and there must have been one tremendous explosion. I could visualize great pieces of hot metal hissing into a froth of rust and soot and blood and spume --- and great waves rolling out--- and perhaps a scream, then this complete and quiet wreck with the silent Ulua gliding past.

On the sandy lagoon floor is scattered a great quantity of small caliber ammunition from this once useful vessel; probably also the ashes of her crew.

No one at the atoll today knows whether the ship was Japanese or American. "Who cares", they shrug.

Such is the wreckage of war.

Giant Clam

In preparation for the expedition we had read as much as possible about the lore of the tropic seas and in many places had come across references to the giant clams. There was little simple factual description of such animals but there were plenty of lurid stories, all of which were very much alike. In them, a native pearl-diver accidently puts his foot in a clam which snaps shut and holds him fast until he drowns or cuts his foot off to get free. (Actually, there are comparatively few pearl islands and the clams at them are not unduly large; pearl-divers just sound better in a story). We never really believed these stories for it was hard to imagine a diver observant enough to find a small pearl who could miss seeing and be caught by a clam of the necessary proportions. There was no doubt that such molluses really existed for there were plenty of pictures of shells two to three feet across; whether they were man traps or not was another question. This ability seemed oversold —— but, we would see for ourselves.

The giant clam, correctly known as a Tradacna Gigas ranges widely thru the tropical Pacific from the Indes to the Tuamotus. In the Marshalls, almost every coral head has a few in it and although we saw them here and there thruout the remainder of the trip, nowhere else did they appear so large or so abundant. The young Tradacna usually live inside the dead coral; they probably begin life with very tiny shells but it is unusual to see one less than three inches across. How they get started inside the coral rock and how they grow there is a great mystery to me —— but somehow they do and there is no dislodging one without breaking the rock for I have tried it many times and always ended up with cuts on

myfingers. At any rate, the shell grows symetrically and the rock retreats (apparently dissolving) around it so that when the valves are apart the clam exactly fits the cavity. The fleshy part that is exposed when the valves open is called the mantle and there are few more wonderful underwater sights than the iridescent pulsing and rippling of the mantle as water is drawn in and expelled when the animal "breathes". Sometimes blue, sometimes brown; usually speckled and always shining, it courses between the wave-shaped open edges of the shell.

Touch the mantle and the shell closes, sometimes instantly, other times slowly. When closed the edges of the two valves interlock to make a perfect seal and the delicate mantle is completely protected. At this time the clam is loose inside the rock and a foolish diver may be tempted to try and pull it out. It won't come for the clam is bigger than the opening. The largest Tradachna I have seen living within a rock are about a foot across in their longest dimension and the distance between their open valves is not over three inches. As an experiment I touched one's mantle with a twig of antler coral and he closed on it; the twig could be pulled out alright but not without some damage. A similarly caught finger might have been lacerated but could easily have been freed.

The rocks in which these clams start life vary considerably in size; some are mere cobbles, others are rounded extensions of a coral head, sometimes they live in the solid reef itself. It is perfectly evident that as the clam

grows and corrodes away his protective rock, sooner or later he will "run out of rock" and be left completely exposed. Living within the rock, the clam may have any orientation but when free they usually live in a gentle hollow in the soft coral sand bottom with the hinge down and the valves opening upward. The now-exposed shell is chalky white and shows prominent growth lines and before long algae, other shells, and odd pieces of sea life may start growing on it making it hard to distinguish from a boulder or small coral head. I suppose these clams must be able to move about for they are sometimes seen in places where it is unlikely they could have developed but how, I do not know for I have never seen any tracks behind one of a soft part extend beyond the shell. My guess it that the very largest clams are those which had the luck to start life in a large rock thus giving them maximum protection for the longest time.

One afternoon it was necessary to raise an instrument from the floor of Eniwetok lagoon and remake a splice in the submarine cable. We anchored the skiff at the appropriate spot and Warren and Todd dove down and brought up the instrument. While Dafsey and I worked on the splice the divers spent their time cruising among the nearby coral heads. When the splice was half made it started to rain with the suddenness and abandonment that seems to characterize tropical rains; in the States it would have been considered a warm rain but to the two of us in the skiff it felt like a hail storm. Large cold drops and lots of them fell on out naked backs. We gasped a few times, covered the exposed

wires half-heartedly and jumped into the lagoon--- pants and all.

Beneath the surface all was warm and calm. When we ~~would~~ poked our heads out, the cold rain would be blown against our faces and the short steep waves would slap at us making it hard to get a breath. Below, except for the diminution of light, there was no difference between squall and sunshine; the fish swam and the algae as calmly as ever. However a big change took place in the appearance of the surface which I had not noticed from above As each large drop struck the water it would send out three tiny concentric ripples --- at least I think it did --- but of course, they formed and disappeared again in a fraction of a second. In fact, I even thought I could see the drops of fresh water penetrate the salty lagoon surface an inch or so (as they undoubtedly do) but with so many identical droplets doing the same thing at once and the foot-high waves, it is hard to say. At any rate, the effect was pleasantly peaceful and it was accompanied by a gentle hissing and plunking sound.

When the rain ceased we returned to the skiff, bailed it out, and shivering started the splice over again on a dry section of cable. (over) Just about the time it was completed the divers returned and asked for the "end of a line". They had been below for some time and were somewhat reticent about explaining what they had been doing --- mumbled something like, "we've got something down there", and submerged again.

In a few moments Warren surfaced and said, "Haul it in". "What?" I asked suspiciously. "Clam," said Warren.

I may have cussed a little then for it was getting late and the end of a pretty long day; the ship was not in sight, nor the cable tested. It did not seem like an auspicious time to catch clams. Anyway we hauled. First lightly, then more seriously with two and finally three of us on the line before the clam budged. Finally, with a great effort we were able to raise it to about five feet below the surface but it was all hard work. Todd came back and we gasping considered the situation. "It was carrying it fifty yards along the bottom that got me", he said.

Just before dark we persuaded the coxn of a passing LCM* to take us back to the Horizon which had come to anchor several miles out in the lagoon. As it's crew started to lower the bow ramp to take the skiff aboard, we said, "First we have to load our clam". The sailors looked blank. "It's hanging on that line over the stern", we explained.

Six husky men raised a mild sweat hoisting one clam to the deck of the "M" and for a while we seriously doubted that the 5/8" manilla line on it would hold. Out of the water, the clam must have weighed over 350 lbs. It was 27 inches in its longest dimension and 23 inches from hinge to edge and all of us were suitably impressed. Arriving at the Horizon, we used a block and tackle to move the heroic souvenar from the landing craft to the boat deck.

Next day Todd removed the deceased inhabitant. The flesh was clean and white and certainly looked good to eat; it

* Landing Craft Machinery; a 56 foot twin screw steel boat used for general purposes in amphibious operations.

would have made enough chowder for three ships like ours but cookie refused to have anything to do with it. The adductor muscle that closed the valves was a gourmets dream pure white, round and at least four inches in diameter; veritably an angel tenderloin, I sliced some steaks from it for a trial but they mysteriously disappeared from the kitchen. Later, in the trip, we found that the natives eat the flesh raw; it's good too, for we tried it in Tongan waters one lunchless day.

The empty shell must have weighed well over a hundred pounds and near its hinge line the calcium carbonate shell material was probably three inches thick. We were pleased by its size and luster; it would have made a beautiful museum piece if we could have brought it back. But we didn't, and that's another story.

It is interesting to speculate on whether or not such a clam could trap a diver; this one was certainly large enough for a foot to enter, strong enough to hold on and too heavy for one man to move. When tested underwater it closed rapidly , too; but it also opened again in a short while if left undisturbed. We concluded that a skin diver might get caught and be drowned although it would depend more on coincidence than a Hollywood murder mystery; a diver with breathing equipment, even if caught, would only need to hold still for perhaps a minute; then, quite likely, the clam would open again and release him. None of the native divers we talked to indicated the slightest worry about clams; their danger has been greatly oversold.

V SHARKS

I do not pretend to be an authority on the psychology of sharks. If such a man exists I would certainly like to meet him and get the answers to a lot of questions that puzzle me. However, for those who know even less than I about these fascinating fish here are some personal observations.

1. Sharks exist thruout the Pacific in the equatorial region and probably some species live well north and south of the tropics. We saw them around the ship in deep water almost every time the ship stopped even though we were as much as a thousand miles from land and at some time or other at almost every island group. Where we didn't see them ourselves, we were assured by the natives that they were frequently about. I concluded that a diver might encounter a shark anywhere in the tropics.
2. I have swum on the surface and underwater in close proximity to sharks at Guam, Bikini, Eniwetok, Fiji, Tonga, Falcon Island, and in the deep sea, often as close as four feet. I have never been attacked or intentionally bothered —— only inspected or ignored. Once a six-foot shark brushed me with his pectoral fin and I tweaked it, half expecting him to turn and snap, but he gave no sign of annoyance.
3. If there is any authentic record of a shark attacking a completely submerged man I am unable to find it. Occasionally they nip at a man who is wading or swimming on the surface (about once a year on the California coast) but this seems to be mostly curiosity or a case of mistaken identity. If there were authorities on the subject they would probably disagree on this point.

4. Sharks are fast agile swimmers with large jaws full of sharp teeth; there is no doubt in my mind that even a small shark could be pretty difficult to handle. Like people, or dogs, probably some are nice and some are mean. A swimmer should be as wary as a postman in a block full of bulldogs

5. Sharks seem to have regular eating habits: they like their usual foods at regular times. I have seen them cruise thru schools of small fish who seemed unafraid or at least felt secure in the knowledge that it was not feeding time. A swimmer crossing a shark's path at lunch time would be in about the same position as a man snatching a bone from a mastiff.

6. Shark repellent is sold at your nearest drugstore --- sodium acetate; vinegar would probably do as well. Sharks behave as though they think this material very obnoxious; apparently to their senses, it resembles a dead shark. I only ever tried it once (see Chapter V) and the sharks left temporarily. This is indecisive though because often I have dived into waters where we could see sharks; they immediately retreat to the limit of vision and circle about; when I ascended they returned to the original spot.

7. It is said that sharks are best handled, if they come too close, by means of a short metal-tipped prodding pole with a point sharp enough to be annoying but which will not break the skin. A few prods should

irritate the shark and get the idea across that he is unwelcome. Many swimmers carry sheath knives, supposedly for protection, but my experience in watching men try to kill a virtually helpless shark on deck tells me that it would be pretty hopeless to try and kill one underwater; a knife wound either might be discouraging or infuriating.
I would guess that an angry shark could do serious damage to a swimmer with one stroke of his tail if a nick displeased him. Personally, I carry an ordinary pocket knife in the pocket of my trunks for general purposes and have never carried a large knife or spear.

8. If your dinner table was a conveyor belt moving at irregular speeds of from 5 to 35 miles an hour you'd probably learn to snap fast too. This is what a shark must do to keep from being hungry; he snaps first and considers taste and palatability later. When he is around humans he expects his food to come as a splash thru the surface as it usually does. A surface swimmer splashing along may awaken this response and the shark must move fast for the competion is fierce; the underwater swimmer appears to him as a large, slow moving animal worthy of more careful consideration. So far none have been attacked. We did take the precaution of warning the mess-cooks not to throw food scraps overboard when we were in the water or about to enter.

In the search for the truth about sharks we asked many of the native islanders about their experiences. There was

a note of sameness in the stories. These people worked in and around the water a lot, fishing with spears and nets, making long trips in light canoes, catching turtles, hunting shells. Yes, they occasionally saw sharks. No, they were never bothered but several years ago in a village on the other side of the island (always the other side) they had heard of a man being bitten by ----------and so on. Always it was vague. There was plenty of respect for the sharks but not much fear.

At Suva, Fiji, in the companionway of the Baird I ran into an armless native about 50 years old. Under his left stub was a package and he indicated his shirt pocket with a nod. In the pocket was a weathered piece of paper; a letter. It said, "This is to introduce Elijah, the bearer who, at the age of 15, lost both arms to a shark. He sells magazines now; won't you buy one to help him keep his self-respect." It was signed by a religious service organization. For 3 shillings I got "Uncle Bob's Bedtime Tales" but this was not the real story I was after. Bob Livingston got that from him with gentle questions and made a record on tape.

In Elijah's youth a cruise ship had stopped at Suva and the passengers lined the rail throwing pennies overboard to watch the native boys dive. Someone also threw some food into the water which attracted two sharks who snapped it up hungrily; tiger sharks he thought. And into the midst of the brawling, feeding sharks some tourist tossed a silver

coin. All the boys were now out of the water but the attraction of this shining wealth was too much for Elijah and he went after the coin.

Thirty odd years of armless living in the Fijis has given him a tolerant graciousness. He speaks no evil, even of the sharks. "They weren't angry at me", he says, "they were only eating and thought I was food by mistake."

extra space >

In Tahiti I had occasion to talk at some length with Mr. Hare, á Viriamu, who is probably one of the greatest skin-divers in the world. Now 42, he has been diving for pearls and pearl shell since he was 16 thruout the islands of French Oceania. He frequently dives to 21 fathoms and stays below for over two minutes. When the pearl lagoons are closed he lives in Tahiti and spears fish for a living. What could he tell me about sharks? Well, often sharks were seen, in fact there were four identifiable kinds, but never had he had any trouble with them; sometimes they were as much as 3 brasse (18feet) long. Such animals did make him nervous but often by moving to a new location 200 - 300 meters away one could loose the shark. He knew of only one man who had been bitten; this man was spear fishing off an outer reef and a small shark had badly lacerated his shoulder (when it healed the man went back to diving).

I had heard that sometimes a rumor that a large shark was in the lagoon would cause the fleet of pearling outriggers to quit for the day. "Why", I asked, "do the pearlers quit if none have been bothered by sharks?"

extra space > He grinned and shrugged his shoulders with a sheepish look.

The most jolting shark story came from the least expected

place: home. At Samoa letters from my wife and Dr. Rolf Bolin reached me in the same mail; both were on the same theme, i.e., "Quit fooling around with sharks".

There was a clipping too, entitled, "Scientists Hunt Huge Killer Fish", which started off like this:

> Pacific Grove, California, December 10 (I.N.S.) --
>
> A 15 foot killer shark that bit and slashed a 17 year old swimmer to death off Pacific Grove, Sunday, was the target of a hunt by marine scientists. The hunters wanted to find and kill the huge fish and also authenticate the first known case of a man-eater shark attacking a human in Pacific coastal waters of the United States.
>
> Dr. Rolf Bolin, assistant director of the Hopkins Marine Station, indicated his belief that the killer was a white shark, rare but not entirely unknown in West Coast waters. Bolin called this type "the only shark for which definite records of unprovoked attack on human beings can be found."

I was impressed by the irony of the situation. Formerly a resident of the Monterey Peninsula myself, I had swum in t those waters many times and never had seen or heard of a shark but when I got to the tropics and became accustomed to having sharks about, then comes this authentic tale of a shark attack in waters I would have considered to be among the safest in the world.

I suggest that the reader add these comments up and draw his own conclusions. Perhaps I have been luckier than I know and somehow never encountered a large"man eater" who was feeling mean at his feeding time. I shouldn't care to either, for there is no doubt that sharks have killed many men; neither do I have any intention of giving up diving just

because there are sharks in the water with me. My experience to date is that a mutual non-agression agreement works satisfactorily; I'll leave them alone if they dont annoy me.

VI NIGHT DIVE

On the entire trip only one dive was made at night. It was a shallow dive and a short one but because of the somewhat unusual circumstances seems worth describing. Diving at night is an intriguing business and I should like to experiment a little more with it someday for there are so many interesting unknowns. Scientists know almost nothing about what sort of animals are attracted by underwater lights and whether they behave the same at night as they do in daylight. What can a diver do at night that is equivalent to or different from what he can do in the daytime; how does he navigate and how does he see what he is doing? These are fascinating problems —— but not for Capricorn. Our night dive was an emergency matter.

On the bottom of the deep oceans far from land, there is a slow but constant rain of tiny particles; these may be volcanic or meteoric dusts, fine silt carried out from land by ocean currents, or the miniscule shells of marine animals. Over thousands of square miles of ocean floor the same kinds of materials settle slowly, slowly —— but in long periods of time there are perceptible differences in the sediments thus deposited; as climate and ocean currents change, the character of the bottom is influenced and cold water types of animal shells will settle to the bottom instead of warm water types —— or perhaps land materials from one continent will be covered over by materials from another continent. Here is a record of the natural history of the earth itself which extends far back into time beyond man's most primitive runes and hieroglyphics for thirty thousand years passes while the sediments become a single foot thicker. Like the mountain peak that challenges the climber by its mere existence, this soft autobiography taunts the geologist from its hiding place below 12,000 feet of sea water. "Unlock me" it says —— and the oceanographer can do it. With a

sample of these sediments he can work out their chemistry and composition and tell what the temperature of the water was when each layer was deposited and (generally) where it came from. Most important, he can say when the changes occured and how long each condition lasted, for there is a built-in biological calender in deep sea deposits! the countless billions of tiny animal tests (shells) which are known to the trade as Forams. Experts can take a quick look at a smudge of bottom material under a microscope and confidently state its age and the geologic period in which it was deposited, by recognizing the Forams which are known to have lived at that time.

Samples of these soft bottom sediments suitable for analysis are taken in a very special way by a process called coring. Coring is a basically simple idea. A pipe is lowered on a long cable and thrust vertically into the bottom; when retrieved, it contains a neat cylinder of the stratified muds and oozes that form the upper few feet of the ocean's floor. At the top of this long narrow column or core are a few microscopic flakes that settled there during our lifetime; down a few inches are some that landed while Cheops planned his pyramid; and two or three feet down are grains that were contemporary with the earliest man and the hairy mammoth. Naturally, the longer the core the better, because it extends further back into time and an exceptional core may reach Miocene time and calls for a round or two of beers at the expense of the lucky geologist. A lot of cores were taken on Expedition Capricorn and they ranged in length from zero to twenty-seven feet; the failures were as hard work as the successes except that a long nail-chewing wait ended with frustration instead of beer.

It is not as easy to fill a pipe with undisturbed layers of bottom that lie under two thousand fathoms of water as I have made it sound and our coring device was large and fairly complex. It worked like this:

The pipe itself (called a core barrel) was three inches in diameter and twenty-nine feet long; above it were several hundred pounds of weights on another piece of pipe and a triggering mechanism. Inside the pipe was a piston. As this device approached the bottom, the trigger automatically released a loop in the lowering wire so that the weighted pipe fell freely into the bottom; the cable, free for the moment of its weight, leaped up like a giant spring dragging the piston up the center of the barrel and sucking the bottom materials inside. In a second or two, the core was taken and we would start winding in the cable again to see what had been captured.

Sometimes the bottom was not suitable for taking cores (for reasons we never really understood); other times, we were sure that the perversity of the corer itself caused failures. One bright morning in the wide ocean west of the Gilbert Islands, we started in with the greatest of confidence to take a core. Out went the cable; into the bottom went the core barrel; up again—failure! The material of the bottom was too soft and although it would stay in the barrel right to the surface, as we lifted the long heavy pipe from the water to bring it aboard, the core would act like a liquid and flow from the barrel right before our eyes, trailing off in a white stream of ooze behind the ship. We swore a little, carefully saved a few grains that were plastered to the barrel, and did a repeat performance. Same thing again and two failures are more than twice as depressing as one! Just waiting out the four hours required to lower and raise the tools three, two and a half miles of water is a tedious business, but we were determined, and down again went our corer!

This time ship's morale demanded that we get results.

We were losing the core material right at the surface for as soon as we started to bring the barrel aboard, the soft sediment's own weight would cause it to flow out the open bottom end. I, therefore, decided that the thing to do was to hold the corer just below the surface and dive down and plug the end--only about a thirty-five-foot dive.

It doesn't sound so bad now, but when I suggested it, a number of the crew expressed doubts as to my sanity. Conditions were less than ideal; it was almost midnight, the ship was drifting in the open ocean and consequently was pitching and rolling; water was 2,000 fathoms deep, and several sharks were circling the core barrel. Moreover, we had no convenient ladder for getting in and out of the water and the underwater light was obviously inadequate although we set an extra floodlight on the fantail pointing downward. There was no chance of help if anything happened.

I went over the side on a jury-rigged bos'n's chair clad in the usual swim trunks, tennis shoes, face plate and Aqua-lung. With me I carried a bucket on a line, a large wooden stopper and a hammer--and a packet of shark repellant which Dr. Revelle brought aft at the last minute. Things looked a little shaky from the bos'n's chair with only my feet dangling in the dark water but as soon as I dived and got under the weights, I knew everything would be all right. Sharks and shark repellant were forgotten; I clung to the core barrel and hung on, waiting for my eyes to adapt themselves. The light must have been pretty dim but in a few minutes the ship's screw and rudder became distinguishable and the orange colored core barrel trailed off beneath me in the blackness. The corer whipped about in the water considerably for it was suspended from a block

thirty feet above the deck which exaggerated the ship motions and although the rigging crew kept the cable snubbed at the deckline, the blasted core barrel seemed alive to me!

I descended slowly and carefully like a man going down a flagpole in a storm. If the barrel broke from my grasp, its thrashing could easily finish me with one blow, so I clung tightly and whipped about with it. From the first, the barrel had appeared bent but, not expecting this, I had attributed the appearance to some optical phenomena; now I found it to be fact so that instead of swinging straight, pendulum fashion, another component of motion was added which caused my steed to buck in an irregular fashion. No matter, it was too late to let go or turn back now. The lower end of the pipe was finally attained, and, standing on my head so that I could hold the barrel between my legs, I tried without luck to drive the wooden stopper into the end of the pipe. As a second best solution I hung the bucket over the end of the tube and signalled on its line. The tender on the deck pulled the bucket up tight to cap the barrel, and the job was done. I pushed away from the barrel a safe distance and swam leisurely to the surface where I tied my aqua-lung outfit to a line that was passed to me and climbed back aboard via the bos'n's chair. The core barrel was landed safely on deck without loss of core. Eureka! On inspection, it turned out that the end was plugged tightly with red clay and the dive was unnecessary--anyway, we had a core and our morale was restored.

"Look," someone said, "Your friends are back."

In the water off the fantail, lighted by the special floodlight, were two sleek sharks cruising about in the waters I had left a moment before.

VI NO MAN BEFORE

Somehow we humans seem to find great satisfaction in doing something for the first time or going some place where no one has been before. Few places yet remain on earth waiting for man to strip them of their vicarious virginity and adventurers abound who are waiting their chance to climb a higher mountain, explore a deeper cave or visit some remote spot in the polar regions never before seen. Just to be first.

The great explorers of a past era, men like Columbus, Balboa, and Cook, had the superb thrill of seeing and charting for the first time vast areas of earth and ocean; today we explore for mere details, filling in the blank places on existing charts. But some of the thrill is still there for the lucky few who can find a new place to explore --- and such places still exist in the shallow shadowland of the diver.

The great depths of the ocean will probably never be accessible to man directly; he will, undoubtedly, continue to explore the ocean basins by using sound waves and instruments suspended on cables as we did on expedition Capricorn. Scientific advance can be expected in the direction of sensory extension using such devices as underwater television rather than by making man able to personally go to the bottom. I do not say that this is impossible, only impracticable, for it is doubtful that a man on the bottom of the ocean would learn much simply by being there.

From the oceanic abyss the Pacific islands rise steeply and around each is a narrow band of water of depths suitable for diving. Although no tracks remain underwater to tell of previous visits, it is more than likely that at some time in the past the fabulous divers of the migrating peoples of Polynesia, Micronesia and Melanesia have dived around all of the islands. It is true that there is a slightly deeper band of water around each island that we could reach with the diving gear that the native divers could not ---but this is hardly a new location. We wanted to be the first, without question, to dive where no man had been before.

At Alexa Bank our wish came true and when I think of it, that famous line from the Ancient Mariner runs thru my head, "We were the first that ever burst into that silent sea". For Alexa is a drowned atoll; a ring of submerged coral islands surrounding a sunken lagoon whose imaginary surface is a hundred feet below the present level of the ocean. Truly a silent sea. Here we combined science with adventure.

start

Between the Santa Cruz Islands and the Gilberts is a great undersea ridge; it extends in an east-west direction across hundreds of miles of open ocean, breaking the surface with only one small island: Rotuma. To the north, this ridge slopes away into the great depths of the Pacific but to its south the water is comparatively shallow and here, some scientists believe, is a great drowned continent. A continent which would extend from the Tongas across Australia and include the Fijis, Solomons and the island

groups as far west as the Dutch East Indes. The concept of this great continent is based solely on geophysical and geochemical evidence, for to a scientist's way of thinking, continents are not determined by the shoreline of the ever changing sea but by the kinds of rock of which the earth's crust is composed. This great ridge has thus been determined to be part of a continental boundary called the Andesite line; to its north the rocks are oceanic and to its south they are continental.

Astride the ridge, 300 miles from the nearest island group, are several shallow areas called "banks". Penguin Bank, Turpte Bank, Alexa Bank and Pandora Bank; each with the proportions of normal coral atolls but with their highest parts nearly a hundred feet below the ocean surface of today.

