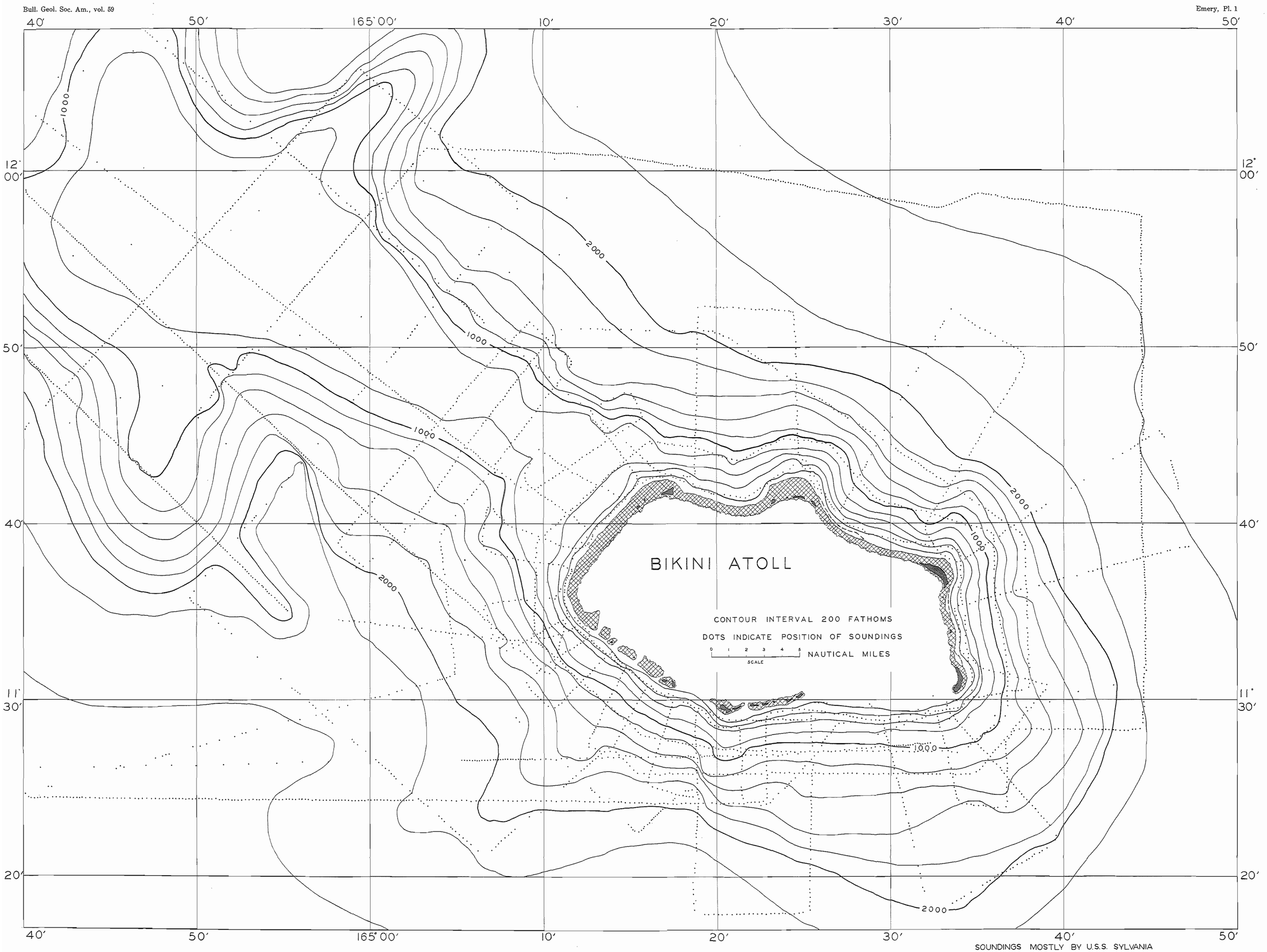

BIKINI ATOLL — PRELIMINARY CHART SHOWING OUTER SLOPES

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 59, PP. 855-860, 5 PLS. SEPTEMBER 1948

SUBMARINE GEOLOGY OF BIKINI ATOLL

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ABSTRACT

The program of investigations made in connection with the atomic bomb tests in the summer of 1946 at Bikini Atoll provided a rare opportunity for obtaining information on the physiography and sediments of atolls. The outer slopes around Bikini Atoll rise from a depth of about 2500 fathoms in a long gradually steepening curve. Between 0 and 200 fathoms the average slope is 25°. On the windward side, the reef at the top of the slope is bordered by a narrow 15-fathom terrace, but on the leeward side by a steep, locally vertical, cliff extending to 35 fathoms. Contours of the outer slopes reveal that a flat-topped mass having nearly the area of Bikini lagoon but below 700 fathoms extends to the northwest. The lagoon itself is saucer-shaped and has a maximum depth of 34 fathoms. Around the lagoon and bordering the inner side of the reef and islands is a 12-fathom terrace. Coral knolls rise abruptly from the lagoon floor, and some of them reach to within a few fathoms of the surface. The middle of the lagoon is floored chiefly by algal debris, whereas the shallow edges are covered by algal and foraminiferal sand. Coral comprises a relatively small percentage of the bottom materials. The outer slopes consist of algal debris grading outward to fine sand and finally to *Globigerina* sand.

INTRODUCTION

A number of interesting scientific results were obtained from the atomic bomb tests (Operation Crossroads) at Bikini Atoll in the summer of 1946, aside from the evaluation of the bomb as a weapon. The major effort of the expedition was necessarily

bent toward studies likely to be important in connection with the bomb, but the number of ships available and the staff made up of specialists in many fields of science virtually insured the making of new discoveries. Submarine geology is one of the fields most likely to gain as a result of the trip, simply because the underwater portions of atolls had not been well studied previously. Modern sampling methods, recording echo sounders, and the underwater camera served as new tools for collecting data. To determine what changes in the topography and sediments were produced by the bomb, it was essential first to understand clearly the character of the bottom before the bomb blast, not only near the bomb site but also some distance away in the lagoon. Detailed studies were also made of the outer slopes, because of the possibility that landslides might be triggered by the explosion. Finally, to determine whether Bikini is a typical atoll and to provide controls for estimating bomb damage to organisms, the near-by Eniwetok, Rongelap, Rongerik, and Ailinginae atolls were studied briefly.

The geological investigations were supported by Military Intelligence Division, Office of the Chief of Engineers, and by the Bureau of Ships and formed part of the work of the Oceanographic Section of Joint Task Force One, under the leadership of Comdr. Roger Revelle.