Were these really sunken atolls or were they once volcanic cones, sliced off level by wave attack at some former stand of the sea? If they were made of coral, which seemed most likely, why had not the corals built fast enough to keep up with the ever-rising level of the sea as had those of the other atolls? Had the change in the water level been unusually abrupt at this particular place because of downwarping of the rocks or had there been some oceanic change that had caused the corals to lag in growth (too cold water, no nutrients, dust in the water blotting out the sun)? Were these banks on the oceanic or the continental side of the Andesite line ? Such were the questions that the geologists

and geophysicists asked themselves as our ships approached the ridge, for in advance our only information was a chart showing the depth of water on the banks --- made by a British vessel 80 years ago.

Out of the discussions a three point plan evolved to attack these problems at Alexa Bank. First, to determine the exact shape of the structure, each ship would cross it several times making continuous profiles with the echo-sounders; this would be translated into an accurate chart for reference. Second, a seismic survey would be run in which the Baird (the listening ship) would anchor on one shallow rim of the supposed atoll and the Horizon would drop explosive charges at regular intervals as it moved away from the Baird towards the other rim. From this, the speed of sound in the rocks, and consequently their density and composition could be ascertained. Third, while the Baird was at anchor a party of divers would make several sorties to the bottom to search visually for details which might prove or disprove the drowned atoll theory.

The divers would look for the small features which characterize the upper and outer edges of atolls; features like surge channels, solution pockets, the Lithothamnion ridge, and the abrupt edge of the reef. They would bring back impressions of the appearance to be sketched and written down, photographs of the terrain, and specimens of the present life, if any, that inhabits the bank. It was an

ambitious program, this first full-scale geological dive of the expedition, and we were all anxious that it succeed.

One thing was pretty certain; no one else had ever seen Alexa Bank. In fact, it was not at all sure that we would see it ourselves for small shoal areas hundreds of miles from land can be very difficult to find since they are often out of place on the charts. Moreover, since our last landfall the ship had stopped repeatedly and and drifted in unknown currents while we cored and sampled. But Captain Davis brought us to it without hesitation while we speculated on how many hundred ships must have passed over the bank without suspecting its existence and certainly having no reason to stop there. Divers before ? Impossible!

The first dive was made on the afternoon of December 8, 1952 from the deck of the Baird. Conditions were nearly perfect; the sky was blue and the water was clear and calm; no currents, winds or waves disturbed us. From the surface, a swimmer with a face plate could just make out the bottom some eighty feet below, for the Baird was anchored on the highest point of the rim. With eagerness and enthusiasm we slipped into the Aqualungs, jumped overside and started down the descending line. Directly below, circling the line, were two of the ever present sharks, each about five feet long, but as we descended, they enlarged their circles and almost disappeared into the blue haze just at the limit of vision where they stayed until we surfaced much later.

The bottom we found was like a desert; there was a line of low rounded hills perhaps six or eight feet high with very gently sloping sides and to their west, where the bottom flattened, alternating rows of light and dark material were distinguishable. On the hills there was an occasional Midas cup coral but on whole the scene appeared rather desolate; not at all like the normal atolls with their bright fishes and luxuriant coral knolls. As we descended the pattern faded and details became more apparent. The white sandy-appearing material resolved into countless skeletons of Halameda, a calcoreous algae, each a thin white disc about a quarter of an inch across. The dark rock-like material proved to be dead coral lumps, each covered with algae and the home of small clams, shrimp and crabs; in the shadows hovered a few fish. The bottom was far from devoid of life and yet, by comparison with the glamorous reefs of the Marshalls which we had just left, it seemed very drab indeed.

We deliberately fixed the scene in our minds and set about collecting specimens of the bottom materials in the large burlap sacks we carried. For some reason I never seem to be satisfied with specimens that are less than heroic in size and only the fact that they appear much larger in the water than on deck saves me from bringing back truly monstrous chunks of bottom. On this occasion I selected one large rock teeming with life and a couple

of coral cups. There was a lesson to be learned in collecting this type of coral and I learned it --- the hard way. The cups seemed alive in their entirety; that is the entire outside and inside of their walls had living animals protruding, each with its thousand poison darts called voses. Since the cups were firmly rooted to the bottom I clasped the entire cup in a firm bear-hug between my arms and chest and heaved. The coral came loose but not before my skin had been penetrated in ten thousand places by the darts. Although they created a burning sensation, somehow I was too dense to realize that I was not merely scratched on the sharp edges and resolved to get one really large cup for my garden at home. I tied my sack to the descending line and went back for more punishment, this time selecting one that seemed to be about the size of a bathtub but which, fortunately, turned out to be only about two feet across. After breaking the great colony loose, I worked it across the bottom and personally conducted it up the descending line to the surface an inch at a time. With the greatest of care it was hoisted aboard and packed in excelsior, eventually returning to La Jolla in style atop the "A" frame of the Baird where the rotting of its inhabitants was least offensive. For several (over)

That night in the wardroom while the ship recrossed the atoll again continuing the survey with the echo sounder, the divers assembled around a microphone to discuss the findings and plan for the morrow. It is a scene that will always remain vivid in my

memory for we re-enacted it after nearly every dive. Bob Livingston would set up his tape recorder on the green-covered table and the divers, Munk, Dill, Jackson, MacFall, and I would lounge, half-naked in the Equatorial heat, against the dark wood paneling and tell what we had seen to a microphone. Such sessions would always start methodically with Dr. Livingston intoning the date, latitude and longitude, and circumstances of the dive and rise to a climax as Dr. Revelle, the expedition leader, would question the divers on details. The end was invariable with "Anything else?" and some mumbled, "Nos".

After an hour or so of discussion, the consensus of opinion was that we had examined the inner edge of the atolls rim and that the place where we had dived would have been, in a normal atoll, the edge of the lagoon. The place which could throw the most light on the history of the bank would be the extreme outer edge where the bank dropped steeply into very deep water. This edge could be expected to be from a quarter to a half mile east of our former anchorage (over) Whether the edge would be shallow enough to be explored by divers could not be answered in advance.

On the next morning, armed to the teeth with diving gear, cameras and sample sacks, we started for the edge of the reef in the ships launch, guided by whistle signals from the Baird. The launch moved slowly east, towing behind it on the surface a man with a face plate who watched the bottom and reported its changes and our progress untill the water became too deep and it was lost from view.

Then, from
[illegible] time to time we sounded the bottom with a lead-line; annoyingly, it deepened quite gradually and we passed beyond the diving range without encountering an abrupt edge. It was necessary to return to a spot shallow enough to dive where the bottom looked interesting; the place selected was a rolling terrain of low brown hills whose tops were a hundred feet below the surface. We anchored the launch and slipped off into the water descending on the anchor line.

Here the corals were slightly more abundant and certainly much larger than at the location seen on the previous day. Some were great platy sworls over six feet across like great stone flowers. We sampled and took pictures; MacFall with the Rolliflex, Dill and I with the 16mm movie cameras. On the surface the specimens of materials that we brought up which had appeared brown on the bottom were a glistening emerald green; I kept thinking how if the water were drained away so the greenness of these hills would show, it would shame the best kept lawns of our sub-aerial world. I remember selecting one unusually fine white coral bowl and working my way up the anchor line with it; there was considerable current and the bowl required both arms so I had to cling with my flippered feet and an occasional handhold. Several times I fell over backward and found myself hanging upside down by the grip of my feet; slowly I would right myself and start up again. Twenty-five feet from the surface, my tanks ran out of air and with huge disgust I

had to let the bowl fall, watching it slip from side to side as it settled back to its native land as I surfaced for a breath of air. It was gone forever because there was no time to get a new air tank and go back down again since the ship was already blowing the recall whistle. We returned, concluding that this time we had been the crest of what might once have been an island.

In the afternoon we dived again from the ship to find still a different, appearing bottom which seemed to be rather typical of what might have been the lagoon floor. At 120 feet the bottom had sort of a polka dot appearance with areas of dead brown coral pebbles set in a background of white masses of Halameda plates. Small corals grew sparsely but this place had even a poorer fauna than the previous sites. Still we pried and sampled with a will and I had just filled a sack with specimens of a dozen varieties of small corals when I got the feeling that my air was low. I started for the descending line motioning Livingston and Dill my intention to surface and dragging the sack behind me. At the line my air was gone but I started up, confident that more would come to me as the pressure relaxed; it did, but there was none to spare. Finally, breaking water, I spit out the mouthpiece and gulped the lovely air --- still carrying the sack of samples.

Director Revelle, on deck, thought this very funny. "I believe you'd rather drown than drop those damn rocks", he said.

Like almost scientific experiments, we didn't find out what we expected to but discovered something else instead, for

Science always asks more questions than it answers. Adventurewise, it is fun to think that we were the first to ever reach Alexa Bank; it'll probably be a long, long time before anyone tries it again.

VIII THE REEFS OF FIJI

The port of Suva is the undisputed center of the south seas today and like roads to Rome, all shipping routes radiate from there. It is too small and rickety to be called a modern city and yet there is a cosmopolitanism that rivals many great cities and a hustle that would be admired even in Los Angeles. Suva and the Fijis have much to recommend them; there is the climate of Hawaii (Fiji is about as far south of the equator as Hawaii is north); the diversified and growing industries of mining, darying, shipping, lumbering, and copra processing; and the spider-like satisfaction of being at the center of a net that leads to opportunity in any direction.

To go anywhere among the islands one goes to Suva first and then on sucessively smaller and smaller boats wends his way to the destination- - for travel in the tropic seas is cheap once you get to Suva. For a pound you can range a thousand miles if you don't mind being a deck passenger on a copra-trading schooner and carrying your own food; for a few extra shillings you can get space in a cabin --- and almost always with passengers of the opposite sex, which is apparently arranged with forethought to make the trip more enjoyable, But there is no need to leave Fiji to see much of the best in the south seas; a few miles from Suva the modernism drops away and out of sight of the road the jungle with its occasional village of grass huts is substantially the same as it was hundreds of years ago. Here the native Fijians, replete with the great bushy black heads of hair live in tribal simplicity much like their ancestors---close to the fish-filled bays and under the graceful palms cocoanut.

Yams, bananas, tapioca, breadfruit, taro and avocados grow almost uncultivated at the back door and pineapples, pawpaws, clams, fish, and tortoise are obtainable with only little more effort. The wonderful climate with temperatures rarely under 70° and lots of good water and beautiful scenery made these little villages seem idylic to us slaves of civilization. These people appeared to have everything necessary for good living--and have it effortlessly so we asked ourselves again the white man's riddle of the south seas, "why dont we stay here and live out our lives calmly and easily in a psycosis-free grass village?" But man does not live by bread fruit alone and we passed wistfully on. A single road circles the island of Vita Levu on the narrow coastal plain; no roads and few trails lead to the rugged and mountainous interior of which little is known to today's inhabitants.

Koralevu Bay

Queen's Road, two hours' drive from Suva, passes a gentle embdyment where steep, white sands are overhung by tall palms: Koralevu Bay. In a way it reminds me of Hawaii's Waikiki beach where I have often swum and strolled and told myself that I was in the playground of the Gods. No wonder that the Hawaiian kings lived there and kept Waikiki for a park---but that was before white-skinned haoles brought raucous civilization. Koralevu today must be something like Waikiki a hundred years ago; anyway, it I were a God I'd play at Koralevu now.

Parallel to the south coast of the island and ignoring the ins and outs of the shoreline is a clean, straight, white line of surf which marks the edge of the broad shallow coral reef. Opposite the headlands the reef is narrow and opposite bay mouths it is wide; on its edge waves from the south Pacific expend themselves in frothing impotent breakers. Across the middle of the wide reef at Koralevu is a narrow channel where flowing, fresh waters from the land have held back the coral growth and here the deep water approaches almost to the beach. Although the surface of the great reef is flat and dead and uninteresting, along the outer edge and in the walls of the channel, the corals grow madly and there are deep dark cracks and undercut caves which put a gleam into the eye of the underwater swimmer. Here was an underwater topography completely new.

Along a half mile of the beach bordering this blue bay with the white fringed reef is an area of cultivated palm and cropped green lawn. Between the palms a little stream flows and along its banks are a number of grass shacks ---boras--- with modern conveniences added. This is Koraleva "Rest House", a tropical Britisher's idea of an American motel in Fijian style, and an excellent idea it is.

Each bora is a wonderful piece of woodworking and weaving. Above the concrete floor rose large posts of fern-tree wood which supported the sill

stringers to which were lashed the rafters and their bracing. Over the whole framework was a foot or more of carefully laid grass, said to weigh five tons. We were astonished at the solidity of the construction for "grass shack" has a rather flimsy sound but we were informed that most of the shacks had withstood the great hurricains of the previous year better than the small European style houses. Doors and windows were framed of wood western style and at first we regarded this and the concrete foundation as a concession to prudish tourists; later we noticed that the newer Fijian houses had these features too.

Dr. Ted Folsom and I shared a bora only a few feet from the waters' edge where an outrigger canoe was beached just above high water. Lying in bed at night we could see the dark jungle silhouetted against the clouds and catch an occasional twinkle from the surf across the bay. The quiet magic of the tropical stillness let our minds float free as we "breathed in the balms of the fronded palms in the hush of the moonlit night."

A brilliant six o'clock sunrise awakened me and I crawled from under the white pagoda of mosquito netting and hurried out onto the beach at once to see what the night tide had left. Like beaches the world over it had the virginal air that remains when the clean sweeping tide erases all the footprints and piles the sea shells and coconut husks into neat orderly lines; native women and children were washing in the steam mouths and great trees whose name I do not know were dropping blossoms on the sands.

When I returned at 7:30 a Fijian waiter was just serving "tea" (coffee in bed) to the others and reminding them that breakfast would soon be ready. It developed that there are three 'teas' a day at the 'Rest House' as well as the three meals and while we were a little surprized to find they started before breakfast, it was agreed that this was an excellent idea. Rest House was undoubtedly well named and I can think of no pleasanter place to relax; on this visit, however, we had little time and a lot to do.

The plan was to examine the steep sloping outer edge of the reef and the

walls of the deep channel thru it and see what the cracks and caves were like. Surface swimming and skin-diving to their upper reaches on the previous afternoon had shown us what to expect and we planned accordingly. Livingston, Dill, Jackson, Folsom and I were well equipped with Aqualungs and swimming gear but we started with a dilemma. If we went at high tide we would have to swim across the reef, thereby wasting much of our precious air supply before we got to the edge; if we went at low tide we could walk in water between our knees and ankles, a fairly easy job unencumbered but difficult and even painful while burdened with heavy equipment. We finally decided to take the equipment around in the outrigger while the rest of the swimmers and our host waded across the reef.

Until the equipment was loaded and Ted and I left the beach we had never given much thought to outrigger canoes and their manipulation--this we demonstrated at once. After all, one could see the natives and their whole families paddling about without effort and with the outrigger for stability, well, what trouble could you have? It certainly appears solid in the water and we thought we dimly remembered seeing great bunches of bananas piled on the outrigger beams and sails being nonchalantly hoisted by grinning brown sailors. What we couldn't quite recall was what they did for a gyro-stabilizer, for our canoe would never have stood for such treatment without one. As for the balancing value of the outrigger float: Ha! It has about the same function as a tight-rope walker's pole; I will say this for the float, with it, it is possible to balance the canoe. Barely. One must sit exactly; repeat, exactly in the center of the canoe as the least deviation will cause the float to dip under or rise from the water as a disquieting reminder that the creature is about to capsize. The paddlers sit at gunwale level with feet placed tandem in the narrow bottom. The forward paddler can paddle only on the side away from the outrigger, the rear paddler must work on the opposite side. In one of our frequent rests we decided that one right and one left handed man was required for efficient operation.

I suppose nearly all outrigger canoes require bailing; they are hollowed from a log which is likely to have an occasional knot or check-mark and as the interior is removed the stresses in the wood change and cracks open. These cracks can be patched by filling them with tar and sewing the sides together with copper wire. But since patching requires more concerted effort than occasional bailing, this chore is put off; besides an occasional wave slops over the side. A bailing can is an absolute necessity and we were not without one. Now trees are round and so are the canoes made from them--both inside and outside. This seems obvious to me now but when our host gave us a British biscuit tin to bail with we murmured no protest. In fact the British have an expression, "square as a biscuit tin", which I will not soon forget. Ours was nearly a foot on a side and square as square could be and barely small enough to go between the sides of the canoe. By suitably bending one side of the can we were able to make it reach within a few inches of the bottom of the canoe. Bailing with it was incredibly awkward and gaining on the incoming water impossible. May I be forever damned if I ever put to sea again in a round boat with a square bailer; I had rather spend eternity driving square pegs into round holes.

We were happy in our ignorance and loaded the air bottles and equipment into the thing and started out with Ted at the rear steering paddle. We paddled on the right, then on the left; we paddled into the waves and across them; we steered, rudderlike and by backing water, we blamed the currents, the wind and the drag on the float. None of these operations had much effect on our craft; legend has it that these are speedy craft that skim over the water like a flying fish--this one had obviously not heard that legend and was substantially unchanged from its original log-like qualities in its sea handling respects. Painfully we inched our way out the channel and were actually approaching our objective when some bigger-than-usual waves spilled their tops into our hollow log; the outrigger float started to sink and I jumped out. Ted was very relieved to be

rid of my inept assistance and assured me as I swam past that he could make the last hundred yards without help. (He did too, in about half an hour). Eventually the canoe with our equipment was beached far out on the reef and I got a lung from it, and swam leisurely out the channel entrance only a few feet below the surface, putting my head out every few minutes to see where the others were and orient myself.

These reefs were much less beautiful than those of the Marshalls but were just as interesting to us because they were new variations on the old theme. The corals were different shapes and colors as there were species we had not seen before; fish were much fewer and less brightly colored; but mostly there was a new feeling in the water because of the radical difference in the appearance of the submarine topography.

On the channel bottom there was a dirty white silt not at all like the white shifting sands we had known and the reef walls instead of being simply steep and ragged with corals were sheer or even overhanging and comparatively smooth. Colors were grey-green at shallower depths but here and there was a bright mantle, a few shiny cowries clinging to a coral frond and, brightest of all, a large number of bright blue starfish. Electric blue in color, they lay on the reef everywhere and we could not resist bringing back a dozen or so which retaliated by immediately dying and adding to the distasteful smells of our other deceased beauties.

I reached the edge of the outer reef and swam parallel to the coast just outside the breakers and above the edge of a submarine precipice. To my left was deep blue water and to my right there was the usual profusion of corals living in water less than fifteen feet deep; well nourished by the coastal currents and well lighted in the clean water far from shore, they grew beautifully and prohifically in the narrow band between the cliff edge and the flat dead reef

Along the edge I encountered Bob Dill; he had carried a lung across the reef and was now busily hacking away at coral specimens in the shallow water beyond the breakers, putting the best into a canvas bag that was slung about his shoulder. We agreed by a shouted conversation carried on between passing wave crests (when we would pop the mouthpieces into our mouths) to descend the steep outer face to see what it was like at depth. Although on the whole the reef edge was quite straight, there was an occasional gash and we selected on of these for a pathway. Down it went, a V-shaped submarine canyon cutting perhaps thirty feet into the reef edge at the surface and less at depth since its bottom sloped a little less steeply than the nearly vertical reef wall. From its sides fans and plates of coral projected some of which were as much as four feet across and down the canyon bottom there was a bare covering of slowly sliding coral debris. We descended deeper and deeper. There were ledges, dark grey green with an occasional yellowish coral knob and on these were more coral fragments and white dust. A wave of the flipper would stir up a storm of fine coral dust—a tempest in a canyon, which drifted slowly away in the gentle current. The light grew dim and the corals appeared dead; a small barracuda sniffed at us and passed on. We had no way of measuring our ultimate depth but it was certainly over 150 feet; at this point there was no change in the blueness of the deep water or the appearance of the cliff and since we had a limited air supply which was being consumed rapidly, we returned to the surface.

Miners, who spend their working hours in dark dripping mines, rather expect to find a cloudy rainy day on the surface and when the cage reaches ground level they are pleasantly surprized by sunshine and blue sky. (At least I was, each day for years). Rising from the greyness of deep water the change is much less abrupt but the feeling is about the same; there is an implied warmth in the red color and the direct sun rays; a feeling of being surrounded by near-surface c.
life and motion unlike the somber and quiet inactivity below. The deep diver

rises into this totally different world and is reminded that invariably the "top 50 feet is the best diving".

Back in the shoal area of the reef edge I could not resist breaking off a few choice coral colonies to take back for souvenirs and with these in hand started thru the breakers. This was a basic mistake and was doubly compounded by the fact that I was wearing fins instead of my customary tennis shoes. As anyone who has tried it knows, it is practically impossible to walk in shallow water with swim fins even under good conditions. On a very rough and coral covered reef in the surf with 90 pounds of air bottles on the back it is impossible—that is the only thing I distinctly remember. The first wave started me in and the rest rolled me alternately in and out over a surface which would surely have disgraced a fakir's bed of spikes.

Somewhere along this rough route the corals I was carrying disappeared but I had souvenirs enough imbedded in my knees and heels and hands. Bob had made the crossing much more easily and stood watching with sort of an anxious laugh. When I finally struggled to my sore feet he said, "You've had it". So I had.

We waded way back across the reef to the canoe and encountered Dr. Livingston inspecting the edge of the freshwater channel and waiting for companions so he could go deeper. We joined him and the three of us ranged shoreward along the side of the channel; the upper forty feet of its walls was quite vertical and rose from a softer bottom which sloped away at about thirty degrees towards the channel center. There was a very abrupt line between the clear warm water of the reef and the dirty colder waters of the channel; however throughout its length there was almost always a narrow vertical band of the clear water against the reef wall.

Together we probed into the caves as our eyes became accustomed to the dimness and swam thru the narrow crevasses. Only about 25 feet deep, these great cracks seemed much more because their black walls were so close together; there was just

barely shoulder room in many places and our bottles banged loudly against the walls; often we touched both sides at once. Then they would widen out to six or eight feet and branch; the bottom was covered with soft white sand and near the tops were live corals. Fish were few and we saw not a single eel or octopus—animals which ordinarily like such places.

It was a most successful operation and we returned with some fine shell and coral specimens much to the envy of our shipmates; even Dr. Folsom, worn down by his struggle with the outrigger, agreed. We left Koralevu reluctantly; for about six dollars apiece we had stayed the night in private boras had three good meals three teas and been guided on the reef. Try that at Waikiki some time.

Serua Island

Close to the south coast of Vita Levu is a green island not over a quarter of a mile across at the widest part. Most of this little island is quite flat and on the flat part is a neatly laid-out village of grass houses which partly overhang the water. At each end there is a steep conical hill perhaps 200 feet high; on top of one hill is the tribal cemetary, on the other are some unpainted frame government buildings no longer used. This is Serua, the legendary capital of Fiji, once the seat of the governors; even now the spirits of its great chiefs look out from the two hills. Between the island and the mainland is a shallow flat reef and at low tide one can easily wade across this natural moat thru soft silt and water rarely over the knees. Seen from the road which winds high above thru the jungle on the mainland, Serua is a dream of a tropical island stylized by Walt Disney. The hills are so steep and so regular, the houses so well-aligned, the reef so green that one gets a strange feeling of unreallness. Only the wooden government house on the eastern hill and the large tree where the trail across the reef begins, break the symmetry. Standing atop the hills it is easy to picture in one's mind the days of inter-tribal warfare when swarms of howling cannibals brandishing great warclubs must have sortied across the reef to attack the forts which once crowned the important hills along the coast of the mainland. And probably after a hard day's fighting they came back across the reef bearing captives slung on poles for their evening meal.

Today the Seruans make more peaceful trips to the mainland to visit and tend their cocoanut groves and truck gardens and fruit trees for the soil of their own island is not suitable for growing these things. The remainder of their economy is based on the sea and generations of experience in submarine hunting have made them among the best swimmers and skin divers in the Fijis.

One warm December day it was arranged that they would demonstrate their underwater abilities for a party of observers from our ships and in a gala picknicing mood we waded the reef to their island to watch. East of the island a barrier reef partly enclosed a large lagoon-like area and here there was generally shallow water with coral knolls and a rough reef about four feet below the surface. This gives way to a deep and devious embayment so that within a half-mile of the village there are zones of all diving depths.

Natives and scientists, evenly distributed between the water and two long narrow flat-bottom punts, set out slowly to explore the underwater terrain and each other. The swimmers went first, skin diving to look and to spear --- the punts followed, propelled by husky natives who stood aft and punted along pushing on the coral with long poles when the water was shallow enough, rowing when it deepened.

The natives used two kinds of spears, each of which was about five feet long with a slim hardwood shaft. One of the types of spear heads was a light metal trident about five inches long from fork to point and with the usual double barb in the center and half-barbs on the outer tines. The other spearhead

was unique in my experience. It was a circle of barbless needle-like bamboo points about 8 inches long looking a bit like an old fashioned broom. The points were tightly bound around the shaft at their base; towards the business end, they flared out. I suppose the idea was that points on opposite side of the circles would continue to widen as they passed thru the flesh, trapping the fish as effectively as a barb. Both spears seemed to be quite effective.

Out along the reef we ranged like a school of porpoises, some surfacing for breath as others dove the bare two fathoms to the bottom; at least we were as playful ---but without porpoise speed and grace. The natives speared a number of fish, mostly too small to be worth cooking but all of interest to those in the boats who would not have seen them otherwise. It gave us all a chance to inspect them carefully and photograph the bright colors in the sunlight; as they died, they faded and changed colors like rapidly rotting changeable taffeta. As always there were new varieties; on every dive during the entire trip we saw at least one new species (new to us, anyway).

Most interesting to me was a lion fish (Pterois Volitans) which was speared as it held still on a mottled coral cluster and tried to hide. (Some fish will just not believe that you can see them and persist in holding absolutely still and trusting to their protective coloration until actually touched.) The lion fish is comparatively safe in this manauver since he

not only appears almost exactly like the rocks but also he has highly poisonous spines projecting from his dorsal fin. This specimen had wide dirty-brown vertical stripes alternating with somewhat narrower white bands with irregular boundaries; It's lower jaw protruded and the pectoral fins were very long and featherlike, the membranes between the spines having separated. The fish was about a foot long and the poisonous spines on his dorsal fin were nearly three inches long. The native who speared him held the spear firmly so that the fish was a respectful distance from his body and shouted warning words in Fijian which were translated by our British guide. The Lionfish looks a great deal like the Scorpion fish of the California coast and is undoubtedly closely related. (Although the scorpion also has poisonous spines which make a painful wound, he is not deadly.) I remembered an authenticated story about a man who had found a Lionfish while skin diving and intrigued by the way it held so still, tried to catch it barehanded. The poison worked instantly and he was lucky to have friends about who dragged him from the water and took him to the hospital. Within six hours his blood pressure had dropped to twenty and death was very close; he passed the crisis though, and by the next day was completely recovered. After this story, and some others about poisonous shells and sea urchins, I was very careful indeed where I stepped and what I touched.

Sea snakes are quite rare but on this trip we got a pretty good look at one thru the courtesy of Dr. Ted Folsom. Ted had just located a pair of beautiful white cowrie shells and was in the process of picking them off the bottom when the snake brushed his shoulder. Ted and snake each left instantly in opposite directions, he with only one of the cowries. At this time I was in the boat and when the snake swam past was able to lift it out of the water with an oar for a few seconds. It was about three and one-half feet long and generally dark green with small black and yellow dots. All sea snakes are venomous (like their cobra cousins) but fortunately they have small mouths and are unable to conveniently inject the poison into humans.so that they are not much feared by the natives who will sometimes push them to one side with a bare foot. I was quite content to let this one swim away, however.

When the boats reached the abrupt drop-off into deeper water they were moored and we put on the Aqua lungs and followed the slope down. The upper fifty feet were quite lovely with very jagged and irregular coral heads ~~which~~ that arched over to form small caves and grottoes which had many cock's comb oysters welded firmly to their sides; below them the steep slope was covered with dusty coral debris so that after a quick look around, I returned to shallower water and swam along the bottom forty feet below the surface looking for shells. Here I found my first pearl-shell; the knowledge that there was an infinitesimal chance of its containing a pearl did not discourage me from making a gurgling whoop into the mouthpiece. Here also were fine large leopard cowries and scorpion shells and triton trumpets. Serua reef was a wonderful spot for shell collecting and we brought back dozens, from the bottom and bought a few from the natives for good measure.

In fact, I think that it was shell collecting that we liked to do best and sometimes other underwater work suffered because it was hard to resist the temptation to look for these beautiful souvenirs. The cowries were the most attractive, mainly because their outside was so shiny and polished whereas the other shells were generally drab and covered with sea growth and required much more work to clean. I had heard that in the past the cowries were used for money in denominations according to their rarity. The highest unit was the golden cowrie.

It took a long time to even find anyone who had seen a golden cowrie; finally, Mr. Morris Hedstrom, of Suva, showed us one. It is truly a beautiful shell, and has a rich and regal look about it; it has the usual cowrie shape but the entire back is a clear orange-gold color which breaks off cleanly at the white lips on the underside. What it used to be worth one can only guess; perhaps a spear or a wife or a cow. In Suva today, it is said that the standard price for a matched pair is 20 £ (around $70) ---if you can find them for sale.

IX SUBMARINE VOLCANO

20° - 19' S, 175° - 25' W is the site of a weak spot in the earth's crust known as Falcon Islands. Here is its history as given in the Sailing Directions:-

> Falcon Island made its appearance first as a reef in 1865, and later as an island in 1885.
> In 1877 smoke was seen rising from the sea at this point.
> In 1889 the then-existing island was surveyed by the British vessel Egeria.
> By 1894 the island had disappeared to such an extent that it appeared as a low streak of black rock. Later in the year it was seen to be about 50 feet high.
> In 1898 the island had disappeared leaving a breaking shoal but 2 years later the shoal was above water.
> There was no trace of the island in 1913 and in 1921 only breakers and discolored water marked the position.
> In 1927 the island was reported to be one mile in extent and have smoke issuing from it.
> On March 17,1928 the island was 2 miles long 600 feet high and in heavy volcanic eruption.
> Great volumes of smoke were seen in 1933.
> In 1936 there were erruptions every 15 minutes from a submarine volcano off the southeast corner of the island.
> No volcanic activity was in evidence in 1938 and the island was 30 feet high and a mile and a half long.

On December 22, 1952 on our way to Tongatabu, the Baird set a course for Falcon Island with the intention of observing and photographing this unreliable piece of property in its present condition; we no inkling as to whether there would be an active volcanic mountain or a small pile of wave-washed ash. There was neither. As the ship approached the site, cheaking its position at frequent intervals, we could see no land of any sort but the trace of the bottom, drawn by our echo-sounder, showed it rising steadily under us. At 100 fathoms Capt Davis slowed the ship

to three knots; at 100 feet he stopped it and as we drifted slowly ahead the bottom continued to shoal. From the forward deck we scrutinized the water surface and tried to see thru it. Then three larger-than-average swells passed under us and as they did we could see them bend to make a warped diamond pattern as they moved over what must have been very shoal water.

The ship rumbled as the screw started to turn and the rudder went to hard left just as the watch announced "80 feet", on the intercom. We pulled away from the unseen danger and gave the area a wide berth in passing on to our immediate destination but Falcon Island continued to occupy a foremost place in our thoughts.

Such a dramatic history was very appealing to geologists anyway but the knowledge that the surface of this yo-yo island was within easy diving range made Falcon irresistable to a party of diving oceanographers. The more we thought about it, the better we liked the idea of making an underwater examination of a volcano.

Were there occasional eruptions or rumblings that we might be able to hear underwater? Would there be hot springs? (often found near dormant volcanos). Would the water be clouded with fine ash? (We had seen streaks of discolored water). Would it look like the slope of a volcano, littered with volcanic bombs and debris or would the rocks be hard and massive like a dike? Would there be any life about or does volcanic activity have a toxic effect? We wanted answers, and would return somehow to get them.

On December 29, after Christmas at Nukalofa, the Baird returned and hove-to just south of the "island" to launch a skiff. In it were Aqualungs, underwater cameras, sample sacks and bottles, Bob Livingston, Walter Munk, Phil Jackson and myself. There was adventure in the air as we rowed confidently towards a patch of light green water which was just the color of many a coral reef we had seen in our life among the atolls. Phil hung over the stern peering downward thru a view-box and described the bottom we were passing over as being a rippled and dark volcanic sand about 40 feet deep; on our way to better things we passed witho

rising perhaps 20 feet from a mass of small volcanic cobbles which sloped away in three directions. On the fourth side, there was a little valley, also cobble filled, separating the rocks we were on from a similar but slightly deeper formation. In this valley Dr. Munk inserted his thermometers into the bottom in an attempt to measure the heat flow from the sea floor which might indicate recent volcanic activity. While intently watching the instruments he was aware of a shadow, and turning saw a shark watching too —— over his shoulder. Sharks are such curious animals.

Dr. Livingston waited patiently in the skiff until I returned and gave him my lung so he could descend too. Then we upped anchor and worked along the reef to the south. Its character changed somewhat; the small dike broadened out to form an undulating coral-covered surface over loo feet across and as shallow as 18 feet in some places so the its high points were quite accessible by skin diving. Here we appreciated Captain Davis' foresight in not bringing the ship any closer. What a place to be shipwrecked this would be! Hundreds of miles from even the rudest port, for although solid rock was very close straight down, the unbroken ocean surface reached away to the horizon in every direction. We thought for a moment of Captain Bligh who was put off the Bounty near this spot and eventually travelled 3500 miles in an open lifeboat before he reached help.

As before, the boundaries of the reef were abrupt and the sides vertical; here we could not see the terrain from which it rose —— only the intense blue of deep water. It is curious feeling to come suddenly upon the edge of such a cliff. One's sub-aerial instincts makes him involuntarily draw back as though there were some danger of falling off, and even in this weightless world we were inclined to stay on the shallow top with only our heads extending over the edge. As an island, Falcon could never have had the beauty it has as a shoal; bright colonies of coral dotted the surface and as usual there were great numbers of highly colored fish. Here for the first time I came upon a school of Moorish Idols ——

comment. The sand disappeared as the water deepened again but in a few minutes he saw two huge yellowish rounded knobs with tops only about 30 feet deep which rose from deep blue water; on their surface were some corals growing and a shark cruised about; this was our first new piece of information: living coral, and bleed pressures went up accordingly. Then the bottom was lost from sight again but things looked better every minute and we pulled harder on the oars intent on reaching the shallower reef marked by the green water.

To our dismay, on arriving there we found that the green color came from fine volcanic dust particles suspended in the water which apparently had no relation to the depth and although we rowed thru it for some distance and took soundings, our lead line never reached bottom for it was only 200 feet long.

In the meantime the Baird had moved about considerably while making a depth survey and taking snapper-samples of the bottom materials. Only then did we realize that we had, with incredible luck, gone directly over the middle of the island's high point on the first pass; now to find it again. The only reference point was the green streak of discolored water and we knew it to be moving with the current; the bottom had not been seen for half an hour. A zigzag course was indicated and for thirty, hand-blistering minutes the skiff went back and forth in what seemed the most probable area until a yip from the man at the view-box signalled the sight of bottom. The reef rose abruptly —— we all looked to see what it was like this time before it got lost again —— so abruptly that it was necessary to row the skiff to just the right spot so that the anchor line would reach bottom.

Over the side we went; I with the sample sacks, Walter with some thermometers and Phil with a camera; as we did, the ever present sharks cruised off into the blue. The top of the reef was of dark volcanic rock, slightly domed and largely covered with coral colonies from one to two feet in diameter. It was about 30 feet wide and perhaps 100 feet long being divided in the middle by a crevasse. The sides were vertical and fairly smooth, without coral growth,

possibly twenty or so of the black and yellow striped dandies that are usually seen in pairs. I nosed into their hollow and they scattered like sand in a current eddy trailing their long pennant-like dorsal fins behind.

The sight of young coral growing directly on volcanic rock far out from land was an experience unique and even exciting to a geologist; here we could look back thru time and see how the great atolls must have started 20 million years ago. In the past 15 years the first corals had taken hold on Falcon Island and already there were colonies two feet across --- all living free and uncrowded in the clear water --- springing truly phoenix-like from the hardened lava of the dormant volcano. Each white and pink and light blue coral colony sprouted separately from the clean dark basalt, still uncluttered with the usual coral refuse. Some day, if no more eruptions occur, the corals will completely cover the basalt and, filling their own voids with lime and rubble, rise to low tide level and then spread sidewise making a shallow reef such as those that rim the atolls. It will grow upwards following the still-rising sea level and perhaps join with a spreading reef from some volcanic remnant we did not discover and then be capped with an island and cocoanut palms. Such is apparently the ori in of other islands in the Tonga group.

Our dreams of the next million years ended with a ringing in the ears. It was the man in the skiff banging a wrench against an air bottle --- the signal to return to the surface, for the Baird was impatiently tooting.

What did we accomplish at Falcon Island in our attempt to add to the knowledge of marine geology? Well, we learned that there is a hard core of dense volcanic rock which will probably l st aginst wave action for a long time --- may even become the base of a coral reef. We found that many varieties of corals are able to get started and grow to considerable size in less than 15 years and with the corals come the specialized reef fishes (although it is hard for me to see how these little fishes find their way to a new reef far out in the open

sea). There were no hot springs and no appreciable heat flow from the rock itself but of course we do not know if we saw all of the highest portion or if the active southeast corner of 1936 is different from the place we visited. And of course there may still be rumblings at odd times.

The Falcon Island dive was well worth the effort, both for geology and adventure — for it is an adventure to visit a submerged volcano, even though it is temporarily inactive. We'll watch the newspapers for the rest of our lives looking for a little news item at the bottom of page five which may say, "Passing ships have reported new volcanic activity at Falcon Island in the Tonga Group. Smoke was seen rising from thirty miles away and floating pumice——————————".

IX THE TONGAS

Expedition Capricorn's two ships rendezvoused at Nukalofa in the Tonga Islands on a beautiful summer afternoon: Christmas Eve, 1952 and all of our party will long remember the wonderful and kindly manner inwhich we were recieved there. No wonder these are called the Friendly Islands; strangers in their land in the holiday season, we were invited into homes, greeted with presents, serenaded by dozens of bands and chorouses, and given the run of the country. To ~~partly~~ reciprocate in part we held a shipboard cocktail party so that the Tongans could inspect the ships and their elaborate scientific apparatus. So greatly impressed were our new friends by the mass of electronic instruments that in a matter of minutes came the hopeful request that we would send someone to repair the palace radio. Apparently it had not worked in weeks and the nearest parts and technicians were in Fiji. This chore fell to Allan Jones, our electronic trouble shooter, who was partly repaid for missing the cocktail party by the gratitude of royalty.

For Tonga is one of the few remaining independent monarchies in the world and our guest of honor was Prince Tungi the prime minister and son of Queen Salote who was en route to the coronation in London. At the princes special request we had a diving exibition. He is said to have been quite a swimmer himself in his youth and we were anxious to make a good impression. Now in his upper thirties he spends most of his time keeping the government running on a very modest budget; the free diving technique seemed to appeal to him because of its simplicity and inexpensiveness. Possible he envisioned its use in the creation

of some new industry such as pearling, or in the expansion of the country's fishing and clamming facilities; at any rate he seemed greatly interested and asked many questions about the equipment and its use. As a Christmas present Director Revelle gave the Prince a framed enlargement of the Aqualung in use at Alexa Bank.

Phil Jackson and I made the dive and Bob Livingston stood with the prince calling signals and describing what we were doing. On deck we felt a little uncomfortable, even immodest, in swimming trunks among the smartly dressed visitors who were having cocktails but once in the water normalcy returned. For a harbor the water was clean and clear and we selected the water just astern of the Baird for the demonstration. A gallery of hangers-on sat on the edge of the wharf and the Prince and his party lined th e ship's after deck.

There was no way to get into the water gracefully so we jumped from the work-basket which is about four feet above the water. Phil went first creating an impressive splash; then I clutched my face mask with one hand to hold it in place, bit down hard on the lung mouthpiece and followed; with the other hand I reached behind my back and held down the bottle straps--this is good practice when jumping as there is a good chance that the bottle will slip upward and the regulator strike the head. The jump carried me well below in a great cloud of bubbles; I took a few breaths to check the gear and continued on to the bottom for a sample. Choosing a small rock from among the great clutter of old cans, tires, bottles and batteries that littered the harbor bottom, I

brought it slowly to the surface, showed it, and dropped it again. Every harbor has a bottom like that but I thought a sample of trash might embarrass the Prince. Then down again for a few minutes so that the audience could watch the exhausted breaths rise as groups of bubbles in my trail. Phil was doing the same thing but I sort of lost track of him. When I surfaced again Bob called, "Show how you can clear the face mask underwater." I filled the mask with water showed everybody and then ducked underwater and blasted it out by holding its upper edge while leaning backwards and blowing thru my nose; the water is forced out under the lower edge of the mask. When I surfaced with an empty mask Bob appeared satisfied. "Now show how you can remove the mouthpiece underwater and put it back again." This time I removed the mouthpiece above water so that all could see and held it above my head as I sank. The hoses, of course, partly fill with water but it is not difficult to clear them. You put the mouthpiece higher than the regulator and rising air bubbles clear out the intake hose; then put the mouthpiece in your mouth, roll on the left side and blow out hard. This clears the exhaust hose. Sometimes this latter operation has to be repeated to stop an annoying gurgling in the hose but it is possible to get fresh air from the start.

When we finally surfaced, the Prince nodded a "Thank you". The simple exhibition was over and Phil and I loaded our diving gear in a skiff and clambered aboard the Baird

to change into our cocktail clothes.

From Huck Finn I recall that many singers and actors of Mark Twain's day found it desirable to bill themselves as having made a command performance "before crowned heads". Today with the increasing scarcity of monarchies, I think Phil and I must be among the very few who have made "command dives".

Spearfishing at Nukalofa

Many stories have been told about the wonderful divers of the South seas but in their telling and re-telling truth and fiction have become inextricably intwined. Native divers are reputed to have done fabulous things; stay underwater many minutes, go very deep, and use breathing and diving tricks, of which white men know nothing. It was Helen Raitt's job to investigate native diving method for the N. R. C. Panel on Underwater Swimmers and to report the details of any techniques, devices or ideas that might be used in the U. S. Helen arrived in Tonga ahead of the Baird on the vessel Tofua and immediately went to work to arrange a demonstration of spearfishing. Carl, a local British-Tongan and two of the native divers were to guide us among the reefs in Nukalofa bay, show us the best places to dive and give the exhibition.

At the appointed hour we were waiting in the skiffs alongside the Nukalofa wharf, with our gear ready when Carl appeared above and called, "How about a hand with these spears?" The first one he passed down was 10 feet long; the next one was 14 feet long; the big one was 16 feet long. Straight hardwood saplings with the bark removed and a spike a foot long inserted in the end; no barbs.

We had all seen a dozen brands of U. S. spears, none half as large as the smallest of these. I mentally compared old whaling harpoons with these and found them wanting. Each of us had the same thought, "This, I wouldn't miss".

The bay at Nukalofa is a soft pastel green; it is shallow, and warm and there is lots of sunlight. Two little islands with tall palms sandy beaches and one red roof apiece have been put there as models for passing sailors to dream about. One's name is Maka haa, rivaling Bali hai for poetic beauty.

Between the islands and the mainland there is a reef in some places only four feet deep, and here the corals grow with exuberance; never has coral been so happy or so prolific as on this Tongian reef. Here the great flat bowls and webs intermeshed like a silver and gold watch mechanism. Elsewhere the competition for sunlight would have killed off the lower colonies but here they grew equally as well. Between the rigid branches there was scarcely room for the small angel fish to swim and the edges stepped off slowly and with dignity into deeper water.

It was to the boundaries of this reef that our guides brought us. At a depth of 25 feet the bottom changed to fine white coral sand with occasional small coral heads and here the natives chose to fish. This was a bad day, they said, too cloudy and the water too murky, but they put on the tiny goggles that seal against the eyelids, threw their long spears into the water and quite naked, jumped in themselves.

The spear just barely floats and the iron spike keeps its end depressed at an angle of about 30 degrees with the surface; this is apparently a very convenient position for ready use. The fishermen swam slowly along the surface looking behind each coral head for a suitable quarry.

When such a fish was seen, it was frequently within range of the long spear already and it was only necessary to ease the shaft into alignment and thrust. Since before making the thrust, the point could be brought to within as little as a foot of the slowly swimming fish without scaring it, a high percentage of kills was inevitable. If the fish was deep, the hunter would dive down to bring it into range before making the cast. The point was barbless, and there was some danger that the fish would wriggle off; to prevent this, the point with the speared fish on it was driven into the bottom to hold the fish until the swimmer could get there to hold it by the gills and take it back to the boat.

My problem was to get motion pictures of this, and as the native diver moved along the surface, I, in an Aqualung, with a ready camera followed along behind him on the bottom. Behind me, in fulfillment of our buddy-system rule, swam a very bored Walter Munk. My subject had rotten luck. Either there weren't many fish or we scared them or something, but for over a half hour we moved about from coral head to coral head without much luck. Finally, we came to the edge of the reef and suddenly the fisherman struck. He got his fish very neatly but the fish, dragging the end of the long spear with him, dodged into a small cave. Things started to get exciting. The diver came down to see what he could do about getting the fish and I jockeyed into position for a shot. Just as I got set he returned to the surface for another breath. On his next dive I was ready; he came gracefully down, with his feet trailing up behind him grasped the edge of the coral cave and looked in at his

fish. This was the shot I was after and the camera started to buzz. At this instant the view finder went black and I looked up to get a great view of Walter's rear end as he got between the camera and the native to look into the cave too. Apparently the native thought the fish was not worth the effort and withdrew his spear; he never hit another one.

We learned about long-spears, saw and photographed a beautiful reef and found that these were not the great divers of the south seas. Those we saw later.

There was also another dive; a dive I didn't make but I remember it because the thought of making it fascinated me --- but there was no time. In a remote village on the main island I talked to a local fisherman about fishing methods; he uses traps, lines, nets and --- a mouse. "A what," I said.

"A mouse; look here," and he showed me a conical rock about four inches long with four short wooden "legs" tied to one side and a large bright piece of cowrie shell on the other; a tail of grass stuck out behind and the whole business hung from a string. It did vaguely resemble a mouse.

"It's for octopus," he explained, " I just lower it to the bottom and jiggle it once in a while; pretty soon an octopus comes along and wraps his tentacles firmly around it. Then I pull him up. He hangs on tight."

I was entranced by the thought of such a process and asked if he thought I could get motion pictures.

"Sure," he said, "you won't bother them if your're a few feet away. One comes along about every ten minutes."

What the octopus thinks he's getting one can only guess surely there are not enough mice settling to the bottom to make this a regular food item --- but the system apparently works. I'll bet a lot of people in the States would like to see moving pictures of it working, but, slaves to schedule, we sailed next day without getting them.

ODD JOB

Because of its beautiful simplicity, free-diving apparatus can be used to great advantage on many small waterfront jobs. It is not quite as easy as it looks for the spectators do not see the work that goes into filling and transporting the compressed air bottles or in periodically checking the regulators. (This is another way of saying that the Aqualung has the most desirable quality of an oceanographic instrument; the field work is easy and the more difficult jobs are done back in the laboratory.) Wherever we went people heard about how easy it was for us to go underwater and do jobs that were difficult or impossible for them. Consequently, we had many requests to locate lost anchors, inspect pilings or ship bottoms and do odd jobs underwater. Most of these we turned down but one short example is illustrative of the value of our tool.

George Mann, one of my new-found friends at Tonga, and proprietor of the Nukalofa Taxi and Garage Company, has a small speedboat in the harbor at Tongatabu. The day we arrived, the propeller came off. Somehow he retrieved the propeller but his problem was to get it back on the boat without the considerable inconvenience of rowing the boat to a place where it could be beached for a low tide or put on ways. It might have been possible to replace the propeller by skin diving but it would have taken many hours and many dives. The problem was to fit a key into the shaft, slip the propeller on, tighten a bolt on the end of the shaft

and insert a cotter pin. This simple operation took me 15 minutes from start to finish and was about like working on a car on a grease-rack. For this modest effort George rewarded me with a handsome, ornately carved chief's double Kava bowl which, appropriately enough, is supported by a pair of turtles. It was the only one of its kind we saw in the islands and I felt embarrassed at such a rich gift for such a simple service.

A breath of air

It is not an uncommon thing to run out of air while on the bottom. I have done it often and never felt seriously endaggered but the cirsumstance which I am about to relate had the effect of increasing my caution in the matter of air supply.

No one can say just how long a bottled air supply will last because it depends on a number of variables, the most important of which are the diver's rate of breathing, the depth at which he is working and the temperatures of air, water and swimmer. Roughly, a standard single bottle will last a man one hour thirty feet below the surface and a half hour at sixty; the double bottle unit will do twice that.

On Capricorn expedition we mostly used combinations of these bottles which contained air compressed to 2200 pounds per square inch. If the air inside one of these bottles (the volume of which is about half a cubic foot) were released into a balloon at sea level, the balloon would surround 80 odd cubic feet. If the same amount of air were released into the balloon some distance under water, the balloon would occupy a much smaller volume but, if allowed to rise, would gradually increase in size until at the surface it occupied 80 cubic feet. The size is different but the amount of air is the same.