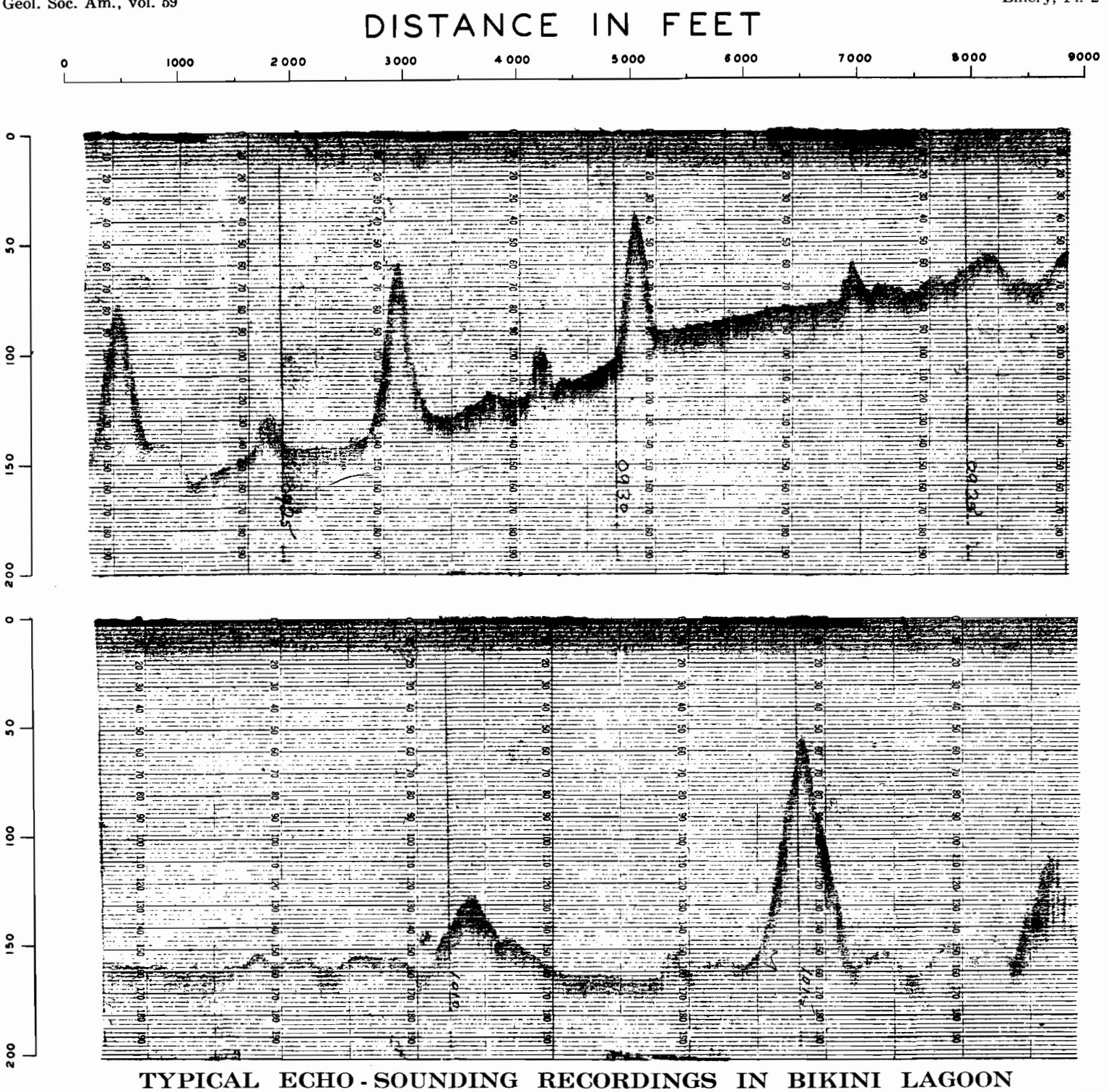
OUTER SLOPES

Bikini is one of several atolls at the north end of the Marshall group. The region is in the trade-wind belt, with winds blowing from the east and northeast. The water current and the swell come from the same general directions. In this part of the ocean most of the sea floor lies at a depth of 2500 to 3000 fathoms, or 15,000 to 18,000 feet. The foundations of the coral reefs rise on long gradually steepening slopes above the general bottom level.

Plate 1 shows a preliminary chart of the outer slopes of Bikini Atoll with a 200-fathom contour interval. Dots indicate the position of the soundings used in drawing the contours; however, all the soundings were taken by a recording echo-sounding device which makes a continuous profile from which soundings can be read at any convenient spacing. About 8000 miles of such sounding records were made on the outer slopes and in the lagoons of the atolls. The slopes shown by the chart are gentle near the base and progressively steeper nearer sea level. Between 0 and 200 fathoms the average slope is 25°. The smoothness of the outer slopes is interrupted by spurs which lie seaward of the major projections and angles of the reef and extend from the surface down to the base of the atoll.

Between the reef projections and within the indentations on the east and north sides of the atoll there is a 10- to 15-fathom terrace. Its outer edge is indicated by a dashed line in Plate 1. On the opposite side of the atoll, the leeward side, the shallow terrace is absent, and in its place a steep, locally vertical, slope borders the reef edge and extends to a depth of about 35 fathoms.

The outer slopes of the other atolls surveyed are generally similar in steepness and in the presence of spurs and shallow terraces. Rongerik, and Ailinginae atolls lie so close to each other that their slopes intersect at a depth of about 1000 fathoms.