The air in the lungs and mouthpiece tubes acts the same way and as the swimmer rises it expands; however since his lungs stay the about same size, they require less air to fill them as he nears the surface. This means that a swimmer who has

just exhaled at 80 feet, say, and finds no air in his tanks to inhale, can start toward the surface and expect his lungs to be full again long before he gets there for that which was already in his deflated lungs and tubes will expand enough to fill lungs again as the pressure decreases. It is true that this air has had some of the oxygen removed from it but man only uses a small portion of the oxygen he takes in on each breath and the air can be used over again. Breathing is largely a matter of comfort and habit and is not necessarily related to the body's demand for oxygen for experiments have shown that a man can feel perfectly comfortable while breathing in an artifical atmosphere that contains no oxygen --- (of course he soon becomes unconscious).

On the day of this particular dive, we had the problem of examining and sampling the bottom far from land in a search for geological data. It was in the Tongas, between the Haapai and the Tongatabu groups on a broad flat reef area, 120 feet deep that we went overside; Jackson, Munk, and I. We had a descending line, consisting of a 50 lb. lead weight on a length of rubber covered wire, which hung to within about 20 feet of the bottom . (For dives from a drifting boat or ship, I consider a descending line to be essential and for all dives of fifty feet or more it is certainly helpful. Such a line allows the diver to ascend or descend more rapidly than he can swim and to stop at intervals for clearing the ears; moreover, it is a pathway back to the boat and an orientation point.)

I descended first to about 80 feet at which depth the bottom was plainly visible, and was somewhat surprised to see it moving past so rapidly for although the ship was hove-to, it was being swept along by a current of at least a knot and a half, a fact not at all apparent to those aboard. As I considered this and looked up to see whether the others were coming, the Fenjon camera came into sight as it was being lowered to me on a line. It was obviously too dark for pictures so I went quickly back up the line to the surface and ordered it retrieved; then I descended again to join the others near the bottom of the line. Just as I got there the descending line parted somewhere above us. Thinking that the weight was so satisfactory (and hard to replace so far from home) that it would be a shame to loose it, I signalled the others to help pull upward on the line. We held on and swam upwards for several minutes but to no avail, the weight was too heavy , so we dropped the broken line and surfaced. Already the Baird was over 100 yards away. With the parting of the line, Dr Livingston had sensed the probable trouble and was standing quite naked on the rail with a line around his middle. As soon as we surfaced he dove in and swam rapidly towards us and, when he gave us the line, the men on the Baird dragged us back to shipside. We waited there in the water while another descending line was rigged and then went below once more. The two previous descents had drawn heavily on the air in my single-bottle tank but the time had passed so rapidly that I gave it no thought. Fortunately, the other men had larger units on.

This time we three descended and held to the line right at the weight and hung there watching the bottom go past only about fifteen feet below us. There were wide white-sand channels thru darker reef material which had a rather scanty growth of coral and calcareous algae on it. Here again we had a chance to watch an underwater instrument at work; this time one of the deep water cameras was being tested. This particular camera is constructed so that it and it's light source are supported by a vertical framework under which hangs a "trigger-foot". When the foot touches bottom, the camera, and its strobe-light fire simultaneously and reload automatically. By retrieving the supporting cable a few feet and then lowering it again until the cable goes slack, a series of photographs of the bottom can be taken. Such instruments are based on the premise that the ship is holding fairly still. As we watched, the camera descended only fifty feet away from us, touched and the light flashed, presumably taking a picture. In theory it should then have been raised a few feet and lowered gently again to touch and photograph a new spot but because the winch was difficult to operate and the ship was moving fairly fast, we saw the line pay out and the camera dragged along the bottom bouncing crazily on the reef. In a little while it was raised clear and then lowered again to touch once more at a rather flat angle because of the motion of the ship. In such ways we learn something about instruments and how to operate them.

Now although the ship and the surface waters were moving at the same speed, the water near the bottom was moving much more slowly because of bottom-friction and we could feel ourselves being dragged thru this comparatively still water by the descending line. To let go was to fall behind the ship at once and we knew that a man's head is a pretty small object to see in the waves of late afternoon; especially with the deck crew watching the descending line.

We still had the problem of getting a bottom sample and to do this meant letting go of the line. I experimented a little by swimming alongside of the line and found that I could keep up with it without much trouble, so I decided the thing to do was swim ahead a little way, dive and break off some corals and then swim back up and catch the end of the line.

The plan worked beautifully, I got ahead, dove and broke off one coral, then another and started up. Just as I pushed off the bottom, the weight with my companions riding on it passed overhead and I ran out of air. Sucked in and got nothing. In 120 feet of water this was no joke but even then I did not regard the matter seriously and swam upward a few seconds longer before I decided to drop the hard-won coral samples. The descending line was rapidly disappearing in the blue but of course I could not afford an instant of horizontal swimming; up was the only possible salvation. Remember that the practiced diver makes each breath last to conserve air and that at the moment of sucking more air, the diver has exhaled fully. Always before there had been some

warning that the air was getting low --- usually there are a few hard breaths, but this time it stopped short. I was completely out of air and no doubt about it.

As I have said, it is usually only necessary to rise 20 feet or so to get another breath because of the reduction in pressure and the resulting increase of volume in the tube and lungs. Not this time, and I started to feel concerned and swim harder.

When I had risen 50 feet (70 feet below the surface) and still no air, I started to shed the lung, swimming harder all the time. What use, I reasoned, to have that extra drag if I'm not going to get any air at all out of it. I kept the mouthpiece in my mouth but unbuckled the belt, had the shoulder straps off and was just about to duck out when I was finally able to get a small breath out of the thing. It wasn't much but it was enough.

By now I was only about 50 feet from the surface and my legs ached from the intensive effort; I slipped into the Aqualung harness again and secured the belt. This entire part of the ascent could not have taken very long, probably only a minute, but a minute without air when one is unprepared and not much prospect of getting more can be a pretty long time. Until I got the breath, my entire concern was to get some air --- fast--- and I must confess I took part of the time to consider the possibility of drowning. After the breath, the realization that the ship might be drifting away too fast to overtake became predominant in my mind and I wondered a moment how long a

man could live swimming in the open ocean --- a much worse fate to be lost from the ship with night coming on than to drown at once.

I broke water nearly 150 yards from the ship, gulped some wonderful free air and hollered, "Help." --- mostly for want of a more concise phrase.

This, of course, was a surprise to those who were expecting us to rise along the descending line but again Dr. Limingston tied on the line again and swam out after me. By now there was no danger of loosing the ship anyway since in the surface water both ship and I were drifting at nearly the same speed but I was glad to be helped anyway.

It's surprising how much an experience like that can make one appreciate a small breath of air.

Barracuda

It must be very rare for a diver to bring up treasure from a sunken ship --- just about as rare as finding a pearl in a pearl shell. But hope springs eternal and it is easy to believe the things you want to believe; besides, our prospective treasure was fairly modest.

Helen Raitt brought us the story at Nukalofa in the southern Tongas; a story of a ship sunk in a shallow bay during World War I. A ship with a cargo of whisky, that lay in quiet water at the island of Vavau, 200 miles to the north. Gold ingots could scarcely have been more effective.

At the time, the Baird was not scheduled to stop at Vava'u and leader Revelle had no intention of going there; a few days of pressure and he took a more reasonable position. Geologists are the greatest rationalizers on earth. Did they mention the ship or the whisky? Not once. What they wanted to do was work on the geology of the island and to determine whether the rocks were volcanics or uplifted coral reefs. After a while they believed it. The non-divers balked the same way but they were insincere; they were really after a chance to trade for mats and kava bowls.

So, on one of the brightest mornings in my memory, the Baird steamed slowly up the narrow waterway in Vava'u and dropped anchor off Neiafu. In 10 minutes the skiff was overside with five divers in it ---headed up a narrow arm of the bay for the sunken ship.

Reaching what we thought was the vicinity of the wreck we beached the boat and tried out the equipment in shallow water; this was partly to see what the bay floor was like and get the feel of the place, partly to take some test photos.

In these waters were some fine small submarine gardens; the fish were not so bright and numerous as those in the Marshalls or the water so clear but the spiny echinoids and the black pearl shell helped to make up for this by adding a sort of svelte glamour. These animals live in clusters which? and at the least sign of intrusion wave their long sharp spines slowly, hoping to impale the intruder. The spines on these were as much as a foot long and did not look pleasant to tangle with. There are many varieties; some are highly poisonous, others are edible raw and considered quite a delicacy, still others have thick heavy spines which were once collected for slate pencils but not being good at identifying the various species I leave them all alone. The black pearl shells (8 - 10 inches long) were firmly attached to something solid a few inches below the sand and put up quite a battle; in the end they were torn loose but some of us were cut by their sharp edges. Although the shells had a brilliant pearly black luster at first, this disappeared in a few weeks and the shells cracked.

There was no sign of the wreck and our looking became half hearted; perhaps it would be easier to go ashore and get a native to show us. We landed at a place where a trail could be seen and followed it over the hill to a

group of grass shacks. Ambling down the main street of the village we were hailed by a group of men seated cross-legged on mats under an awning of palm fronds. This was morning kava time and the Chief, who spoke English well, invited us to join the party. The Chief sat at the head of the mat with Dr. Livingston at his right (natives have a great deal of respect for M.D.'s but are not much impressed by PHDs); at the other end of the mat a good-looking woman in her 30's was making the kava, and around the edge sat about 10 of the towns elders. We fitted outselves in and waited.

Kava making is a fascinating process: in the old days the root used to be chewed by the maker until it gave up its juice which was then spat into the bowl and the process repeated. Saliva gives it flavor they say. In these modern times though, the root is pounded between two rocks until it is frayed and pulpy; then the pulp is added to some water in a wooden bowl and kneeded, wrung and squeezed until the water takes on its flavor. Our kava maker looked fairly clean and I didnt mind her hands in the kava but it would have been nicer if she hadn't continually wiped her forearms and elbows with the pulp. Presently she seemed satisfied with the brew and the ceremony began.

One man, probably called the kava passer, scoops up a half cocoanut shell full of the light brown liquid and passes it to the honored one kneeling as he does so. As the man drinks, the passer leads the rest of the gathering in a slow measured hand clap. Kava is to be drunk with a

single raising of the cup; when it is completed, the audience all moan and the passer goes back for a refill. There is only one cup of course so it takes time to get a drink. The Chief was first, Bob Livingston next, then us lesser lights, and then the village men. I didn't mind the wait so much but the fact that some of the natives who shared my cup had filariasis or elephantiasis was a little disturbing. There is nothing to do but accept with a smile and try to look as though another instant's wait for such a delightful drink would have been fatal; anything less would be insulting to your hosts.

Kava has a rather strange taste and leaves a not unpleasant tingling sensation in the mouth; after a while I got used to it --- even liked it a little, but it will never compete with Coca-Cola even on Vava'u, because it is flat (like "branch water" in Ted Folsom's words) and is usually served warm. One could drink a gallon of kava without approaching the effect of one good martini but it does, after a few drinks, slightly anesthetize the roof of the mouth. Most important, a little kava stimulates conversation.

So we sat in the shade in this pleasant village and talked as an ever increasing audience of kids, pigs and dogs gathered about us. We talked about the rhinoceros beetle, the Chief's bad arm (elephantiasis) and his need for aspirin, the price of copra and the value of research in the deep ocean. The Chief would occasionally stop and bring his friends up to date in Tongan.

we asked about the ship.

"But of course, I saw it burn myself. Burned for two days before it sank."

Mentally we heard corks popping in the heat but we pressed on for details. The ship it seems was loading copra from this very village when it caught fire. If there was any whisky aboard the captain probably drank it while the crew was fighting the fire.

"But," when he heard about our diving apparatus, he would be, "Glad to send a guide to show us where the ship sank." With inspiration he added," And he could bring back some aspirin from your great white ship."

We caught on, thanked them all with bows, and left with our guide. He was, it turned out, the village schoolteacher and spoke English well. A skin-diver himself (for fish) he asked intelligent questions about details of the Aqualung and seemed most impressed by what we told him. Without hesitation he took us to a spot directly over the wreck-- by instinct, perhaps by complex bearings he did not explain. I leaned far over the side of the skiff so that my face and mask were underwater; about ten feet down was the top of the mast thickly encrusted with corals and algae. Just at the limit of my vision (about 35 feet) I could see a platform which seemed to be part of the deck.

"It looks easy" I chortled and went over the side immediately starting down; Livingston and the others would be along in a minute. The upper twenty-five feet of water was crowded with jellyfish but by watching carefully I was able to thread my way thru them (and avoid their consequent stings) and reach the clear water below. There I could see much deeper and it became

trees and that the actual deck was another 50 or 60 feet below. Above me the others were in the water and dodging jellyfish so I continued to decend slowly---even apprehensively.

The hull seemed a long way down; the water became a little murky, the sea life on the mast less abundant. Finally I landed softly on the deck next to a large cargo winch, its cable still neatly wrapped in place. Grasping the deck railing I stood upright and found myself looking down a ladder that led to a dimly-seen well deck; in its midst was a black pit--- the open cargo hatch. There were piles of coral rubble on the deck and this puzzled me for I wondered how they could have got'en there since the deck must have stood at least twenty feet above the floor of the lagoon; perhaps they were piles of something else with only coral fragments on the surface which had fallen from the mast. Turning to explore in the other d direction, a shadow caught my eye and I looked upward expecting to see the other divers arriving for they had had plenty of time. Instead five long slim shapes were passing about twenty feet above me; they went off into the blue then appeared again and passed going the other way.

Barracuda, and at least six feet long. Thru my mind two sets of ideas flickered simultaneously like strobe lights: one was the barracuda stories I had heard---- what they could do to a swimmer with their long jaws and sharp teeth; the other was reasons why it was no longer necessary to inspect this particular wreck at this moment. The other divers had seen these dangerous fish from above ,and making a similiar comparison, elected to remain topside. For it is said that barracuda much smaller than these will bite a steel fishing line in two and snap off the

end of a wooden fishing pole without much effort. In fact a shark attack that I investigated at Eniwetok turned out to be a barracuda attack (it had nearly severed one of a swimmers buttocks); there is plenty of evidence that they are vicious animals.

I did not really expect trouble but is is always well to approach the unknown with care. After watching them go by once more I surfaced, fast. Never even saw the jellyfish.

In retrospect I suppose that Barracuda are about like sharks and will not likely attack a man who is wholly submerged and leaves them alone. In clearer shallower water I'll test that theory sometime.

There wasn't any whisky there anyhow.

X SUNKEN TANKER

On the island of Tutuila in American Samoa is a semi-circle of jagged mountains rising 2,000 feet above the ocean. They were once the rim of a great volcano, which in the distant past exploded, blasting one side of its crater completely away; thru the gap rushed the waters of the South Pacific to fill the crater bottom with an elongated bay. Passing years have seen this steep-sided amphitheater take on a dense cover of jungle and the once sharp and fire-scarred rocks soften a little. Between the steep slopes and the water's edge is a narrow but comparatively level rim and thru the dense bushes and trees that grow right to the highwater mark, one can make out the indistinct outlines of white houses. On the bay's calm surface are usually a half dozen of the delicate and swift Samoan outriggers.

This is Pago Pago, quietly content to be the most beautiful and dramatic harbor in the South Seas. Across the bay from the village, the Rainmaker towers high above its fellow peaks to intercept and exact tribute from each passing cloud to keep the slopes and the city green. Every Samoan within sight of this tower of lava is a weatherman, for even the smallest child in Pago knows enough to head for shelter when a cloud approaches the Rainmaker.

In the late afternoon, the Baird approached this verdant bowl thru a misty rain; but this in no way deterred her company from standing along the unsheltered rail to admire and photograph this northern bulwark of a great volcanic chain that extends to New Zealand. Along the Samoan south coast which was our landfall, sea cliffs, brown and steep with great caves underneath, were fighting a losing battle to protect the green hills from the relentless sea and in the dark caves at their feet we could see the white splash of the southerly swell as it sloshed about under the mountain, cutting fifth-column-like from behind and below. An occasional spouting plume of water lept a hundred feet into the air as the jagged rocks fought to milk the last erg from the tormenting waves--and the white spray would fall ever so slowly,

back into the churning battle-ground.

Within the outer reaches of the bay the mountains reached out in a low and narrow coastal plain to meet the more subdued ocean and grass-roofed villages set about with palms showed hazily thru the darkling air with the romantic quality of the not-quite-known. Here and there a bright red roof and a stateside-type painted frame house showed as a spot of color against the softness of the island.

We slowed to pick up the pilot from an ex-Navy personnel launch and then with renewed confidence made full steam towards white buildings and piers which we raised thru the mist. Above us, Rainmaker's crest was lost in the clouds but on his lower limbs we could see trees growing on slopes so steep that vines drooping from their outer branches hung far below the trees' own roots. The white club buildings on Goat Island Point loomed dead ahead and near it the superstructure of the HORIZON mingled with palm fronds; perhaps the faintest trace of resentment or maybe it was envy, flowed thru the watchers by the rail for the HORIZON always arrived in port first. We sighed a little, muttered a little and braced ourselves for the inevitable taunts as the BAIRD tied up just ahead of the HORIZON. For although we always swore we were second into port because we worked longer and harder at sea, they always insisted the HORIZON was faster or more efficient. (It wasn't either).

The pier to which our home-away-from-home tied up was in sad condition indeed and rather gave the impression that it had gotten too close to a block-buster. Opposite each ship there was a comparatively smooth area of reinforced concrete but the part of the pier between the ships was a no-man's land. Sagging bars of reinforcing steel showed thru broken and missing sections of concrete decking and rust from the skewed girders dribbled between fractured and chipped concrete casings. A giant, stomping angrily on the pier would have produced such a result.

Above Goat Island and this puzzlingly shattered pier, on a rocky prominence reached by a long flight of steps, is the Govenor's mansion with its incomparable view of the volcanic bowl and Pago Pago Bay, and as we eagerly opened the long awaited mail from home we found among it invitations to climb the steps to an official cocktail party —— in our honor.

But there was an hour to spare first and en masse our company headed afoot for the sights of the city which was a quarter mile further up the bay. For sailers are fugitives from the sea who live on the philosophy that the purpose of a ship is to take man to new lands —— it is the means to an end and not a thing to be loved for itself alone. The true sailor exists only to get ashore at the next port and once there, quickly satiated, he is not unhappy to be coaxed or carried back aboard where before the vessel drops the pilot outward bound, he dreams of the next port. Dreams that may extend far inland, leapfrogging the waterfront taverns which his realistic subconscious mind tells him he will never pass.

The village of Pago Pago consists for the most part of a green grassy oval about a hundred yards long rimmed with whitewashed boulders on which a perpetual game of cricket is played by the native children. Between the oval and the hillside a single row of two-story white buildings stand in stately middleage relying on their green setting for beauty by contrast rather than on neon trinkets,

brushing to one side their stepchildren, the tawdry cafes (beer parlors) whose social standing does not seem to permit a street entrance or a view of the park. The stepchildren were unseen but not unheard and the tinny tinkle of a honky-tonk piano rattled about in the alleys and scuttled crabwise along the gravel pathways. The crews, in doing what came naturally, followed it to its source and arrived in the nerve-racking relaxation of the "Moonlight Cafe" where they became semi-permanent residents. From their hilarious attitudes in flash-pictures taken there late that night compared with their sad appearance next morning I judged that it had been a successful excursion.

On the bay side of the grassy oval, an open walled native house with a steep straw roof lying on a tracery of bent wands and supported by poles, shelters a group of Samoan women who squat about a central aisle weaving baskets, stringing shells and encouraging the passing tourist to examine and buy. Tourists that we were, we handled their carvings, discussed the shell necklaces and haggled over the prices but the men of the HORIZON had, an hour before, skimmed the cream. The best pieces were gone and fortified with a few dollars, the natives were able to deal more sharply, being able to risk the loss of a sale for the chance of a bonus price. In their eyes we were wealthy men from an inconcievably wealthy land and we bought anyway, for concepts of great riches are modest in this grass shelter and a few hundred dollars would have cleaned out the place.

The American tourist has a certain disadvantage in buying the wares of native craftsmen --- or at least faces a moral dilemma. The asking price usually ranges from very reasonable to ridiculously low (by home standards) and there is no real reason to argue about it. On the other hand, one loses the respect of the natives instantly if he buys without some haggling --- and future prices for himself and other such foolish people go up.

Ask the cost of some item for which they have no established price and they will consider a moment and then say, "Twenty dollars", this being such a vast sum that they have no comprehension of its real buying power; On being refused

They will suggest as an equivalent alternative an "old pair of pants".

Into the Samoan house of native craftwomen I walked, carrying in an old pillow case trading items of incomparable value which brightened the eye of every inhabitant: a child's plaid dress, a flowered blouse, and pink satin slip. What a slip! In fact it brightened my own eye and I considered for a moment taking it home to inquire of my wife how she could afford to part with such good clothes ——but it was too late. I was besieged with complex offers of assorted pieces of merchandise for each item and let the blouse and dress go without much of a struggle for some beads and table mats and a model outrigger. Bidding for the slip became more frantic and was accompanied by many inter-female side remarks in Samoan, made between bared teeth. This was really very curious because the median size hip-spread of the bidders was at least one axe-handle too large for the ex-drapery of my slim wife. One little girl with a shy smile offered a small basket; it was a poor trade and I would have turned away but Dick, standing behind me, said in a nudging voice, "You hard-hearted dog, how can you refuse those wonderful eyes?" He was right; besides, it looked as though it might fit her and so she won out over her heftier and better stocked competitors. With a pillow case now full of souvenirs I headed back down the road for the ship to get ready for the party.

The govenor's mansion was a real oasis where we were reinstated among civilized people who take ice in their drinks —— a technique which Americans consider essential but which the British cultures of Tonga and Fiji abhor. We stood in a second floor reception room walled with a checkerboard of tapa cloth and mats and gazed out long windows at the grey bay during the last moments of daylight. There was a native orchestra and dancers to dance the old Samoan dances, there was the tinkle of the wonderful ice; and there was Govenor Ewing himself to tell us the story of the shattered wharf.

Pago Pago was quite a naval base during the war but with peace the base shrunk rapidly and finally was completely deactivated leaving only deserted

warehouses and barracks. One of the Navy's last ships to call (in 1949) was the tanker Chehalis. While transferring fuel oil or gasoline it caught fire and there was an explosion which had wrecked the pier where our ships were now tied. The fire could not be controlled and so to save a possible larger explosion, the bilge cocks were opened and the lines cut. The blazing ship, some 300 feet long and displacing around 2500 tons drifted only a short way from the pier before it rolled over and sank. Scuttled, to save itself from a worse fate.

The Govenor, in non-political life a steel man from Youngstown, Ohio, had taken an interest in the wreck partly because its exact location was unknown and it might be a menace to navigation and partly because of what seemed to be attractive salvage possibilities. Would we take a look at the hulk and describe it to him? Try and stop us; the appeal of a sunken ship is tremendous.

So, on January ninth, while the governor waited on deck with a hundred questions, five of us went below to look at the Chehalis. Details of the dive and the ship's appearance are still clear in my mind. On the first descent even though there were five of us looking, the water was clear, and the ship had been seen for a moment the day before, we missed the huge target somehow. We surfaced for reorientation, selected a new spot and went down again; on the second dive I landed on a six-pointed cross, the Plimsoll mark, and away from me in all directions stretched a great steel floor, the ships port side, which now lay horizontal. With one hand I cleaned the fluffy brown sediment (about ¼" deep) off the cross and its white paint shone clearly again against the gray hull. The depth of this upper side I judged to be about 110 feet.

I swam over to the rail and looked straight down across the now vertical deck which disappeared in darkness below; from the hazy blue depths the barrels of a twin machine gun pointed surface-ward. The railing was made of three chains and passing over I grasped one and got a cut on the hand; sharp clams had made a home there. Down the deck thru the rigging I descended, being

careful not to foul in any of the many booms and funnels and pipes that I passed. Most all of the heavier metal parts seemed in good condition and the paint was largely intact. A cable, which had once stayed the mast, broke under my hand and the lower end fell away into the unseen. I finally reached the place where the ship's starboard side was in contact with the bottom but it was pretty dark and hard to make out details; I remember feeling certain that the side was not buried in the mud more than a few inches. This was the damaged side but there was no sign of any explosion; as far as visibility would permit, the sheer strake followed a smooth curve just as it did on the upper side. The ship's side simply lay flat against the bottom in nearly 160 feet of water.

I ascended again to the rail on the port side and swam along it, following its gradual curve down into the blueness until I reached the bow; the port anchor was still in place and looking newly painted. Then sternward, passing above the superstructure.

My brain was not working very well; vaguely I realized this. Objects which should have looked familiar became just abstract shapes; I forgot to look for important details and the dive became pointless as general dullness crept over me. A trail of bubbles rose from the deckhouse below and I knew that some of the other divers must be down there but it never occurred to me to join them. On to the stern, which fell away below me and descending along its smooth curve dimly made out one propeller and the rudder and then swam between them, absently feeling a great bronze blade with one hand as I went. I looked downward over the keel but saw only darkness and then slowly returned along the red bilge-keel to a point opposite the Plimsoll mark from which I ascended.