TYPICAL ECHO-SOUNDING RECORDINGS IN BIKINI LAGOON

SEAMOUNTS AND DEEP "TERRACES"

One of the most interesting features shown by Plate 1 is a seamount which is tied to the northwest side of Bikini Atoll by a narrow deep neck. The seamount has a minimum depth of 680 fathoms, and its outer edge lies at about 750 fathoms; accordingly, it is extremely flat-topped. The area of the flat top is approximately equal to that of Bikini lagoon. Surveys were also made of several other seamounts which are more isolated. The tops of all the seamounts are flat and lie between depths of 550 and 1100 fathoms.

Deep terracelike structures that closely resemble the seamount tied to Bikini fringe some of the slopes of Eniwetok Atoll at about 750 fathoms. One lies south of the atoll, another northwest of it, but there is no indication of similar structures on the northeast and the southwest sides.

The flatness of the seamounts and the terracelike structures may be the result of past wave erosion, but heavy dredging equipment was not available for checking this possibility. Hess (1946) has described the Eniwetok structures and similar flat-topped seamounts and has termed them guyots.

LAGOONS

BIKINI

In contrast to the outer slopes, the lagoons of the atolls are very complicated and have far more detail than can be shown on small-scale charts. A chart of Bikini lagoon based only on Japanese lead-line soundings shows that the lagoon is a broad saucer having a 10-fathom terrace near the reef separated by a fairly steep slope from the middle deeper area. Numerous coral patches, or coral knolls, are present, and many of them rise to within a few fathoms of the surface. Much finer detail will be available when all the expedition's soundings have been plotted. Preliminary plotting of part of the soundings shows that a large depression in the 10-fathom terrace extends about 8 fathoms below the general level of the terrace.

The soundings reveal many coral knolls, and they appear to be slightly more abundant near the slope between the terrace and deeper part of the lagoon. Two typical lagoon profiles drawn by a recording echo sounder are shown in Plate 2. One of the profiles was made at right angles to the slope from the 10-fathom terrace to the deeper water of the lagoon, and the other is typical of the deep lagoon area. Both profiles show that the coral knolls rise abruptly from an otherwise fairly smooth floor. Several coral knolls were surveyed in detail with lead lines or were studied in diving operation. Some are very steep, nearly vertical, while others consist mostly of dead and loose coral fragments which form a kind of talus slope of about 45°. During the echo-sounding work it was discovered that the sounding records made over hard sandy bottom were much denser and narrower than those over the soft algal debris near the center of the lagoon; therefore, some interpretation of bottom composition can be made from the acoustic properties of the bottom.

ENIWETOK

The lagoon at Eniwetok Atoll has the same kind of topography as Bikini lagoon. About 200,000 soundings from recording echo-sounding tapes were plotted in pre-

liminary form by the Navy prior to the expedition. These soundings served as a basis for the contour chart of Plate 3. About 2300 coral knolls are shown within the lagoon, giving it an irregularity which departs markedly from some of the conventional ideas of billiard table flatness of coral lagoon floors. Many of the coral knolls are so steep that the drawing of contours around them was impractical, so these are indicated by hachures.

A 10-fathom terrace borders the lagoon side of the reef along the east, north, and northwest sides of the lagoon. The terrace is widest where the reef bends outward away from the lagoon and narrowest where the reef is indented toward the lagoon. This relationship also exists at Bikini Atoll where, in addition, surveys of the outer slopes showed a shallow terrace seaward of the reef indentations. In the northwest part of the lagoon, where the terrace is widest it contains a depression which extends about 8 fathoms below the terrace surface, like the one at Bikini. The physiographic relationships suggest that the 10-fathom terrace was once a reef surface, upon which the present, younger reef has grown.

A deep channel drains eastward through one of the passes in the reef (Pl. 3). At the point where the channel crosses the reef and the 10-fathom terrace its depth is about the same as the maximum depth of the lagoon. Each atoll has one such channel: Bikini at the southwest, Rongelap at the southeast, and Rongerik at the south side. The channel of each atoll becomes shallower toward the center of the lagoon; the channels may have originated as outlets of lakes left by a glacially lowered sea level.