Once back on the BAIRD, my thinking returned to normal but I had the feeling I had experienced some form of nitrogen narcosis for the first time; only the vaguest memory remains of the latter part of the dive for my brain never

recorded it properly.

In a few minutes Livingston and Dill returned from their inspection of the deckhouse, bringing a metal chair from inside the cabin to prove they had been there. "Too dark to see inside," said Livingston.

The dive was fun and the information appeared to satisfy Governor Ewing but it left me with a feeling of incompleteness because of what was not done; we had no submarine lanterns or cameras suitable for taking pictures at such depths and we never got inside to see what damage the fire and explosion had really done. From our hasty examination though, the Chehalis looks like a still valuable piece of machinery. I'd kind of like to go back to Samoa and salvage it myself.

Just before the BAIRD cast off from the wrecked pier, one last native boat came alongside with a few items to trade and in it was the girl who had traded for the pink satin slip. I winked at her and made the palms-up motion asseciated with hiring chorous girls. She caught on and lifted her dress an inch or so to show a narrow band of pink satin. The smile that went with it was easily worth its original price.

XI TAHITI

Tahiti is the traveller's dream, the bachelor's paradise. Without seeming radically different from the other beautiful isles of the south seas, it has an air about it that is unique --- perhaps a touch of Paris brought by the free and easy French colonial government. Somehow, without having the energy and opportunity of the Fijis, the friendliness of the Tongas, or the beauty of Samoa, it outdoes them all in a subtle way which is hard to describe. Perhaps this is because the visitors to Tahiti are mostly appreciative sailors, for Tahiti is a sailors island if there ever was one. With the first exciting view of Papeete harbor and its many white yachts moored stern-to the park-lined parapet and the crowded trading schooners tied to the main wharves the blood pressure must inevitably rise. The town itself, in the words of its French-speaking natives is, "How you say, flamboyant". Flamboyant is the word; from the gaudy Yacht Club which practically overhangs the quai thru the strangely patterned streets to the market there is an oo-la-la of color in the air. And beyond the town the jungle rises steep and green on the slopes of Orohena. Everything is fun today. There is love, music, flowers; tomorrow never comes.

Best of all, from the sailors point of view, are the girls. Young, pretty girls, whose avowed purpose in life is to have fun with sailors --- and they make it a full time job. From all over the island and from the other islands

they come encumbered by only a flower in their hair, a small purse and a guitar. They carry health cards as required by law but their love is not for sale --- the only price is a good time. The sailor buys drinks, food and sometimes presents; the girl furnishes guide service and a place to sleep. If the sailor is without funds (British sailors arriving are chronically broke because of their country's stringent money laws) the girls pay for everything --- it's all in fun.

This fascinating free-love society seems to center about Quinn's Tahitan-Hut which is at once the trysting place, the bar of bars, and the social center of the water-front. Almost the instant our ships touched, crews and scientific party alike headed for Quinns. None, I think, were disappointed, for except Sunday mornings and election day, it is open continuously and the flow of people in, thru and around the bar is astonishing. At night there is an orchestra, protected from the dancers it stimulates so strongly by the bar itself; at other times music is from tape recordings played by the bar maids until some group of customers demands silence --- so that they can play their own guitars. Here we drank anise and absinthe and watched the Tahitian hula --- not like the calm poetic dance of Hawaii but pure sex with only the most diaphanous cloak. I wouldn't have missed Quinns for anything but the rest of the island was appealing too and off I went on foot and by bus to see it. Diving, of course, was completely forgotten during the three

precious days we stayed in Papeete but there were some aquatic adventures ashore which have the high flavor of the south seas and seem worth the telling.

If you are among those who have come to ride roller-coasters and jet planes with boredom do not give up hope of a thrill until you have tried a Tahitian bus ride. Todd Carey and I did one Sunday morning and for forty francs we rode eighty wild kilometers thru dust and rain and some of the world's most wonderful scenery. From the blandly happy faces and the studied naivity in the attitudes of the other passengers we concluded that the natives used the busses simply for transportation --- but it was not easy to share that view.

Our trip was a pilgrimage to Taravue and the isthmus leading to "little Tahiti" where Robert Louis Stevenson once lived while he wrote "The Master of Ballantrae". The proper bus was located standing quietly at a Papeete corner, loaded with people, apparently waiting for us; every seat was taken except the choicest two --- the center rear. Let me explain that Tahitian busses are not arranged like U. S. busses; they are more like a long low truck with seats running fore and aft along the sides and a double row down the center --- four rows arranged so that the aisles are a practically impassable forest of legs and kids. The sides are open but there is a roof; a stoutly supported slab surrounded by a low rail which corrals the baskets, bicycles, gunnysacks, tires and miscellaneous baggage of the voyagers

below. Across the rear of this vehicle there is a low step which is the only official entrance and exit, and seated as we were at the end of the center benches, we could dangle our legs over this step and see where we had been. To be sure the scenery was somewhat obscured by three large tuna fish which a fellow traveller had hanging from the roof, and on fast turns it was necessary to avoid the wide arcs they made, but Tahiti, as it receded from the stern of the bus, was beautiful. After a halting apologetic beginning, during which our steed picked up additional passengers who melted into seemingly full seats, this modest front dropped away and we careened south over asphalt roads towards our promised land. Behind us unrolled the green coastal plain, sometimes jungled, sometimes planted in great lawns and well kept palms, where the wealthy lived. Nearly always we could see the start of the towering mountains closeby on our right and the windward reefs on our left. Like kids on a new merry-go-round we clung to a roof support and gaped as the scenery whizzed by.

From time to time the bus would stop and a little man who rode standing on the rear step would step down and saunter about, whistling, hands in pockets, carefully looking away from the bus. The bus would start, rather noisily, and when the whine of the gears reached a suitable frequency he would suddenly pretend to notice and run like mad to overtake us amidst the noisy encouragement of the other passengers. It was his game and he played it well for there were some

stops when I would have sworn he would not make it but he knew his limits better than I.

About twenty kilometers out, the road became rather narrow and crooked with a heavily overgrown cliff on one side and jungle sloping gently away on the other. The bus slowed just sufficiently to maintain its equilibrium on the curves and we were overtaken by a young Chinese boy on a motorcycle. There was certainly not room for three vehicles to pass abreast and it was quite impossible for the cyclist, the passengers, or the driver to foretell the approach of anything from the opposite direction. But no matter, all joined in a hilarious game of back-seat driving; stakes were the motorcycle and the boy's life. He would cruise along about 50 feet behind until the road would start to straighten a little and then would quickly open the throttle and come up even with back of the bus. At this point he would receive the benefit of about fifty evenly divided opinions as to whether he should proceed; they were delivered as chants and shouts in Tahitian, French, and Chinese. "You can make it, what are you afraid of?" and "Don't be a fool, there's a car coming. He'll knock you in the ditch."

If the motorcycle moved ahead a little the driver would try to head him off and the shouts became louder, "Go ahead," and "Turn back before you get killed." If it retreated to the former safe position astern, there were disgusted cries of "Sissy" (Tahitian equivalent) and

pleased grunts. Between each change of position there was uproarious laughter by everyone.

After three or four bold attempts and sheepish retreats the boy put his life on the handlebars and roared past. On this occasion everyone cheered wildly and wished him a good trip. A few kilometers later we passed him sitting under a palm tree; apparently he was only out for a Sunday ride.

On the roof there were numerous barrels of ice which were unloaded one at a time with considerable ceremony, at each of the native beer parlors along the route. When we stopped I kept thinking that some one would get off but instead more riders got on; the situation changed from full to crowded and the pressure of the riders forced us ever towards the rear. A light rain began and slowly the reason for our reserved seats dawned on us; we were in the wind eddy of the bus and all passing particles were inevitably guided towards our seats. We sheltered the other passengers and their happy smiles showed that they appreciated it; the rain was not so bad; who cares about a little water? It was when the rain and the pavement stopped simultaneously that the situation became difficult. Great swords of dust entered from the rear --- to such an extent that the other riders pretended we were not doing a satisfactory filtering job and even glowered a little at our ineptitude. Then a helpful gentleman lowered a canvas curtain; it excluded dust, view, and the tuna fish; our associates smiled again.

Finally at the junction of the isthmus road we received a blessing in disguise: several more people got on and we were forced from our seats entirely. Todd asked the driver if we could ride on the roof.

"Mais non!" --- and much more in French that we did not understand very well about rules, safety, baggage, etc. It was a long tirade accompanied by much emphatic head shaking and arm waving; at its end the driver winked and we climbed on the roof.

Roof riding has its good and bad points. We could now watch where we were going; in fact we had to, for there was serious danger of being slugged by a branch if we looked away for an instant. But it was worth every ache and bruise and I recommend it as the best way to see Tahiti. I remember lounging on some dirty copra sacks partly sheltered from whipping leaves by a large basket of fruit; each time I ducked a bicycle pedal caught me in the ribs. Monarch of this freight deck was a boy about twelve years old (son of the driver, I think) ---there was not a label or tag on a single parcel but he knew exactly where every bunch of bananas and old sack was to be put off and just before we got to the right place he would stomp twice on the roof over the driver's head with his bare foot to stop the bus. When the parcel was unloaded, he would stomp again and off we would go.

We raced past neat wooden and grass houses along the shore, past long canoes (40 feet or more) in sheds, past fish nets hung out to dry on limbs overhanging the water.

There were bright flowers, great banana trees, strange fruits, copra plantations, and small streams. In one stream, two young Tahitian beauties, clad only in wet pareus, stood knee deep in the sparkling water and with a gesture of modesty covered their bare breasts by hugging themselves as we went by. Travel is so broadening.

At the end of the line we got off the bus and were confronted with the problem of lunch. In atrocious French, accompanied by barbaric gestures I explained our problem to several natives while Todd alternately reveled in my worldliness and pretended not to know me. We were directed to a Chinese general store in which a very beautiful Chinese girl passed us the items we pointed at and indicated a greasy table in one corner where we could eat. Cold beans eaten from a large green leaf, sardines, crackers and lemon pop; she smiled warily, at men with such strange tastes. I was able to drag my friend away from this lovely creature only because of an obviously difficult language problem and we set out on foot to inspect rural Tahitian life.

Being schooled in the best traditions of U. S. Travel Agency folders, I rather expected Tahiti to abound with tall waterfalls falling from green, jungle-clad cliffs into deep clear pools; each pool containing one or two bare breasted girls clad as nature intended --- or perhaps in a pareu that would cling tightly to the lower extremities. Imagine the excitement when, as we walked along this back road, we spotted a waterfall rising above the jungle only a few

hundred yards away that appeared to come up to the most rigorous specifications. Without missing a stride we turned from the road onto an oft-trod trail. How many girls would be there? --- for it was only a question of number. How would they be dressed? --- or would they? The wet leaves scattered before us as we plowed upward thru the jungle past pig wallows and banana trees and boulders. The morning's scene had been a shout of encouragement.

The pool below the fall is a deep blue, almost black, the everlasting mist keeps the rocks nearby covered with emerald moss and the falling water makes a white maelstrom. If Tahiti is a gem, this pool is its most sparkling facet --- even without girls.

So we did the next best thing; we stripped down and jumped in. Let the girls find us. Of course, they never did for I suppose Tahitian girls rarely swim in pools at the bottoms of waterfalls if they can find another bathing spot closer to home. If they don't, they certainly should, for it is a wonderfully satisfying experience.

The lower part of the falls drops clear for at least 150 feet past dark red-brown volcanic rocks and ends with a splatter in the little pool; a pool no wider than 35 feet or deeper than a tall man. On the outside it is dammed by boulders and cobbles and overflows in a pleasant rapids that disappears into the jungle. You just haven't lived until you've floated on your back under a Tahitian waterfall and looked up at the great tumbling drops of water leaping at

you while each little shift of wind makes an adjustment in the pattern. The water was cool, cold by tropic standards, and occasionally the main body of the falling water would shift and hit us full in the face with an invigorating slap; we came out in a few minutes --- loaded for ba'r; it was the nicest half hour I had in the South Seas. Todd agrees.

On the following day I walked some four or five kilometers from Papeete to the pool of Pierre Loti. The rutted dirt road followed a small stream and on this day I really got to see one of the girls bathing in the traditional attire; however, when I approached she covered herself and her husband (hiding in a tree) threw mangoes at me. There was nothing about husbands in the travel folders.

To judge by his statue, Pierre Loti was a pretty effeminate sort of a man but he certainly lived in a wonderful place. Here in a jungle clearing the stream widened and deepened above a rough dam of boulders and bobbles. The pool is not over 25 feet wide and twice that long; on the far side are some rocky shelves that make an ideal diving platform for small boys. When I arrived there were about a half a dozen such creatures splashing about in the water and an elderly man was sitting on a rock bathing his feet. On the low wall that separated stream and road sat a mixed audience of a dozen Tahitians.

Unable as I am to resist exotic swimming places, I stripped to my underwear shorts and made what was intended to be a graceful dive into the pool. Such shorts are

intentionally made so that they slip off easily. Mine did; I slid into the water leaving them floating at the point of entry. Surfacing amid appreciative applause and some cheering from the gallery, I swam back thru the clear-as-glass water, put them on, smiled and bowed. Although I was watched very closely from then on, the onlookers were clearly disappointed by my subsequent preformance.

Somehow I have always thought of spearfishing as a sport which requires a considerable body of clear water in which the fisherman swims about in a search for his quarry and dives to make the kill. Following the little mountain stream down from the pool of Pierre Loti, I was surprised to see two young men clad in trunks and face plates and holding spear guns, standing ankle deep in this oversized brook. Well, live and learn.

The two fishermen were Chinese on an outing (one a by strange coincidence recent engineering graduate from the University of California) and were glad to show me their techniques.

One system was to lie on the bottom in the deeper parts of the fast-moving water facing upstream, clinging to a rock with one arm and the spear gun with the other. The fisherman would peer upstream at the openings between rocks where a fish would be likely to pass --- and presumably spear one when it came thru. None passed while I was watching. Since the water was less than knee deep it was easy to get an occasional breath by just lifting the head slightly.

A second method they used was to wade into the quiet deep waters by the bank (possibly 2 feet deep) where roots of trees made recesses in which the fish would hide. The hunter would stoop slowly down until his face plate was underwater and then look about under the roots for his prey. These were just the sort of a place that a trout fisherman might try in the U. S.

"Fish," one said, "are hard to find today --- but there are plenty of large eels." When I looked skeptical about this point he ducked into a pool right at my feet and immediately speared and threw on the bank an eel at least as large as my arm with a very mean looking set of teeth. It looked too big to live comfortably in such a small stream; at least it made the stream seem too small to hold both eels and me. I left.

XII PEARL DIVING

Two thousand miles south of Hawaii, in the midst of French Oceania, sprawls a chain of islands a thousand miles long: the Tuamotu Archipelago, known also as the Low or Dangerous Islands. In contrast to the towering black volcanic peaks with narrow fringing reefs and deep water close to shore which makes navigation in the Societies and Masquesas comparatively easy, the Tuamotus consist of dozens of low islands and atolls interspersed with reefs and shoals. Often these are difficult to see, or out of place and inaccurately shown on the charts. Navigation aids are few and there is an excellent chance of encountering a hurricane in the December to April season. It is no wonder that these isles are a veritable graveyard of ships and bleaching skeletons high on the reefs record the outcome of luckless voyages. "Missing, with all hands." Today only small trading schooners, which can enter the protected lagoon and whose skippers know the reefs and channels well, visit these peaceful islands; but the Tuamotus were once far-famed and much visited for they held the same kind of attraction that drew men to the Klondike and the 'Rand and the Comstock and Great Bear Lake. Natural wealth, in the form of pearls; riches for the diver who could go deeper, stay longer --- and was lucky. Each shallow lagoon was a possible treasure trove and in Victorian Europe each woman a possible customer. The natives became

excellent divers; a handsome graceful people who had lived by the water for uncounted generations, they devised a system of searching for pearls that would have maintained an industry indefinitely. Using only a view-box, which allowed them to observe the bottom from their outrigger canoes, the natives would search for pearl shell. They would paddle about inspecting the bottom (thru the clear waters they could see 50 feet or so) and when a pearl shell was sighted, a naked diver would swim down, grope about for the shell, (for he had no goggles) dislodge it and surface. These were the "good old days" of pearling when there were plenty of pearls ---obtainable to 50 foot depths and divers did well with minimum risk. Inherent in the difficulties of getting the deeper pearl shell was a conservation system; the deep areas of the lagoons gave the pearl-oysters a chance to breed undisturbed.

When it appeared that there was real money to be made in this undersea mine which replentished itself, Europeans took up the white man's burden in Oceania. With theppatience thoughtfulness that laid the now crumbling foundations of today's Colonial empires, they wrecked the system by bringing diving machinery and native skill and endurance were no longer at a premium. With air furnished from the surface a man could go to any depth in the lagoon, stay for hours at a time and bring back hundreds of shells each dive instead of just a few. This was real progress and the first to use the new gear made fortunes. Unfortunately, no breeding grounds were

left and there was no discrimination as to place, season or shell size. By 1921 the lagoons were cleared of pearl shell (parau) and economic depression came to these pleasant islands. The Europeans took their diving gear and left, much to the delight of the natives and the few remaining parau which at once started repopulating the lagoons. Then, almost too late, the French government began to protect the almost extinct animals in earnest by imposing stringent laws. In three years there were a few adult paraus; their population growth was watched carefully and as they returned in numbers, limited diving was allowed. No machinery could be used and no air supplied from the surface; only natives of French Oceania could dive. Glass goggles were permitted however, the only concession to modern methods. No one is allowed to stop their canoe over a closed pearling ground --- for under the pretext of fishing --- who knows?

On January 20th the Baird visited Takaroa atoll and while it zigzagged around the atoll making hydrographic and magnetic surveys, a lucky few of us had the good fortune to get ashore in a small boat and learn first hand about the pearl divers of 1953. Takaroa atoll is a warped oval about 12 miles long and 3 miles across; a coral ring, surmounted by about 16 islands of varying sizes and surrounding a quiet lagoon.

The only village occupies a small island adjacent to the entrance channel into the lagoon. As we approached we

quay and when we reached the channel opening in the outer reef, an outrigger canoe came alongside containing the Chief of the village and a policeman (who had obviously put on his official cap and shirt in a great hurry).

The two of them welcomed us in French and came aboard our power boat; the outrigger was taken in tow. We backed up the channel in the face of a three knot current and tied up along side of a low concrete structure that serves as both wharf and village square, amidst the wondering gaze of most of the 300 population.

Almost at once we found our man in Mr. Taumata Mapuhi, a native son, who had been educated in New Zealand and speaks English, French, and Tuamotan; moreover he is a pearl diver and the son of a famous diver and has a nice home only a few yards from the landing. We were invited to sit on his porch and talk about the pearl shell industry. Mr. Mapuhi, who preferred to be called Tommy, is in his early forties. He has a wife, seven girls, and three boys and is a pillar of the local Mormon church which claims over 80% of the populace. Tommy has been diving over 20 years --- mostly at Takaroa but occasionally at other islands. "You should see it here in pearling season," he said, with an expansive smile. "This is quite a place, when a thousand more people are here. Of course, they do not live on this island." He pointed across the atoll to a larger island, "That one is reserved for the outsiders --- but they come over in the evenings to go to the store and the churches and play pool."

of which one is opened for pearling each year. Before the opening of the season in April, pearl merchants, mostly from Tahiti, round up the best divers they can get, and transport them , free, with their wives and children from Tahiti to the visitors' island at the pearling grounds. In all, some 600 -800 people will be moved, of whom 10% are divers and they stay for a 4 or 5 month season. The merchant advances money on the prospective harvest and furnishes the equipment. The diver and his family, in return, agree to sell only to that particular merchant. All the merchants offer the same ppice (45 Francs)per kilo for shell in 1952) so the competition for the best divers is based on added attractions. In season there are movies, pop, ice cream, pool tables, beer, and magazines offered (sometimes free) as an added inducement to attract divers.

Although the standards of living are higher than ever and the net incomes are at a maximum, the divers still talk of the good old days when there were pearls. As recently as 15 years ago Takaroa lagoon produced a thousand tons of shells , big sheils too; last year, 180 tons. Worst of all, there are few pearls. (poe) In the 180 tons of shell sold in 1952, only 3 small, fourth-grade pearls were found; the divers are as well paid as they were when pearls were comparatively abundant, but the thrill is gone, for the chance of making a month's pay in a single dive has almost disappeared.

shell; with only two seasons for a aparau to grow from 4½ inches to full size of 8 to 10 inches there is little time left for the poe to develop. To prove his point, Tommy tells of diving at Marutea in the ~~Marquesas~~ Gambiers in 1947 after that lagoon had been closed for seven years during the war. Many pearls were found --- perhaps one in a thousand shells and he himself found the second largest. He immediately paddled ashore but the news of the find preceeded him; a pearl buyer was waiting on the beach and gave him 30,000 francs cah (about $500.00) for his poe. He did not work the rest of the afternoon; two weeks later he found another --- but not so large. Perhaps there should be a longer period between seasons at Takaroa, he muses.

On opening days of the season there is a mad race to get the easy shells --- (those in comparatively shallow water); men, women, and children all dive around the edges of the open part of the lagoon where the water is less than 6 fathoms deep and beneath the dignity of a true diver. The shallow, near-shore areas are soon cleaned and the poorer divers drop out; then the real work of the season begins.

Each diver's equipment consists of an outrigger canoe with an anchor and a long anchor line, a four to five kilo lead descending weight on a line and a shell basket made of netting. With only these simple items, a good native diver can wrest 30 to 40 dollars worth of pearl shell a day from

Each weekday morning at about seven a fleet of fifty odd outriggers set out across the lagoon (roto) for the pearling grounds and in each canoe is a diver and his helper. When they arrive at the selected location, the canoes form a line facing into the wind, space themselves 20 to 25 feet apart, and drop anchor. The helper lowers the shell basket over the side so that it hangs a few feet above the bottom and the diver prepares to dive. He puts on his diving goggles, called titea-parau, and hangs on the side of the canoe inhaling deeply for a minute or more to fill his lungs and blood stream with oxygen. In one hand is his descending line, and his toes are curled around its lead weight; the breaths are exhaled with a soft whistling sound achieved by retracting the lower jaw a little so that the wind is guided across the lower teeth by the upper lip. A number of divers preforming this breathing exercise together are said to make a somewhat musical sound not unlike the cries of a flock of birds. Just before the dive a great last breath is taken and the diver heaves himself up for an instant; as he slips back, the helper releases the descending line and down goes the diver, started by his inertia and pulled by the lead weight. As he falls he holds the line with a gloved right

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* Natives use the unit brasse or hand instead of fathom. All three units are exactly 6 feet or 1/1000th of a nautical mile and roughly the distance between hands when one's arms are outstretched.

of the divers in the fleet will not come up on schedule. This most frequently happens to the younger, less experienced men who will overestimate their endurance and try to stretch a dive to get a couple of extra shells. The effort of ascent requires more oxygen than they have left and they fall,unconscious, to the bottom. The ever-watchful assistant immediately summons the divers from the nearby boats to make a search and they will dive and bring up the missing man who is immediately draped across the middle of the canoe, his legs dangling in the water on one side and his head just above water on the other side. The helper then sits in the bottom of the boat and alternately squeezes and releases the divers chest in an apparently efficient form of artifical respiration --- which has been in use in these islands for many generations. About half the time the diver will be revived (pretty good under the circumstances, I thought) and after a few days of rest will be back at work again.

Their other diving troubles are not serious. Some have sore ears (but hear allright) and sore eyes (from salt water) but fungus infections seem to be unknown and sinus trouble is only rarely experienced. On certain occasions divers complain of nausea and their eyes blur; at other times they will "come home drunk"---probably a form of nitrogen narcosis. But they know the value of health and stop diving for a few days until such symptoms entirely disappear and they xx feel completely cured.

crazy in the sense of becoming childlike. This [redacted] due to continued oxygen starvation of the brain. The present generation of divers say that they have quit making the great number of deep dives which caused this and have nothing to fear; instead of 100 deep dives a day they only make 50.

The helper works for 5 francs per kilo of shells. For this he retrieves the descending weight each time, hauls in the catch and cleans the shells . An honest helper is essential, for in cleaning the shells one finds the pearls; for this reason some divers use their wives as helpers.

Three shells per kilo; one kilo per dive; 50 dives per day. At 45 francs per kilo the diver makes around 2250 (Oceanic) francs a day, his helper, 250. It is nice work in beautiful surroundings; who could ask for more? Tahiti is only 300 francs away if one feels the need of bright lights or schooners calling nearby every week will bring anything you need from Papeete.

On comparing these notes with those taken from the conversation with Hare, a Viriamu of Tahiti, who was mentioned earlier, I found that Mr. Mapuhi was conservative. Since Mr. Viriamu is certainly one of the finest divers in the islands and each year visited a different atoll his figures are quite acceptable. He is a handsome intelligent man and although I spoke to him of complex matters thru an interpreter he quickly grasped the meaning and answered as

Mr. Viriamu emphasized that he spoke only of "good" divers; in all the islands there might be 20 "good" divers. These men could make 100 dives a day to depths of 20 fathoms. When I seemed astonished that men could go so deep he said, "Well, two or three women go that deep too, (and then deprecatingly) but mostly the women only dive 14 hands," (84 feet) .