BOTTOM MATERIALS

There are several types of sediments or bottom materials in the submarine portions of the atolls. The collection of about 2500 bottom samples permits the making of fairly detailed sediment-distribution charts, both inside the lagoons and around the atolls. Nearest shore in Bikini lagoon is a coarse foraminiferal sand, a continuation of the beach sand. This grades lagoonward into a narrow zone of fine sand. At about 20 fathoms the sand gives way to *Halimeda* debris which covers most of the lagoon floor. *Halimeda*, a kind of calcareous alga, appears to be the main contributor to the sediments of the atolls. When alive, it is a string of oval, flat, green segments which break apart and bleach to white when the plant dies (Pl. 4, fig. 1). Branching corals are present in many samples, but the chief areas of coral growth are the coral knolls.

During the course of the work about 700 underwater photographs were taken, mostly in the lagoons. They show that *Halimeda* in depths of about 30 fathoms is a thin carpet of living plants over an unknown thickness of white loose *Halimeda* debris. Nearer shore, various algal and coral fragments lie on a sandy floor (Pl. 4 fig. 2). Corals found on the shallow reef and the shallow tops of coral knolls are mostly fairly massive or bracketlike (Pl. 5, fig. 1). At 10 or 15 fathoms, however a branching form dominates (Pl. 5, fig. 2).

The sediments of the outer slopes of the atolls appear to be somewhat simpler in their distribution. Beyond the reef edge, the bottom deepens very steeply, especi-

05′ 10′ 162°15′ 20′ 25′

40′ 35′ 30′ 25′ 20′

11°

BOGON I.
BOGAIRIK I.
LIDILBUT I.
ELUGELAB I.
EYBBIYAE I.
BOGOMBOGO I.
BOGALLUA I.
ENGEBI I.
MUJINKARIKKU I.
BIILEE I.
BOKONARAPPU I.
YEIRI I.
AITSU I.
PUJIYORU I.
EBERIRU I.
ARANIT I.
BIIJIRI I.
ROJOA I.
ARAMBIRU I.
PIIRAAI I.
RUNIT I.
CHINIEERO I.
JAPTAN I.
CHINIMI I.
BOGEN I.
MUTI I.
PARRY I.
ENIWETOK I.
WEST SPIT
RIGILI I.
GRINEM I.
LIBIRON I.
BOGAN I.
BUGANEGAN I.
IGURIN I.

SMALL STEEP CORAL KNOLLS
DEPTH TO TOP OF CORAL KNOLL IN FATHOMS
OUTER EDGE OF REEF
INNER EDGE OF REEF
SAND

ENIWETOK ATOLL - LAGOON

1 0 1 2 3 4 5
STATUTE MILES
CONTOUR INTERVAL - 4 FATHOMS
1948

DEPTH ZONES - IN FATHOMS
32 28 24 20 16 12 8 4 0 REEF LAND

BASED ON BOAT SHEETS CONTAINING 180,000 SOUNDINGS
BY U.S.S. BOWDITCH - 1944

ENIWETOK ATOLL-CONTOURED CHART OF LAGOON

ally on the leeward side of the atoll. Probably the chief constituents of the steep shallow slope are corals and *Lithothamnion*. Beyond the steepest portion, corals were found to depths of only about 35 fathoms. *Lithothamnion* was found only in the same shallow depths. Between 20 and 200 fathoms, *Halimeda* debris appears to dominate. It grades through coarse sand to fine sand at about 500 fathoms. Half a dozen short core samples from the flat surface of the deep seamount bordering Bikini Atoll consisted only of *Globigerina* sand.

CONCLUSIONS

The charts and the data outlined are preliminary and are based chiefly on field plotting and field estimates. They should not be used for drawing many conclusions until they are verified and supplemented by more detailed studies of the large collections of bottom samples and soundings. Several years will probably be required to complete the study of all the data, but it is believed that the results of the study may throw much light on the various theories of reef origin.