It is hard to be sarcastic thru an interpreter but I couldn't resist asking how deep the children went.

He never hesitated. "Each year there is a competition for boys ten years old; they go to 6 hands (36 feet) and bring up something from the bottom to show they have been there --- not pearl shell, you understand,"

I tried a different tack. "What are the records for diving in the islands; how deep; how long?"

The deepest dive of which he knew was one of 27 hands (167 feet) made by the famous Mapuhia of Hao. Mapuhia had stayed under over 3 minutes one time too, but now he has stopped diving because he is too old.

"How old is Mapuhia?" "Seventy-two; he quit diving two years ago."

Before leaving Takaroa, I asked to see some divers in action and two local boys volunteered. With nearly the entire town for an audience we three slipped into the water alongside the quai, I, with face mask and fins; they, with goggles. As they sucked air in and whistled it out I imitated them; then we all heaved up a little and dove, turning over in the first few feet and swimming down

surface, breathed and dove again. This time I stayed down when the others returned to see how much their breathing exercise helped; later I found that I had stayed so long the villagers had worried and asked the native divers to check and see if I was allright. Next time we three dove again we pulled ourselves down the steep slope by the coral boulders that were strewn there. At around 35 feet my face plate was jammed tightly against my nose and I stopped. The native boys with their small goggles kept going down gesturing for me to follow but I knew better. Returning to the surface we found that the swift current had carried us some 20 yards from the point of beginning. With the advantage of swim fins, it was easy to swim back ahead the local divers who were greatly impressed and wanted to try both mask and fins. The mask they quickly rejected but the fins were greatly appreciated; they had seen fins advertised but had never believed that they would be much help. Immediately they spoke of getting more pareus each dive by the use of fins; but some one asked the inevitable question. "Will the French pearling laws permit such an aid?"

No one could answer. If they are allowed, though, I would like credit for introducing the swim fin to one of the finest groups of swimmer-divers in the world.

Let go, let go the anchors;
Now Shamed at heart are we
To bring so poor a cargo home
That had for gift the sea!
( )
Let go the great bow-anchor—
Ah, fools we were and blind
The worst we stored with utter toil,
The best we left behind!

These lines from Kipling's "Merchantmen" went thru my mind over and over again on the long voyage home. Had we really gotten the most out of the first free-diving explorations in the tropical Pacific? It is not fair to judge ourselves in this matter but it is pretty safe to say that now we have had these experiences we can do a much better job on some possible future trip --- but you have read our results and must judge accordingly.

Already I am looking forward to another trip and notes on the things we missed are becoming new projects. We didn't encounter any of the great sharks (over 15 feet) nor did any of the giant grouper cross our wakes although tropic sea literature abounds with stories of these great bass-like fish that can swallow a man with one gulp---all but the legs anyway. Perhaps it is just as well. We saw no giant rays although a helicopter passenger at Eniwetok described one as being "as large as the shadow of the rotors". Next time we'll bring back the biggest clam shell ever.

I have yet to collect a golden cowrie, ride a turtle, or wrestle an octapus. Some time I'll go in pearling season

with a bigger camera that holds more film and underwater lights for deep color pictures-- for the pictures we got on this trip were most encouraging. Perhaps there'll be a wrecked ship to salvage in some romantic port or an underwater cave to explore. Next time.

These are only dreams; foolish dreams I suppose, but not so unlike the ones that took me to the south seas in the first place. Perhaps they can do it again.

This is the end of the [illegible]
dealt primarily with diving on the
Capricorn Expedition. What follows are a few miscellaneous
bits of writing done at the same time
about other aspects of the expedition

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largely covered with a thin film of water known as ocean. A table-size globe, for example, with earth features shown to true scale would have an ocean about 1/300 of an inch deep--less than the thickness of its paper covering. However, to the inhabitants, who are prone to measure things in terms of their own size, the oceans look terribly deep and the fact that the average depth of the Pacific Ocean is over 12,000 feet (4 kilometers) seems most impressive. These inhabitants of earth are strange creatures, too, if you consider them objectively; and among them are a few whose entire lives are dedicated to the exploration of this thin film of water. They are called oceanographers.

There are several kinds of oceanographers. Some study marine plants and animals, some study the physical nature of the water and its motion, some examine the materials of the ocean to determine its chemical constituents and some feel they must learn about the structure of the ocean bottom. On an expedition, all these men are brought together by their common difficulty: they cannot examine their territories directly but must work remotely by dangling a line into the abyss and hoping that the net or instrument or sample bottle will bring back the desired specimen. For oceanographers are men who work in the three-dementional darkness of deep salt water. With hopeful anticipation they watch by the hour as the cable runs out and in again; finally a dredge comes aboard. These strange men will crawl into the dripping mouth and plow their hands thru the cold muck in hopes of finding a bit of life, a fossil, or (best of all) a fragment of granite. Perhaps the net or dredge will come in torn, broken, fouled in the line, or just empty; perhaps it will be completely lost. With a sad expression and perhaps some quiet cursing the scientists will rig another or attempt a different kind of sampling.

unsolved problem, and the tool for probing—a cable. Let us consider the cable. To extend our sight we must reach out with photo equipment or television; to extend our hearing we must place a hydrophone; to extend our sense of touch we must feel about like a blind man with a stick. An oceanographer's sensory extension is the cable; and the science is built around it. To hold the cable, pay it out and reel it in there must be a winch; and to hold the winch, a ship .

The Great Winch

Oceanographers do not exist as free bodies; they can only live in intimate association with a winch. A reporter without a typewriter, a baker without an oven, or a carpenter without a saw are infinitely more ready to carry on their trades than a winchless oceanographer. With a winch he can tow nets, lower cameras, take cores, do dredging, take water samples and temperatures and amass thousands of bits of specific information about the state of the ocean and its basin. Without a winch he is only a philosopher speculating blindly on the unplumbed depths and living in fear that real information will upset his speculations.

Basically a winch is a very simple mechanism; it consists of a spool driven by a motor which can wind up and let out cable that is wrapped around the spool. Any self-respecting oceanographic vessel can be expected to have several winches of various sizes for special purposes. There are usually at least three: a small B.T. winch using 1/8" wire; an intermediate winch for nansen bottle casts and light coring with 1/4 " wire; and a big winch with 1/2" to 5/8" wire for handling heavy gear in deep water.

The winch of which I now speak is not to be compared with such machines; by mortal standards it is colossal. I think of it as the great winch of the Baird.

The great winch is composed of three major parts: the winding mechanism which sits like a squat unsmiling Budda just astern of the boat deck; the storage reel for the 8 miles of cable which is hidden away below decks; and the control panel covered with shiny dials, gauges, counters, levers, plungers, and flashing lights which occupied a commanding position on the boat deck.

wrights, mechanics, islanders, admirals, and visiting firemen would stare in dazed wonderment. The dozens of men who slipped in the puddles of hydraulic oil that it periodically spewed out swore at it in guarded, respectful tones and looked over their shoulder as though half afraid of being smitten down for such blasphemy. Director Revelle in thinking of it alternated between ulcers and ecstasy. Chief Engineer O'Brien would sit nearby warily chewing a cigar and regarding its operation with the air of a world series umpire who knows that at any moment his position of command may be drowned in a shower of pop bottles. In port, scientists and crew alike would proudly expound its virtues, relative size, and potentials at considerable length to bar companions; at sea, some of the same men would slink past watching it out of the corner of their eye and muttering lucky sayings. It was said that Brownie, the Bosun, who had to repair its ravages on the cable, occasionally put long-splices into his bedding as he slept.

The great winch was our pride and joy--and our greatest worry. Would the cable go out and come in again without throwing a kink? Would our jury rigged accumulator work? Would the cable ride in its grooves on the winder?

We admired it--and feared it. Was it not the biggest, most complex winch in the world with the longest wire?--but--might it not throw a kink with miles of cable overside so that we would have to inch it with come-alongs in until we got a grip on it again and then eventually respool it again at some strange port.

In a way we loved the thing. It was sort of like keeping an adult gorilla in the house. Fascinating, unique, powerful; full of unknown idiosyncrasies and not quite under control.

The Budda's awsome appearance as he sat among his gear boxes, hydraulic motors, fancy brakes, sheaves, and piping was exceeded slightly by his sounds. At the cold command of the operator's fingertips would come forth gasps, grunts, whines,

more difficult to describe. Frequently a mad crecendo would be climaxed by the cable moving half-a-foot. There were no noticeable whistles in the mechanism; they were not necessary, of course, but we puzzled a bit about the strange whim of chance that left out such a handy and obvious sound. In the focsl, filtered by many steel walls, we could feel his moods by the faint sighs and vibrations that reached us so that few slept soundly when Budda was not serene.

To keep our great mechanical idol in semi-control we had Bud King. Bud's relation to his charge was about like that of an elephant boy in a teak train; he could guide with gentle prod and whispered inuendo but never force the great beast. At the signal from the fan tail to move the wire Bud would push buttons and levers, read dials and throw switches. Sometimes nothing would happen. He would look thoughtful for a moment--then mutter something about the brakes. Down from his shiney tower he would climb to loosen bolts and peer into reservoirs, turn valves and release air. Then back to the controls; thus goaded the beast would run. Bud had grown up with the winch. From the day that the Ledeen Works started work he watched the machining, welding and assembly. While it was being installed he crawled in and out of the hold forty times a day watching each pipe being fitted and each bracket welded. He knew the monster as well as anyone. Untested it left the U. S.; the first lowering was accomplished in the southern Marshalls. One incident should have tipped us off in advance. Fifteen minutes before the ship left San Diego Mr. Ledeen dashed aboard with a rough pencil sketch for O'Brien, the Chief. "Look," he said breathlessly, "you'll have to put a valve in here so you can ~~readk~~ release the air brake."

In the weeks that followed Bud became able to play the panel like the organist at the console in Marshall Field's. But the first few trips the cable made in and out were plain hard work.

Namarik

A kink in the great cable required the Baird to make a quiet lee under the nearest shelter so that we could respool and splice. Namorik, in the southernmost Marshalls, was not far off our course and there we went. As it rose from the horizon on our port bow we became aware of a lushness beyond that of anything yet seen, and as those with glasses on the bridge described grass huts, copra drying sheds, outriggers on the beach and natives watching us we knew that this was our first Bali Hai. Rogers and Hammerstein had nothing on us now. Here was a tiny unspoiled atôll, unblasted by atoms or gunfire, without a pier or a tin roof or even a rusty landing craft. It rose from 15,000 ft. of water in a neat coral ring surrounding a small lagoon, and surmounted by two islands, Namorik and Matamat. Namorik, the larger, is long and narrow and encircles the east, south and most of the west of the little lagoon like a protecting arm warding off foul weather and keeping the lagoon glassy. Beneath the tall palms we could see the frond roofed houses and groups of natives standing about, probably discussing us, for the arrival of a strange ship is quite an event. A greenish-white pastel reef covered with a few feet of water stretched between the islands making a milky boundary between the dark blue ocean and the green lagoon. On the crest of the reef, black and ominous, were huge blocks of coral weighing many tons heaved up by great storms--one large enough to support vegetation in the form of vines and bushes.

outrigger tacked towards the smoke. At the narrow north end of the isle we could see the bright green lagoon through a filagree of palm trunks; overhead the thick fronds closed darkly. A light rain fell making all colors slick and dark and the air cool. Here was the story book tropics, the native paradise unspoiled, the jungle bountiful full of easy fruits and brown girls. An end to National Geographics; here was the real thing only an easy mile away. We leaned on the rail and dreamed lovely unrealistic dreams: of diving and shell hunting; of photographing the huts and people; of trading for souvenirs and trophies; of love under the palms. Maybe it was as we pictured it—for we never got to see; our dreams ended jaggedly with the call, "All hands on the cable."

Somehow, in our first operation with the long cable, enough slack got into the system between the winding winch and the storage spool to allow the cable to form a loop; when the tension came on the cable again, this loop pulled tight into a kink making a decidedly weak point in the cable. This bad spot had to be cut out and the ends rejoined with a long splice; to get room enough to make the splice we had to first unspool 1300 meters by hand. The rewinding of this piece of cable occupied most of the scientific party as the Baird lay off Namorik in a gentle rain on the late afternoon of November 30, 1952. We pulled and wound and dreamed.

Before long we were aware of visitors. Two small outriggers, each filled to capacity with a single man, paddled hesitantly towards us. They would approach aways, then drift a while and watch. Finally, in response to encouraging waves, one of them came alongside.

building. They were about 20 feet long, [illegible] deep, [illegible] over a foot wide with an outrigger some 8 ft out to starboard secured by fine interlashed arms. The main part of the hull consisted of a carved bottom with sides secured to it by peculiar X-shaped lashings at the stems and chines and sealed with a tar-like substance. The captain and crew sat on the outrigger arms and wedged his feet down into the main hull; this made the craft ride a little low by the bow--for a reason. The hull apparently leaked a little and every few minutes the paddler would stop and bail, this being accomplished by cupping both hands and heaving the water out over the bow with quick strokes. The bow being lower gave him a natural sump and the water level on his legs was the depth gauge. Even with this difficulty we were jealous of a man who had his own craft and could go where he wanted to in it. We could picture ourselves bartering for one of the neat green craft and carrying it home to San Diego in triumph--lashed to the stack--for the natives there to wonder at.

The occupant of the craft was a handsome, stocky native with even white teeth and a calm smile. Like most Micronesians, he was pretty dark-complexioned and wore a bright yellow band of rolled cloth around his forehead, secured behind, and a pair of bluejeans cut off below the knees. His features were regular, much more Caucasian than Negroid, and he had a proud, honest air about him. Any seeming reluctance vanished with the wave of a pack of cigarettes and he was over the rail with a bound. In excellent English, without accent, he asked the ships business in this out-of-the-way place and seemed to understand our reasons for doing research on the sea about as well as most Navy officers.

war the Navy had taken him to Kwajalein for six months to learn our language. As an interpreter he had returned to Namarik.

Making copra is the principal industry and every three months a ship calls to pick it up and exchange supplies. Other than this trading vessel, ships come very seldom. The copra is loaded into small whale-boat-like craft and taken out to the ship a ton at a time. "Now there are a thousand tons ready to go. Very much work."

"Sure we travel to other islands, Kwajalein, (--see chart--)" "to trade or just for fun." (We were a little doubtful about the fun in crossing 300 miles of open water in an outrigger without navigational instruments.)

The mate presented him with soap and matches as a gift from the ship and, in a light rain, he climbed overside into his slim steed and, balancing the soap and matches delicately on the shelf of the outrigger arm he rejoined his patient companion and paddled towards the beach stopping occasionally to bail. Through the misty rain we could see a group of his friends waiting anxiously on the beach--probably bursting with questions.

"He'll be back with a lot more of 'em," was the ominous prediction. Happily this was true. In the evening Tapaka returned in a large boat--evidently an imported product for hauling copra--with about fifteen of his friends and great bunches of bright green bananas. Selfconsciously they came alongside and selfconsciously we watched them and received the proffered bananas. They scrambled awkwardly over the rail and stood quite still in a tight group as they answered our many questions. How many spoke English? Two. French? None. German? Some old men who remembered from before World War I.

were selected to go to Majuro for six months to learn so that we could explain to our people what was going on and so that we could help with war.

Were there Japanese here? Yes, until Americans came; then many people killed. Your People? Oh yes, many of my people killed and hurt. (This was about all we found out about the war on Namarik; he could obviously have given much detail if questioned closely but the subject seemed to be painful so we dropped it.

Soon Director Revelle came aft. He bore a pile of bright cloth yard goods, some old white shirts, writing tablets, crayons, combs. Very solemnly he set these down on the deck in front of Takaka and made a speech which embodied all the best features of a Hollywood script in which the cowboy-type hero presents his horse to an Indian chief as a token of friendship. Gone was Roger's easy style and smile. In accents grave and words stilted he spoke of friendship between lands across the sea and itemized the articles that were piled on the deck. Leaving out the small words and pronouncing each word slowly and meticulously he sounded like a foreigner reading a telegram to a child. "Cloth," he said, "for your women; and combs for their hair." "Shirts for the men." ("Probably pretty large," in an aside to the ship's crew.) "Paper," indicating the tablets. Do you use paper?"

"Sure," said Tapaka quickly. "We write on it."

"Ah - - - yes! "And crayons for the children to play with." At this Tapaka wrinkled his nose just a trifle with the air of a man who has had to live with children and crayons but he said nothing. To illustrate his message, Roger selected a pink crayon and started to make lines on a sheet

speculate impolitely on the meaning of the lines; in a few moments with the air of a Klee or Picasso adding the last deft stroke Roger held the tablet at arms length and sighed gently. Then he printed below: Spencer F. Baird. It was the ship?

Tapaka was not to be outdone. He thanked us all for the presents and presented Roger with a white cloth package containing some large rattlesnake cowries and a huge and beautiful conch. He allowed us to admire these for a few moments but was not to be put off from his main mission.

"We have money and want to buy cigarettes." Roger considered this a moment, "We cannot sell cigarettes but we can give you some as a present," and beamed. Tapaka beamed and turned to his friends. They beamed over his shoulder. Roger said to the mate, "How about getting a couple of cartons out of small stores and charging them to experience." After a short embarrassed silence and mutual staring the mate returned with three cartons. "For all," said Roger presenting them. "These presents are not just for you but for your friends too." This seemed like a futile remark when made to the only man who understood the words. This time only Tapaka beamed.

It was pretty dark now although the moon was out enough to show the surf and silhouette the island; low, near the water, we could see the tiny orange glows of three fires. The natives went over the side and cast off with mumbled noises that we hoped were thankyous; then they paddled slowly towards the fires and disappeared into the darkness.

We sighed mentally and turned back to work on the cable - - -not

make ashore. Sound the lagoon; make magnetic measurements; collect coral and sand samples; investigate wave refraction.

Roger identified these proposals as boondoggles just as surely as if one of the engine room hands had proposed going ashore to bolster the Kinsey report with new data. He said something under his breath like, "Maybe tomorrow morning early." Those of us who awakened at six found that the ship had been underway since midnight. Bali Hai was far astern and the subject did not receive further attention.

A Hole in the Bottom of the Sea

Yes, there is a hole in the bottom of the sea. In fact, there are several and they very neatly follow the track of the Scripps Institution of Oceanographyts recent Capricorn expedition to the equatorial regions of the Pacific. How these holes got there and what they mean is a story of science, engineering and seamanship. Each one is a bridge to the once-upon-a-time land that geologists dream of; the epochs before the Pleistocene, when South Dakota was a land of primitive rhinoceri and Florida was awash. A bridge that spans 30,000 years per foot.

The earth keeps a diary in her rocks and the geologist is the biographer. By examining rock outcroppings, looking at oil well cuttings, studying mountain folds, watching volcanoes, and mapping mines he can come to pretty accurate conclusions about the great changes in the earth in its long history. By the study of life and evolution as shown by the variations in fossils, these rocks can be compared and dated and traced from place to place. But many areas cannot be examined by the geologists: rocks beneath ice cops, alluvium, jungles, and lava flows are virtually inaccessable. Thus, until recently, the nature of the earth's rocks was known from actual examination of less than 1/5 of its surface. In order to tap the knowledge written on the 72% of the earth's surface under the ocean, the geologist had to devise means of obtaining samples of the sea floor. In some ways, this is the best information of all--and the most difficult to get.

same places for tremendously long periods of geologic time and the present accepted theory is that the Pacific basin has been much like it is today and has been receiving sediments for millions of years.

Far out from land a very slow rain of tiny particles settles down to the bottom; volcanic and meteoric dust, tests (shells) of miniscule animals, and fine sediments from distant lands carried by winds and ocean currents. Once these reach the bottom they lie undisturbed; a diary challenging the biographer to unlock and read it.

It is as though there were a deep box in which a newspaper was neatly laid every day for years and years; the only access to the box is from the top; the deeper you go, the further you get into the past. It's not hard to think of a way to get the top paper, but to go back a few years may be pretty difficult. Now imagine 12,000 feet of water (the average depth of the Pacific Ocean) over the record and you have substantially the same problem that faces the seagoing geologist--now called an oceanographer.

Since the ship Challenger laid the foundations of oceanography in 1872 man has had the ability to snatch the top newspaper. The modern piston type corer used on expedition Capricorn is capable of punching a neat hole 3 inches in diameter and 30 feet into the ocean floor where the water is 20,000 feet deep. This frequently brings up sediment that was deposited in Miocene time _____ years ago.

Fiji was a hard place to picture in advance. We vaguely suspected that there was no longer any need to call the place the cannibal isle and that there were steep slopes with lush green growth instead of the low coral islands we had been visiting. But no real picture formed in our minds;aside from the general outlines on the charts, which showed two large islands and a lot of small ones my first really down-to-earth contact with the Fijis was a hotel advertizement in an old Pacific Islands monthly that Russ Raitt had brought aboard. "When in Suva stay at the Grand Pacific Hotel" it said "delightfully situated on magnificent grounds overlooking the harbor, specially designed for the tropics. Trained Indian waiters. Tariff from 35/." (Fijian currency) And there was an aerial photo of a clean square white building with lots of green lawn and palm trees about. It looked reassuring but not romantic; probably a haven for retired British majors, a place of gin and bitters, a starting point for adventure and the "social center of Fiji".

The next formative visions came with two radio messages received thru International Radio. The first said, "PLEASED TO ACCEPT YOUR AGENCY STOP HOUR ARRIVAL APPRECIATED AND INDICATION OF TYPE STORES," signed
The other was from Helen Raitt and bore the usual stamp of her happy confusion "INVITATIONS ISSUED COCKTAILS SHIPS FRIDAY FOUR ONLY DATE POSSIBLE HAVE CATERER CAN SCHEDULE FIJIAN FEAST DANCING GIRLS FOR SHIP IF DESIRED SATURDAY NITE FIJIAN DIVING DEMONSTRATION. HAVE 20 HOTEL BEDS. SENT FAUBRIDGE AND SCRIPPS ON EXPEDITION TO SEE PETROGLYPHS. GOVERNOR ENTERTAINING ME TONIGHT. HURRY, HELEN.

Dancing girls. --Any kind of girls. Who cares if they can dance? This bucket was 3 months out of San Diego. The prospect of a coctail party immediately

it stirred our imagination; would we dive for them or they for us? And Russ took a little kidding about his wife's dinner with the governor. Blood pressure rose; the mere fact that girls were mentioned in the same message with 20 beds raised the temperature in the engine room a degree or so--and it was already 120° down there.

Out came the chart; Suva Harbor, Viti Levu, H.O. No 2865. On it was shown Hotel Grand Pacific, Public Baths, Obelisk, Gardens, Waterholes, cricket grounds and cathedral. Even more intriguing were notations: Fishing stakes, Magnetic observatory stone, mangroves (20 feet high) and Half Caste village shown graphically among a lot of palm trees. There were "steep grassy slopes, partly wooded" and names like Naingalongalo Harbor and Uthiwai Natamavua (a stream).

A boondoggle in our ship's terminology is a flimsy excuse for going ashore and getting a little free time to do as one wishes. Usually they consisted of hypothetical scientific problems and ideas for investigating them. A man going ashore on a boondoggle did not fool anybody--he was going there for the fun of it and we all knew it. Sometimes he would helfheartedly tell of his alledge findings--but no worthwhile results were really expected. The rest were jealous but not disappointed and only redoubled their own efforts to think of a scheme of their own. In fact after the Horizon had stopped at both Ocean and Rotuma Islands the entire Baird party became suspicious of ship-size boondoggles.

At any rate we could see the problem looming of how to get ashore at Suva. We had three days scheduled there and the ships had to take on full supplies, water; splice the long cable twice; and generally get ready for sea again. Time ashore was expected to be scarce--so schemes developed. The geologists had the edge because of the faintly legitimate reason that the rocks ashore should be studied to determine the sources of the deep sea sediments (of course

by U. S. Geological Survey men). They arranged a trip to the gold mines"to see the structure and petrology". As long as they were going there should be a geophysicist along to see if a magnetic survey was necessary. Black sand collection is always a good gambit (I've used that one myself) and naturally the reefs needed to be inspected for surge channels, lithothamnion ridges and biological specimens,ie., pretty sea shells to take home. The meteorologists wanted to investigate the circumstances surrounding the great January hurricane. Ted Folsom thought up the neatest and most original boondoggle thereby winning our unreserved admiration; he wanted to look for cannibal kitchen middens with human bones in them.

The handwriting was on the wall. Roger bowed to the inevitable fact that the party would scatter thruout the island and thenceforth planned on Burns Philp to do all the ship's work with natives.

The Baird approached Vita Levu at night with radio and at sunrise we had a horizon of land some 15 miles to the north. Jagged, grey-green, it rose thru the misty rain and as we approached we could see the city of Suva's patchy red roofs and white walls lying low on a promontory. Long reefs projected out towards us and behind the line of breakers at their edge we could see the shallow reef thru the clear water. The pilot boat, itself piloted by our first real Fijian came along side and put the pilot on the Baird, the Horizon being left to trail along. The channel was well marked by large range markers on a distant hill and a dolphin at the main right angle turn to Suva's wharves. A dozen of our amateur photographers stood on the boat deck under the flying bridge and cursed the showers. As we moved slowly towards Kings Wharf which was deserted except for the Tielbank of Glasgow (a U. S. Liberty Ship) people

lava-lavas leaning against trucks and sitting on tables; a bit apart was a group of lighterskinned men in white shorts and shirts with white stockings coming to just below the knee--these were the local British--customs, agricultural inspectors, and agents. The waterfront area was sort of a hodge-podge of vacant land, tin sheds, old pilings and assorted piles of crates, sacks, dunnage and scrap iron. Beyond lay the market and the town of Suva which had room for only two flat streets parallel to the waterfront; the rest of it draped lightly over the adjacent low hills. Thru the city itself were splotches of greenery which broke up the bareness of the walls and made the place more inviting.

The air was warm and damp and the faint odor of the island which had been growing for hours was now real and ripe--copra, fruits, sweat and just waterfront. The Baird eased alongside the wharf and the heaving lines and hawsers were taken by bushy haired brown men in short ragged pants and old shirts with the sleeves torn out. Helen Raitt appeared, a transparent raincoat over her blue dress and covered with smiles, her gray hair bouncing as she jumped up and down like a child about to be given a toy. She shouted introductions, hellos, gave messages from home, passed mail, and told the railbirds how things were in Fiji all at once. Much more sedate were the local officials who boarded us to inform Capt. Davis that no one would be allowed ashore until our stores and parts were cleared with customs and we passed a health and agriculture check. To back up this request there was a policeman. A Fijian policeman is a man apart and is not to be confused with ordinary mortals or run of the mill law enforcement officials however romantic their heritage. I feel sure that one of these specimens could separate a mob of wrangling Texas Rangers and Northwest Mounted Police. The specimen who strode down the wharf must have been six feet

smile but no shoes. His blouse was dark blue ant it closed with chiny gold buttons; at the waist it ended in a wide leather belt with a magnificent silver buckle. Below the buckle was a white lava-lava which hung clean and straight to just below his knees where it ended in deep V-shaped serrations. Surmounting this grandly simple uniform was a huge dramatic headpiece--his hair. Black, slightly kinky, radiated in all directions from the man's head and was evenly trimmed off about four inches from the scalp. This gave his head the appearance of a fuzzy black basket ball--and added several apparently unnecessary inches to his height. His nominal badge was a small number, 473, on a silver plate over the blouse pocket but his real badge of authority was his bearing and his dignity. Any weapons, such as clubs or revolvers would have been superfluous--and none were carried. With obvious admiration in their eyes our railbird photographers made picture after picture of this imposing fellow; in return he smiled just a trace more broadly.

The restrictions against our going ashore in no way limited those ashore from coming aboard and since no one objected we soon had a ship full of Fijians. It is doubtful that any of the other ships arriving at Suva was so generous as to let just anyone on the pier who so desired come aboard and so, in a short while, the pent up desires of hundreds of natives to see the inside of a ship was fulfilled. The alleyways, the laboratory, the focastle, the after-deck, and the head were so jammed with natives that it was a real struggle to move about. I retreated to my cabin to read eight long awaited letters and write a quick answer. In an hour we were free to go; two spots demanded our immediate attention: the bank of New South Wales where we got Fiji pounds and shillings for dollars, and the barber shop where hair cuts were two shillings (27¢) and shaves one. I was impressed more by the barber;

and a modest sign: "Ladies and mens hairdressing". A darkened room to the rear was the workshop and an old barber chair was the throne. From the walls above the mirrors the faces of the British throne looked down; the quiet and the perfumed air were restful. The Hindoo barber bows slightly and puts a small square pink cloth around the patient's neck with a quizzical look. "Short" you say "straight on the sides." He takes an electric clipper from a hook and as he turns it on a dim light goes on too; after a moment's work off go both light and clipper and he starts on the main mass of your hair in the gloom. The barber was a paragon of ; his fingers snipped the scissors rapidly and he was soon thru. There was no idiotic talk about the weather, the worlds series or the coming coronation. With a restraint that far transcended all barbers of my previous experience he did not remark on the strange way we wore our hair until some four ex-pollywogs had passed under his scissors. A pollywog, let me explain, is a shipmate who has never before crossed the equator. The shellbacks, or old experienced sailors, seem to think it necessary to have an "initiation" which often consists, in part, of a haircut. Haircut is sort of a loose term which refers to the removal to nearly skin depth of isolated portions of the pollywog's hair; to put it plainly, our hair was very patchy, being alternatively much too long and much too short. The Hindoo did very well considering and even though no one explained how this unevenness came about he accepted the challenge as the natural result of dealing with foreign scientific sailors and snipped stolidly away.

Once relieved of our hair and supplied with new currency we were really "on the town." Curio shops came first. Although Suva sees relatively few tourists there were a number of shops that sold tortoise shell craft work, baskets, mats, seashells, cats-eye jewelry, mother-of-pearl carvings, cocoanut shell work, kava bowls and wooden weapons and spears.

the city well behind did we appreciate the real wonders of Fiji. In a rented motor car with Indian driver we headed west along Queens Road which completely encircles the island at or near the water's edge. Since no roads penetrate the interior, Queens road is just about the only road on the island; it is barely wide enough for two vehicles to pass except on the bridges which are strictly one-car affairs. Thru fantastically dense jungle with fern trees as much as 40 feet tall and great looping vines the road wound its tortuous way--then out across the great fertile valley of the Nauvoo River where tall grass grows to the water edge like a cultivated canal bank. We saw water buffalo up to their bellys in the rice fields straining at primitive wooden plows and thick groves of mangroves along the embayments. A strange animal trotted between the mangrove roots which our driver assured us was a mongoose--imported by the Indians to keep the snakes down. Every few miles were Fijian villages; we would stop and marvel at their simple beauty and exquisite settings. The inhabitants would come out and stare back at us, we would take pictures and go on. There is a remarkable sameness to these villages; most are on flat ground near the water's edge and consist of a dozen leaf, grass and bamboo houses in two neat lines. Between the houses grass grew, neat and green like a lawn; only the most-used trails were brown. There were cocoanut palms overhead for plenty of shade, an outdoor shower or two with thin matting about its perimeter and some out-buildings back away from the main dwellings. There 50 people or so would live.

When Dr. Livingston and Mr. Stanley met, it was as I had always pictured it: a circle of dusky natives, ~~palms swaying overhead, and~~ a tropical village of grass huts. But it was not ~~about~~ Central Africa. For me it happened January 6, 1953, on Ninatobutabu like this:

In our explorations of the Tonga Trench and the Tofua Trough we had gradually developed two lines of undersea mountains, one of volcanic rock and one of limestone bounded by relative depressions in the sea floor. Some of the mountains rose above the surface and made up the eastern Tonga Islands which were coral and limestone; others appeared as isolated volcanic peaks and cones to the west of the Tofua Trough and were distinctly volcanic. As we moved north towards Samoa, however, the two chains became increasingly difficult to distinguish and we had to rely on snatches of information about the islands gleaned from such books as the "Sailing Directions", and the "Pacific Islands Handbook", and on hearsay. For several of the islands in the extreme northwest of the Tongas there was no information available even as to whether they were composed of volcanic or coralline materials. It was important to obtain specimens of the rock, whatever it might be, for three reasons. First to determine whether these isles were extensions of the eastern (limestone) or western (basaltic) side of the chain; second, to determine whether the rock, if volcanic, was within the andesite line; and third to confirm the data being obtained with the magnetometer which apparently reacted violently to undersea volcanics and passed calmly over equivalent mountains of sedimentary rock.

Two islands, Ninatobutabu and Tafahi, and several reefs composed the northwest group and by curtailing our stay in Samoa we could squeeze in a few hours stop-over en route. The Baird approached from the southeast and as we

necessary for the external appearance of the islands was no help. The northern island, Tafahi, was obviously a large volcanic cone but the southern isle greatly resembled the terraced limestones of Vava'u. Was it possible that there was one island of each rock?

Between the two islands the Baird stopped and hailed a tiny native sail boat with about 8 people aboard. They waved violently but continued on so we hoisted Helen's Tongan flag, overtook them and launched a skiff. As the skiff came alongside, the natives were ready with eager handshakes and gifts of bananas. "Did we have a doctor aboard," they wanted to know. Yes, said the man at our oars. "I am a doctor." The natives did not appear overly impressed by Bob Livingston, M.D., who wore only a pair of swim trunks, but asked him to come aboard and look at a sick baby. The craft was from Tafahi, the captain (also the chief of the tribe) explained, and they were taking the sickest of five babies to a native hospital at Ninatobutabu. Bob elected to stay with the sailboat and go ashore; the remaining four of us rowed in.

is populated by people and second, it is largely covered by a thin film of water called ocean. A table size globe which showed relief features constructed exactly to scale would have an ocean about 1/300 of an inch deep--about the thickness of the blue paint that marks it. But the people who inhabit Earth, and measure things in terms of their own size, are terribly impressed by the fact that the average depth of the ocean is 12,000 feet. Some of the people of Earth are stranger than others and dedicate their lives to the study of this thin film of water; they are called oceanographers.

On the California coast at La Jolla, perched on a low cliff facing out across the vast Pacific, stands the white laboratories of the Scripps Institution of Oceanography; and somewhere out beyond the horizon, probing and exploring, are five white ships. These are the obvious physical assets but not the one which keeps the Scripps Institution leading the exploration of the deep sea. The real asset is the combined talents of the scientists who work there, for Oceanography is a complex science which combines the knowledge and techniques of chemistry, biology, geology, physics, and engineering.

Since World War II the seagoing scientists at Scripps, supported by the University of California and the Navy, have conducted five far-ranging expeditions to study various aspects of the Pacific Ocean. "Mid-Pac" investigated the mid-Pacific mountain range; "Northern Holiday" cruised and dredged in a hitherto unexplored area of the Gulf of Alaska (a holiday being a place that has been missed in Navy lingo); "Shellback" crossed and recrossed the Equator many times studying the equatorial currents; and"Trans-Pac" crossed the northern Pacific to within sight of Russian-held Kamchatka making biological collections.

This is a story about expedition Capricorn, for Capricorn was probably the most sophisticated deep-sea expedition that ever put to sea. It involved two ships, working together, which were loaded to the gunwales with the most modern scientific equipment available

by the radio shack. The operator would monitor the night news broadcasts from Los Angeles or Auckland and translate the salient facts into terse typewritten paragraphs which appeared before us on two sheets at breakfast time. We seemed to have no sense of time on ship; Monday meant clean sheets and certain dates were set for arrivals in port. But time and current events had a certain vagueness as they seemed completely beyond our control--we viewed the world quite abstractly.

Until January eleventh. Like most tourists in the south seas nearly all aboard were fascinated by the wonderful native craft work and were heavily stocked up on these lovely and inexpensive items. There were probably a hundred mats and as many tapa cloths; there were canoes and paddles, grass skirts, kava bowls, carvings, cocoanut cups and wooden toys--each waiting to be proudly displayed in San Diego and each with a history of involved trading to be recounted. Until January eleventh.

On this fateful morning as we read the neatly typed morning paper, it seemed as though item four on page 2 stood out in red caps; it said:

> WASHINGTON: NEWS OF A SERIOUS THREAT TO HEALTH AND AGRICULTURE WAS MADE PUBLIC TODAY IN A JOINT ANNOUNCEMENT BY THE US PUBLIC HEALTH SERVICE AND THE DEPARTMENT OF AGRICULTURE. THE MENACE, AT FIRST THOUGHT TO HAVE RESULTED FROM GERM WARFARE STUDIES, HAS BEEN TRACED TO THE SCENE OF RECENT ATOMIC EXPERIMENTS IN THE PACIFIC AREA, THE ANNOUNCEMENT SAID. A PREVIOUSLY UNKNOWN SPECIES OF MINUTE SPIDER REPORTED TO INFEST THE COCOANUT PALM IS NAMED AS THE ORGANISM CAUSING THE MENACE. AEC SPOKESMEN STATED THAT THE RECENT TESTS CAN IN NO WAY BE HELD RESPONSIBLE FOR THE SPIDER, BUT SUGGESTED THAT AN ABNORMAL INCREASE IN THE NUMBER OF TOURISTS RETURNING FROM THE PACIFIC COULD ACOUNT FOR THE INTRODUCTION OF THE SPIDER INTO THIS COUNTRY. US CUSTOM OFFICIALS HAVE BEEN ORDERED TO IMPOUND INDEFINITELY ALL VEGETABLE MATTER KNOWN TO HAVE COME FROM PACIFIC ISLANDS UNTIL DEFINITE PROTECTIVE MEASURES AGAINST THE SPIDERS SPREAD HAVE BEEN DEVELOPED, HEALTH SERVICES OFFICIALS SAID.

All our treasures impounded. How gloomy the dining hall can be. Then our more careful analysts, on examining the wording closely found traces of both scullduggery and Dr. Livingston in the purported announcement.

On January 12, 1953, the Baird visited Palmerston Island; more properly, we came close enough to the island so that the natives could visit us. Our objectives in going there were twofold: First we wanted to discover whether a slight embayment in the western side of the atoll might really result from a submarine landslide and second it was important to see how the magnetometer behaved on a closed course around an atoll.

As we came close, two small sailboats put out from the beach thru a tortuous channel in the reef; seventeen natives altogether, sailing and rowing. On our first survey run we passed them by quite closely and they turned back, discouraged; but on the second pass, we hove to and they came happily along side.

Palmerston Island is a curious place in several ways, genetically, economically, and geologically. Practically all the 74 residents are named Masters--decendants of William Masters, an Englishman who settled here in 18__ with one legitimate wife, a Maori, and two concubines. Mr. Masters had a certain talent for reproduction and begot 20 children who survived to have an average of ten children each. In the short space of two generations one man thus peopled a country. The children have kept their lineage straight with respect to their mothers, however, and each line has its own chief. The head chief now, also William Masters, is the decendant of the first or legal wife. We also had as a visitor the chief of the perpetually bastard side of the family--rather Negroid in some respects; he spoke excellent English and told us about his people and his island. There are now some 100 people on

they are governed, or at least taxed and protected, by New Zealand. They travel back and forth across the lagoon to the other islands, some of which are used for livestock (pigs and chickens) and all of which are a source of copra. Last year they shipped some 200 tons of copra worth 60 pounds a ton.

Most interesting is their outlook on taxes. For many years the tax of the entire island has been 50 pounds per annum - - for this the Masters family can live there; non payment brings the threat that New Zealand will move them to some vague elsewhere. In 1945 the islanders stopped paying the tax. New Zealand threatened. The Masters clan held fast, however, realizing that for New Zealand to come and get 'em would be a pretty expensive project and not worth the effort. After some futile dickering by mail, Chief Masters neatly passed the buck. He wrote a letter to the Council of Cook Chiefs at Raritonga protesting the tax rate. That was in 1949 and no answer has yet been received. With a pious look Mr. Masters (the chief) shrugs his shoulders to give the impression that his fate is in the hands of these super beings and he is no longer responsible. The Scripps audience was not particularly sympathetic; we figured that if the tax was paid it would be about 1/4 of our own rate. I'll bet Vivian Kellums would be pleased though.

Before leaving the men were induced to sing some native songs for us--they chose love songs, each with a story. Once furnished with the bosun's guitar and Helen's ukulele they started with a one - two - three and broke into a rhythmic song accompanied by calls, laughs and side remarks. Obviously accustomed to dancing, the men could not resist an occasional shinny and gesture as the first song progressed. With the

and the third was an unrestrained dance of passionate love done on the hydrographic platform by the lab door. Sung in Raritongan, we naturally missed the meaning of the words (except wahine) but the dance was obvious. Fortunately the music was recorded in entirety by Dr. Livingston and as usual he asked for an explanation of the songs in English--recorded at the end. One large dark man, their radiooperator, took the mike with confidence and explained "We sang last a love song. A song of a boy and a girl making love on a mat in the dark. Suddenly some one strikes a match--is light" (he spread his hands). "The love is spoiled; the flame below my belly (points to navel) went out when the match was lit." The dance needed no explanation. It looked to me as though the flame below the dancers belly continued to the last note, but no explanation was needed. It too was recorded on motion picture film by MacFall.

Our problem with Palmerston Island, however, had its roots much deeper in history. Our chart, the only one ever made so far as I know, was made by Captain James Cook in 1774 and is published by our hydrographic office as one part of chart no ___. As we approached and took bearings on the islands our speed apparently dropped from the usual 11.5 to about 7 knots; later, running alongside we fell far behind the dead reckoning positions. After a complete circuit of the island the difficulty was plain: Captain Cook had drawn the atoll too small. In fact it was quite a bit too small. Instead of the charted 4 miles, it was nearly $5\frac{1}{2}$ miles long. Probably the famous navigator climbed the mast and sketched the place, estimating distances. At any rate in order to make our data valid and usable it was essential that we have an accurate chart on which to plot it so I set to working thru the nearly infinite

number of possibilities. Using the [illegible] cuts on islands, the continuous tines of soundings and the magnetometer coincidence, I was able, after dozens of tries, to place the islands in their correct positions and enlarge Captain Cook's original sketch to a true scale. The finished chart turned out very well and may even replace the old one on the charts some day.

The Baird arrived off Papeete just after dark; the Horizon, of course, was already there and its crew ashore. A tub-like steel pilot boat came alongside and put the pilot on us who immediately went on the bridge and called for standard speed. The entrance to the harbor at Papeete is fairly narrow between two breaking coral reefs but is well marked by red range lights on the hill behind the town. When aligned these lights indicate the center of the channel. I shall not soon forget our entrance into the harbor--neither will Capt. Davis. Most of the party were on the forward deck watching the reefs and the lights; we steadily moved further off range to the left and passed within an easy biscuit-toss of a breaker which curled about the reef on our port side. At the time we thought of this as being over-confidence on the part of the pilot; it later turned out that the steering mechanism had jammed and we were just lucky not to have gone aground. Inside, it was necessary to anchor the prescribed 400 meters from the shore for we were a contaminated ship. We had touched at Tonga and Samoa; areas where the rhinocerous beetle was making serious inroads on the cocoanut palms and thus striking at life itself--for life in the ~~about~~ south seas revolves around the cocoanut palm. It seems that the beetle flies only at night so that contaminated ships can tie up alongside the wharves in the daytime. From an hour before sunset until an hour after dawn the ship must leave since apparently 400 meters is too far the one of the beasts to fly. This seems to be an effective measure, although of course it is mighty inconvenient. We heard of a large freighter that for ten days had put to sea every night and returned in the morning--trying to get unloaded--a two-day job. In the day it would rain and the hatches would have to be covered except for about two hours.

Tahiti--there's a lot to see and it has infinite variation. It was every man for himself--but high up on almost everyone's list was Quinn's. Quinn's Tahitian Hut. It sits in the middle of town on the main street, a short block from the waterfront--and Papeete seems to revolve about it. We had heard a lot about the place and expected a lot--and were not disappointed. It may or may not be true that if you stand in Grand Central Station or at the corner of State and Randolph long enough you'll see everyone you've ever known, but I would consider it to be an absolute cinch that if you stayed in Quinn's for a modest length of time you'd see everyone in Tahiti and a big share of the people from French Oceania. Quninn's occupies a bomboo covered building not over 75 feet square; the center of the street side is a bar and on either side of it is a wide doorway. Inside the bar curves horseshoe-wise into the one large room which is surrounded by small booths. The orchestra sits inside the bar (probably for protection from the riotious dancing they engender), the customers throng everywhere at all hours. Quinns is not exactly a night club for it is open almost continuously; closes just in time for church on Sunday morning but soon opens again for the rest of the week. We were there on election day when there was an enforced closing of all bars; old customers stood bewilderdly about on the street outside with no place to go. When the orchestra goes home the barmaids play a tape recorder or often in the morning the customers make their own music--for every Tahitian plays a guitar. Danish beer is 20 francs; cognac, absinthe, and whiskey are 30. The attraction at Quinns is not the music or the liquor; it's the eligible girls who appear there by the dozens whenever there is a foreign ship in port--and on Saturday nights anyway. They are young, goodlooking things with endless time on their hands and and ready for anything - - -they are even energetic if what you propose

the house (in fact they will often suggest another bar or nurse one beer for an entire evening). Neither are they exactly prostitutes, although each one carries a health inspection card - - caught without it, in the clink they go. Their services are usually free and although they will accept small gifts gratefully it is more a token of friendship than as a payment. They expect to share equally with their partner of the day and must be taken care of; man buys food, drinks, clothes (if he stays long enough) girl furnishes sleeping place, good companionship, travel talk and often V.D. Judging by the actions of the crew and staff, this is a pretty acceptable proposition. We heard of a British ship which arrived loaded with sailors who were flat broke because of monetary restrictions; the girls supplied everything for them--food, money, drinks, and love. It would seem that their adventures are all for fun; it is probably the closest approach to a free love society in the world today and they make the most of it while they are young. I wish I had gone there 15 years ago. Anyway a number of the crew never got past Quinns; they had girls within 15 minutes and stayed "shacked up" until just before the ship left.

Some of the party went around the northside of the island to the Royal Tahitian Hotel. There I am told, they swam and played on the beach with a number of quite nude native girls who seemed to enjoy being viewed and photographed. "Art photos," the men said. Others took canoes and went out on the reef and some spent their time going thru curio shops in town buying tikis, wooden turtles, carved pearl shell and the like. I elected to walk to the pool of Pierre Loti - some 5 or 6 kilometers from town. It was a pleasant walk along a rutted dirt road that bordered

and some trees. Girlish giggles were in the air and thru a break in the trees I could see a young Tahitian beauty wading, nearly naked, in the stream. The other was not in sight from the road but I was over the fence from a standing start to prospect a bit. Almost to the stream a large mango thudded at my feet, and I looked up to see a husband directly above me gathering more ammunition. After an unconvincing attempt to make it appear as though I had been looking for mangos anyway I left quietly. Afterwards I noticed that in Papeete bicycles have no sex; men and women each ride bikes with or without bars on them.

To judge by his statue, Pierre Loti was a pretty effeminate sort of man--a fop in his day--but he had a pretty nice place beside the pool. The pool consists of a slightly wider and deeper spot in the stream already referred to made by a rough cobble stone dam. It is not over 25 feet across and twice that long; on the far side is a low rocky cliff that makes an ideal diving platform for small boys. When I arrived there were about a half dozen of said creatures splashing about in the pool and one elderly man sitting on a rock cooling his feet. On the low wall that bordered the road sat a mixed audience of about ten people. I decided to try the place myself; stripped to my underwear shorts, I made what was intended to be a graceful dive from a large boulder. Underwear shorts are intentionally made so that they can be removed easily and these were in working condition so that when I hit the water, off they came. I surfaced amid appreciative applause and swam back for my shorts thru the clear-as-glass water; after donning

closely but were disappointed by my subsequent performance.

On the way down from the pool I came across two Chinese boys spear fishing in the stream (one of them turned out to be a mechanical engineer from the University of California-Berkeley). Their system was unique in my experience since I had always regarded the ocean as the proper place for such sport; in water rarely deeper than the knees it has a different flavor. One system is to be flat on the stream bed, facing upstream and breathing thru a snorkle hanging onto a rock with one arm and the spear gun with the other and watching the narrow openings between rocks where fish must pass. Another method these boys use is to work only the deeper pools (2-3 feet deep) which often have dark recesses or tree roots where the fish like to wait. Fish, they said, were [illegible] comparatively difficult to find but there were plenty of large eels. When I expressed doubt, they immediately speared and threw on the bank an eel as big as my arm with a very mean looking set of teeth. It looked too big to live comfortably in such a small stream--at least it made the stream seem too small to hold both the eels and me. I left.

On Sunday, the day after elections I decided to go to the extreme south end of the island by bus--just for the ride. At the depot was Todd Carey, off to the same place because it was a former home of Robert Louis Stevenson. For 35 francs (50¢) we rode 80 kilometers on a hard seated, springless, dusty contraption, jammed with bright-colored humanity, that stopped with little or no provocation and went like mad between stops. Such a journey would have been miserable any place else---in Tahiti it was fun; and every incident was a topic for laughter. Probably it is the laughter that makes Tahitians seem so carefree; everything is

is an hour late; these are life's natural amusements.