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U. S. Geological Survey, Washington 25, D. C.
Manuscript Received by the Secretary of the Society, September 3, 1947
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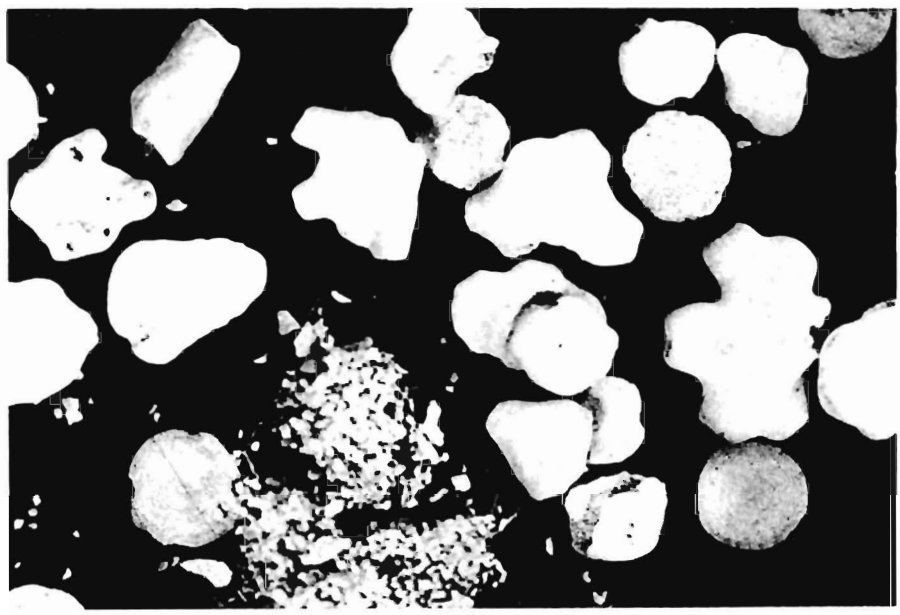

FIGURE 1. *Halimeda* DEBRIS
Microphotograph shows loose segments of *Halimeda* with associated Foraminifera and fine-grained sediment.

FIGURE 2. SAND WITH SCATTERED CORALS AND ALGAE
Underwater photograph (No. 77) in 9 fathoms. Camera is inclined 45°. Length of bottom edge is about 6 feet.

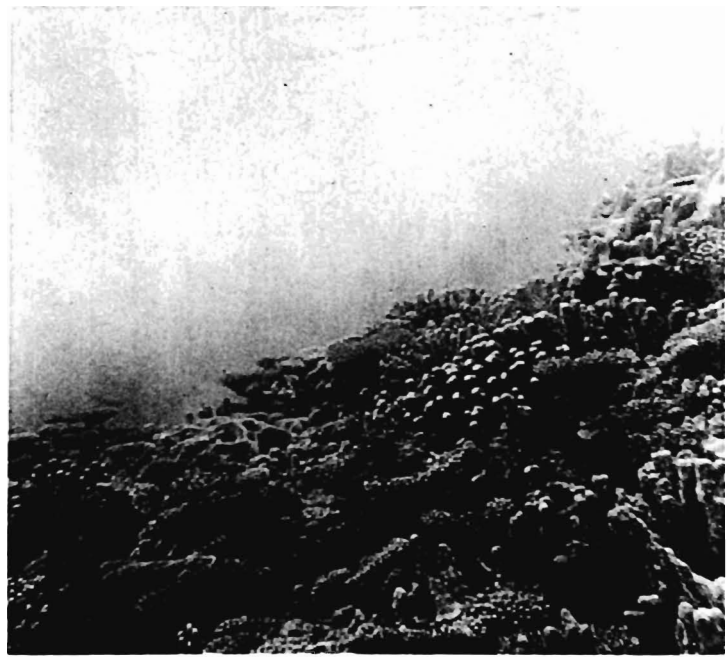

FIGURE 1. CORAL KNOLL
Underwater photograph (No. 585) in 10 fathoms. Camera is horizontal. Length of bottom edge is about 5 feet.

FIGURE 2. BRANCHING CORAL
Underwater photograph (No. 88) in 10 fathoms. Note the school of fish above the coral. Length of bottom edge is about 4 feet.

CORALS OF BIKINI LAGOON

Geological Society of America Bulletin

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Geological Society of America Bulletin 1948;59, no. 9;855-860
doi: 10.1130/0016-7606(1948)59[855:SGOBA]2.0.CO;2