There is no vehicle extant on U. S. roads that looks like a Tahitian bus. It is sort of an elongated pick-up truck, wider and lower, with wooden benches along the sides and a double bench down the middle. The entire rear end is open, which serves as a door; sides are open except for posts which support a flat wooden roof on which baggage is stowed. Ragged pieces of canvas can be lowered to cover the openings if rain or dust gets too bad. When Todd and I found the right bus and got on it was packed except for the end of the center bench - - we should have been suspicious but in our innocence regarded this as luck. One is supposed to ride sideways on these benches of course, but the aisles were full of mixed legs, baskets, banana stalks, kids and assorted small luggage. We let our feet hang off the end. Two large tuna hung from the roof which occasionally swing back and forth in front of the view; and a small boy, who turned out to be the baggage man, clung to the rear step --but it was still a fine place to ride and see the country. As long as we were on the pavement, that is. Then the horrible truth dawned: on the dirt roads we were a heaven sent shield for the other riders from the great dust eddy that the bus stirred up. We had also naively expected that people would start getting off the bus before long; instead more got on and the pressure on our backs gradually increased until we were forced to stand on the step too. Eventually we retreated to the roof for a last stand where we sprawled amid bicycles, boxes of ice, baskets of mangos, jugs of wine, old copra sacks, and the spare tire. The young baggage man knew his customers well; when the bus came abeam of a house where ice was to be delivered, he would stomp his foot and the driver would stop; when all was secure the boy would stomp again and the bus

much horn blowing and cheering from both vehicles. Once past, he would quickly veer off the road and stop quickly leaving the other driver to thread his way thru the passengers - for at every stop a number got off to stand for a minute in preference to the hard seats and stretch. The driver had a game for this situation, too; he was pretty good at starting without warning in an attempt to lose some of his riders. We played safe and stayed within a few steps of the bus but one young passenger always wandered well away; when the bus started he would run for a hundred yards or so at top speed to catch it, leaping on with a triumphant grin. Tahitians are wonderful backseat drivers and at advising passing drivers they were at their peak - particularly motorcyclists. Advice was loud, accompanied by wild hand gestures and divided. A young Chinese boy who wanted to pass on his cycle in a curving stretch of road was both encouraged and deterred by twenty advisers. He finally started to pass but halfway around changed his mind and dropped behind again. This brought a great chorus of French-Tahitian which apparently was evenly divided between words like "chicken" and "I told you so." When he finally went by a great cheer went up.

In Tahiti we ~~was~~ saw rain, although our advance info indicated that November to April is the rainy season very little rain fell on our expedition. But the afternoon of the last day in Tahiti things were different. I was ashore after lunch, and, having forgotten that all doors are locked and all business secured completely from noon to 1 p.m., was patiently waiting for Establissments Donald to open so I could demand more speed in the repair of the ship's refrigerator. Rain began--gently at first; and the high wooden awning kept it off. Then harder, and I

of 30-40 mph - - the harbor was obscured; the doorways filled with huddled people. No further retreat seemed possible and it was getting very wet when a large gust of wind sprung the door behind me so that the lock opened and the door crashed open. I immediately retreated inside with a crippled native who had shared the doorstep with me; we were in the tourist bureau. Tahitian hospitality carried to the nth degree. We made ourselves at home in the dark, content to watch the water rush under the door with each gust. Above the roar of the rain we heard a crash and some hoarse shouting; curiosity being what it is we opened the door and peaked. Directly across the street two of the small trading schooners had lost their bow mooring lines and had been swept about broadside so that they were battering against the stone quai. One crew was battling trying to haul their bow around on a new line before the hull collapsed; the other was attempting to haul their sunken dingy aboard with a block and tackle so they could take a line to their forward mooring buoy.

The porch roof blew off of the Yacht Club restaurant the there was corrugated iron lying about on the streets--siding from the photo shop and other buildings; traffic had completely disappeared. We closed the door and waited till the roar of the rain moderated to indicate a mere downpour--then left carefully locking the door again. I sloshed, ankle deep, the block to Quinns and called for a cognac. Shtayed there too, for several hoursh.

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above the gravel. On three sides this "room" is enclosed with a lattice work of palm fronds which rise about as high as the top. This makes it easy to see what is going on about and carry on a conversation while bathing. As a concession to privacy, the open side is usually turned away from the main road; the walls are intended as a wind break. There is no roof and no need for one. Why shouldn't a bath room get wet?

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On the happy face of Kipiri there is no sign of worry on this account. He is the master craftsman; his work is good and he is proud of it. Some native carvings I have seen appear to me to be little more than wooden doodles or weak copies of the work of ancient artesians in which the fine points of proportion have been lost; others are obviously hacked out for the tourist trade--quick chopping for quick sale. Not so with the work of Kipiri. He selects his own wood, cures it, and saves it--each piece for a future specific purpose. Only the finest of hardwoods: Sandalwood, Miro, Tamanu. These come from the upper slopes of the steep ridges and are increasingly difficult to find. When he makes a bowl it is round; his paddles are straight. A couple of hours climb above Taiohae is the summit of the range; behind is the comparatively dry leeward side of the island, ahead is a wide valley, green with dense tropical forest. This is the valley of the Typee immortalized by Conrad. Where once lived 8000 people there now dwell 110. For it is said that after the terriffic inroads on health and life made by the white man's diseases, by his narcotics, by his saloons, the natives lost the will to live.

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boat came alongside and put the pilot on us who immediately went on the bridge and called for standard speed. The entrance to the harbor at Papeete is fairly narrow between two breaking coral reefs but is well marked by red range lights on the hill behind the town. When aligned these lights indicate the center of the channel. I shall not soon forget our entrance into the harbor--neither will Capt. Davis. Most of the party were on the forward deck watching the reefs and the lights; we steadily moved further off range to the left and passed within an easy biscuit-toss of a breaker which curled about the reef on our port side. At the time we thought of this as being over-confidence on the part of the pilot; it later turned out that the steering mechanism had jammed and we were just lucky not to have gone aground. Inside, it was necessary to anchor the prescribed 400 meters from the shore for we were a contaminated ship. We had touched at Tonga and Samoa; areas where the rhinocerous beetle was making serious inroads on the cocoanut palms and thus striking at life itself--for life in the South seas revolves around the cocoanut palm. It seems that the beetle flies only at night so that contaminated ships can tie up alongside the wharves in the daytime. From an hour before sunset until an hour after dawn the ship must leave since apparently 400 meters is too far the one of the beasts to fly. This seems to be an effective measure, although of course it is mighty inconvenient. We heard of a large freighter that for ten days had put to sea every night and returned in the morning--trying to get unloaded--a two-day job. In the day it would rain and the hatches would have to be covered except for about two hours.

a short block from the waterfront—and Papeete seems to revolve about it. We had heard a lot about the place and expected a lot—and were not disappointed. It may or may not be true that if you stand in Grand Central Station or at the corner of State and Randolph long enough you'll see everyone you've ever known, but I would consider it to be an absolute cinch that if you stayed in Quinn's for a modest length of time you'd see everyone in Tahiti and a big share of the people from French Oceania. Quninn's occupied a bamboo covered building not over 75 feet square; the center of the street side is a bar and on either side of it is a wide doorway. Inside the bar curves horseshoe-wise into the one large room which is surrounded by small booths. The orchestra sits inside the bar (probably for protection from the riotious dancing they engender), the customers throng everywhere at all hours. Quinns is not exactly a night club for it is open almost continuously; closes just in time for church on Sunday morning but soon opens again for the rest of the week. We were there on election day when there was an enforced closing of all bars; old customers stood bewilderdly about on the street outside with no place to go. When the orchestra goes home the barmaids play a tape recorder or often in the morning the customers make their own music—for every Tahitian plays a guitar. Danish beer is 20 francs; cognac, absinthe, and whiskey are 30. The attraction at Quinns is not the music or the liquor; it's the eligible girls who appear there by the dozens whenever there is a foreign ship in port—and on Saturday nights anyway. They are young, goodlooking things with endless time on their hands and and ready for anything - - -they are even energetic if what you propose

each one carries a health inspection card -- caught without it, in the clink they go. Their services are usually free and although they will accept small gifts gratefully it is more a token of friendship than as a payment. They expect to share equally with their partner of the day and must be taken care of; man buys food, drinks, clothes (if he stays long enough) girl furnishes sleeping place, good companionship, travel talk and often V.D. Judging by the actions of the crew and staff, this is a pretty acceptable proposition. We heard of a British ship which arrived loaded with sailors who were flat broke because of monetary restrictions; the girls supplied everything for them--food, money, drinks, and love. It would seem that their adventures are all for fun; it is probably the closest approach to a free love society in the world today and they make the most of it while they are young. I wish I had gone there 15 years ago. Anyway a number of the crew never got past Quinns; they had girls within 15 minutes and stayed "shacked up" until just before the ship left.

Some of the party went around the northside of the island to the Royal Tahitian Hotel. There I am told, they swam and played on the beach with a number of quite nude native girls who seemed to enjoy being viewed and photographed. "Art photos," the men said. Others took canoes and went out on the reef and some spent their time going thru curio shops in town buying tikis, wooden turtles, carved pearl shell and the like. I elected to walk to the pool of Pierre Loti - some 5 or 6 kilometers from town. It was a pleasant walk along a rutted dirt road that bordered

the stream. The other was not in sight from the road but I was over the fence from a standing start to prospect a bit. Almost to the stream a large mango thudded at my feet, and I looked up to see a husband directly above me gathering more ammunition. After an unconvincing attempt to make it appear as though I had been looking for mangos anyway I left quietly. Afterwards I noticed that in Papeete bicycles have no sex; men and women each ride bikes with or without bars on them.

To judge by his statue, Pierre Loti was a pretty effeminate sort of man--a fop in his day--but he had a pretty nice place beside the pool. The pool consists of a slightly wider and deeper spot in the stream already referred to made by a rough cobble stone dam. It is not over 25 feet across and twice that long; on the far side is a low rocky cliff that makes an ideal diving platform for small boys. When I arrived there were about a half dozen of said creatures splashing about in the pool and one elderly man sitting on a rock cooling his feet. On the low wall that bordered the road sat a mixed audience of about ten people. I decided to try the place myself; stripped to my underwear shorts, I made what was intended to be a graceful dive from a large boulder. Underwear shorts are intentionally made so that they can be removed easily and these were in working condition so that when I hit the water, off they came. I surfaced amid appreciative applause and swam back for my shorts thru the clear-as-glass water; after donning

engineer from the University of California-Berkeley). Their system was unique in my experience since I had always regarded the ocean as the proper place for such sport; in water rarely deeper than the knees it has a different flavor. One system is to be flat on the stream bed, facing upstream and breathing thru a snorkle hanging onto a rock with one arm and the spear gun with the other and watching the narrow openings between rocks where fish must pass. Another method these boys use is to work only the deeper pools (2-3 feet deep) which often have dark recesses or tree roots where the fish like to wait. Fish, they said, were [redacted] comparatively difficult to find but there were plenty of large eels. When I expressed doubt, they immediately speared and threw on the bank an eel as big as my arm with a very mean looking set of teeth. It looked too big to live comfortably in such a small stream--at least it made the stream seem too small to hold both the eels and me. I left.

On Sunday, the day after elections I decided to go to the extreme south end of the island by bus--just for the ride. At the depot was Todd Carey, off to the same place because it was a former home of Robert Louis Stevenson. For 35 francs (50¢) we rode 80 kilometers on a hard seated, springless, dusty contraption, jammed with bright-colored humanity, that stopped with little or no provocation and went like mad between stops. Such a journey would have been miserable any place else---in Tahiti it was fun; and every incident was a topic for laughter. Probably it is the laughter that makes Tahitians seem so carefree; everything is

bus. It is sort of an elongated pick-up truck, wider and lower, with wooden benches along the sides and a double bench down the middle. The entire rear end is open, which seemss as a door; sides are open except for posts which support a flat wooden roof on which baggage is stowed. Ragged pieces of canvas can be lowered to cover the openings if rain or dust gets too bad. When Todd and I found the right bus and got on it was packed except for the end of the center bench - - we should have been suspicious but in our innocence regarded this as luck. One is supposed to ride sideways on these benches of course, but the aisles were full of mixed legs, baskets, banana stalks, kids and assorted small luggage. We let our feet hang off the end. Two large tuna hung from the roof which occasionally swing back and forth in front of the view; and a small boy, who turned out to be the baggage man, clung to the rear step --but it was still a fine place to ride and see the country. As long as we were on the pavement, that is. Then the horrible truth dawned: on the dirt roads we were a heaven sent shield for the other riders from the great dust eddy that the bus stirred up. We had also naively expected that people would start getting off the bus before long; instead more got on and the pressure on our backs gradually increased until we were forced to stand on the step too. Eventually we retreated to the roof for a last stand where we sprawled amid bicycles, boxes of ice, baskets of mangos, jugs of wine, old copra sacks, and the spare tire. The young baggage man knew his customers well; when the bus came abeam of a house where ice was to be delivered, he would stomp his foot and the driver would stop; when all was secure the boy would stomp again and the bus

stepped back into a doorway. Then much harder; a real gale, with winds of 30-40 mph -- the harbor was obscured; the doorways filled with huddled people. No further retreat seemed possible and it was getting very wet when a large gust of wind sprung the door behind me so that the lock opened and the door crashed open. I immediately retreated inside with a crippled native who had shared the doorstep with me; we were in the tourist bureau. Tahitian hospitality carried to the nth degree. We made ourselves at home in the dark, content to watch the water rush under the door with each gust. Above the roar of the rain we heard a crash and some hoarse shouting; curiosity being what it is we opened the door and peaked. Directly across the street two of the small trading schooners had lost their bow mooring lines and had been swept about broadside so that they were battering against the stone quai. One crew was battling trying to haul their bow around on a new line before the hull collapsed; the other was attempting to haul their sunken dingy aboard with a block and tackle so they could take a line to their forward mooring buoy.

The porch roof blew off of the Yacht Club restaurant the there was corrugated iron lying about on the streets--siding from the photo shop and other buildings; traffic had completely disappeared. We closed the door and waited till the roar of the rain moderated to indicate a mere downpour--then left carefully locking the door again. I sloshed, ankle deep, the block to Quinns and called for a cognac. Shtayed there too, for several hoursh.

Ninatobutabu

When Dr. Livingston and Mr. Stanley met, it was as I had always pictured it: a circle of natives, palms swaying overhead, and grass huts about. It happened January 6, 1953, on Ninatobutabu like this:

In our explorations of the Tonga Trench and the Tofua Trough we had gradually developed two lines of undersea mountains, one of volcanic rock and one of limestone bounded by relative depressions in the sea floor. Some of the mountains rose above the surface and made up the eastern Tonga Islands which were coral and limestone; others appeared as isolated volcanic peaks and cones to the west of the Tofua Trough and were distinctly volcanic. As we moved north towards Samoa, however, the two chains became increasingly difficult to distinguish and we had to rely on snatches of information about the islands gleaned from such books as the "Sailing Directions", and the "Pacific Islands Handbook", and on hearsay. For several of the islands in the extreme northwest of the Tongas there was no information available even as to whether they were composed of volcanic or coralline materials. It was important to obtain specimens of the rock, whatever it might be, for three reasons. First to determine whether these isles were extensions of the eastern (limestone) or western (basaltic) side of the chain; second, to determine whether the rock, if volcanic, was within the andesite line; and third to confirm the data being obtained with the magnetometer which apparently reacted violently to undersea volcanics and passed calmly over equivalent mountains of sedimentary rock.

Two islands, Ninatobutabu and Tafahi, and several reefs composed the northwest group and by curtailing our stay in Samoa we could squeeze in a few hours stop-over en route. The Baird approached from the southeast and as we

made the landfall, it became increasingly clear that a landing would be necessary for the external appearance of the islands was no help. The northern island, Tafahi, was obviously a large volcanic cone but the southern isle greatly resembled the terraced limestones of Vava'u. Was it possible that there was one island of each rock?

Between the two islands the Baird stopped and hailed a tiny native sail boat with about 8 people aboard. They waved violently but continued on so we hoisted Helen's Tongan flag, overtook them and launched a skiff. As the skiff came alongside, the natives were ready with eager handshakes and gifts of bananas. "Did we have a doctor aboard," they wanted to know. Yes, said the man at our oars. "I am a doctor." The natives did not appear overly impressed by Bob Livingston, M.D., who wore only a pair of swim trunks, but asked him to come aboard and look at a sick baby. The craft was from Tafahi, the captain (also the chief of the tribe) explained, and they were taking the sickest of five babies to a native hospital at Ninatobutabu. Bob elected to stay with the sailboat and go ashore; the remaining four of us rowed in.

'think'

Marquesan Plumbing
the ultimate in P.

1957

two thousand [illegible] from the [illegible] of Hawaii

and 700 [illegible] of Tahiti is a group of high

unmistakably volcanic islands covered with dense green jungle, vital swarming with exotic birds.

These are the Marquesas, the site of [illegible] Conrad's wonderful story Typee; formerly the ~~tropical~~ capital of the French oceanic islands. When the scientific ship Horizon put in to the beautiful cove harbor of Nuka Hiva with me aboard I was quite impressed, even overwhelmed, by the many attractions. The ship anchored and I went ashore with my Swedish friend Gustav in a native outrigger which was transformed

~~[illegible]~~

~~[illegible]~~

for the moment into a ferry.

Gus had been there before on the Albatross, a Swedish scientific ship, and was recognized by one of the leading inhabitants even before he stepped ashore. So we were greeted with words of welcome and friendship ~~that~~ could come only from a true Marquesan. "Greetings," said our native friend in French, "you must both come and stay with me while you are here. It is too bad that my daughters

have just gone to Tahiti for a few
weeks a you ~~[illegible]~~ could sleep with them".

Well, that was a pretty good beginning
on anybodys island. We stayed at the
house all night but Gus and I slept
uncomfortably ~~[illegible]~~ together in a
very sway backed brass bed that had
apparently belonged to Gauguin at one time.
But since We had displaced the father and eldest
son from the place of honor in the only
bed (The women and other children
always slept on the floor anyway) we
were obliged to literally sweat it out.

Our stay on this beautiful island
was limited ~~[illegible]~~ to a few days and we
made the most of it, climbing to the high
ridges to look down the lush Typee Valley
and plunging then the dense jungle to see the
great stone Tikis -- the idols of yesterday.
We ~~[illegible]~~ watched ~~the [illegible]~~ as Kipiri, the last of

the great woodcarver, [redacted] showed us how he carved the intricate free hand designs on the bottom of a wooden bowl. there was a public exhibition of the old Marquesan dances, now mostly forgotten since the local missionaries [redacted] consider them lewd and have tried hard to stop them altogether. we gave presents and received presents in return. Mine were a block of aromatic sandalwood and a small wine bottle filled with scented coconut oil pomade for the hair.

Even against this fascinating background I was most impressed by the plumbing for it symbolized for me the reaction of the [redacted] Polynesian to the pressure of what we like to call civilization.

The Marquesans are a simple people and they act in direct ways to satisfy their needs. For living is easy. there are plenty of fish, fruit, pigs, coconuts. there is ample material at hand for the construction of boats, houses and the easy requirements

of tropical living. There is water in many little springs and brooks; one needs only to walk a few yards to fill his bucket. ------ But, the French goverenor had more modern ideas.

Every house in the Tahitian village must have running water in it. So said the official decree. The goverment would supply all the pipe and fittings; the men would contribute equal time to the installation of the mains and each family would do its own plumbing. Make no mistake about it, the natives thought the goverenor very eccentric indeed to want such a fancy thing as running water in every house but in their own way they complied, following very close to the line of least resistance.

A suitable brook was dammed and in the road -- or rather path which led down the hillside thru the

scattered houses a ~~ribbon~~ trench was dug to hold the ~~a~~ four-inch water main from the dam. I estimated the average depth of the trench to be ~~five~~ inches -- ~~it~~ it had never been backfilled. ~~From~~ From it at odd intervals sprouted one-inch pipes which presumably led ~~to~~ to houses hidden in the trees. Since it was obvious to everyone ~~that~~ it would be useless to try to dig a trench 2 inches deep these lay on top of the ground -- but were rapidly being covered over with exotic vines.

One house had made the arrangement which sticks in my mind as a symbol of Marquesan plumbing. It was on the hillside below the path and its entire water system was open for inspection. The sink was a wooden windowbox with a hole in the bottom lined with coconut fiber beneath a ~~[illegible]~~ window opening on the side of the house. (During unusually heavy rainstorms

sometimes a swatting is hung over the opening [illegible] Suspended on another piece of fiber from the cones was a faucet and directly connecting the faucet with the public main was a single joint of pipe. This swaying budget of pipe with its magnificent simplicity satisfied the goverment requirement--and apparently the householder.

Its the very sort of thing that I think back upon when the complexities of civilization crowd in on me. Perhaps the two piece Polynesian system is best.

Palmerston Island — Cook Group

On January 12, 1953, the Baird visited Palmerston Island; more properly, we came close enough to the island so that the natives could visit us. Our objectives in going there were twofold: First we wanted to discover whether a slight embayment in the western side of the atoll might really result from a submarine landslide and second it was important to see how the magnetometer behaved on a closed course around an atoll.

As we came close, two small sailboats put out from the beach thru a tortuous channel in the reef; seventeen natives altogether, sailing and rowing. On our first survey run we passed them by quite closely and they turned back, discouraged; but on the second pass, we hove to and they came happily along side.

Palmerston Island is a curious place in several ways, genetically, economically, and geologically. Practically all the 74 residents are named Masters--decendants of William Masters, an Englishman who settled here in 18__ with one legitimate wife, a Maori, and two concubines. Mr. Masters had a certain talent for reproduction and begot 20 children who survived to have an average of ten children each. In the short space of two generations one man thus peopled a country. The children have kept their lineage straight with respect to their mothers, however, and each line has its own chief. The head chief now, also William Masters, is the decendant of the first or legal wife. We also had as a visitor the chief of the perpetually bastard side of the family--rather Negroid in some respects, he spoke excellent English and told us about his people and his island. There are now some 100 people on

the island (only one of the atolls islands is inhabited by people) and they are governed, or at least taxed and protected, by New Zealand. They travel back and forth across the lagoon to the other islands, some of which are used for livestock (pigs and chickens) and all of which are a source of copra. Last year they shipped some 200 tons of copra worth 60 pounds a ton.

Most interesting is their outlook on taxes. For many years the tax of the entire island has been 50 pounds per annum - - for this the Masters family can live there; non payment brings the threat that New Zealand will move them to some vague elsewhere. In 1945 the islanders stopped paying the tax. New Zealand threatened. The Masters clan held fast, however, realising that for New Zealand to come and get 'em would be a pretty expensive project and not worth the effort. After some futile dickering by mail, Chief Masters neatly passed the buck. He wrote a letter to the Council of Cook Chiefs at Raritonga protesting the tax rate. That was in 1949 and no answer has yet been received. With a pious look Mr. Masters (the chief) shrugs his shoulders to give the impression that his fate is in the hands of these super beings and he is no longer responsible. The Scripps audience was not particularly sympathetic; we figured that if the tax was paid it would be about 1/4 of our own rate. I'll bet Vivian Kellums would be pleased though.

Before leaving the men were induced to sing some native songs for us—they chose love songs, each with a story. Once furnished with the bosun's guitar and Helen's ukulele they started with a one - two - three and bmk broke into a rhythmic song accompanied by calls, laughs and side remarks. Obviously accustomed to dancing, the men could not resist an occasional shinny and gesture as the first song progressed. With the

barest encouragement two of the men did a full hula on the second song and the third was an unrestrained dance of passionate love done on the hydrographic platform by the lab door. Sung in Raritongan, we naturally missed the meaning of the words (except wahine) but the dance was obvious. Fortunately the music was recorded in entirety by Dr. Livingston and as usual he asked for an explanation of the songs in English--recorded at the end. One large dark man, their radiooperator, took the mike with confidence and explained "We sang last a love song. A song of a boy and a girl making love on a mat in the dark. Suddenly some one strikes a match--is light" (he spread his hands). "The love is spoiled; the flame below my belly (points to navel) went out when the match was lit." The dance needed no explanation. It looked to me as though the flame below the dancers belly continued to the last note, but no explanation was needed. It too was recorded on motion picture film by MacFall.

Our problem with Palmerston Island, however, had its roots much deeper in history. Our chart, the only one ever made so far as I know, was made by Captain James Cook in 1774 and is published by our hydrographic office as one part of chart no ___. As we approached and took bearings on the islands our speed apparently dropped from the usual 11.5 to about 7 knots; later, running alongside we fell far behind the dead reckoning positions. After a complete circuit of the island the difficulty was plain: Captain Cook had drawn the atoll too small. In fact it was quite a bit too small. Instead of the charted 4 miles, it was nearly 5½ miles long. Probably the famous navigator climbed the mast and sketched the place, estimating distances. At any rate in order to make our data valid and usable it was essential that we have an accurate chart on which to plot it so I set to working thru the nearly infinite

number of possibilities. Using the ships dead reckonings, the position cuts on islands, the continuous lines of soundings and the magnetometer coincidence, I was able, after dozens of tries, to place the islands in their correct positions and enlarge Captain Cook's original sketch to a true scale. The finished chart turned out very well and may even replace the old one on the charts some day.