RESEARCH REPORT
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SUMMARY OF THE BATHYSCAPH TRIESTE RESEARCH PROGRAM RESULTS (1958-1960)

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THE PROBLEM

Conduct environmental studies at great depths in the ocean using the bathyscaph TRIESTE as a research vehicle. Also, modify and improve the bathyscaph for research purposes.

RESULTS

1. The dive series of Project NEKTON I proved the practicability of manned vehicle descents for research purposes to the deepest known depths in the ocean. The satisfactory operation of the various vehicular components and the scientific instrumentation under conditions of deep submergence and exposure to high hydrostatic pressure demonstrated the validity of the design principles that have been incorporated in the TRIESTE.

2. The scientific observations and measurements made during Projects NEKTON I and II yielded valuable new data on sound velocity; temperature and salinity structure; water clarity; bioluminescence; the distribution of suspended particles and plankton; water current at great depths; sea floor features; and the general environmental conditions in the deep Marianas Trench. For example, bathyscaph scientists have:

a. Found that, in general, measured values of sound velocity at great depths were less than those computed. Sound speed at a depth of 5760 meters on Dive 76 south of the Marianas Trench was about 1555 meters per second.

b. Determined the presence of intermittent currents on the deep sea floor, a phenomenon which present physical oceanographic theory has not explained.

c. Proved that particulate matter exists to some degree to all depths in the oceans.

d. Established that, with proper lighting, water conditions in the deep oceans permit visual observations to distances of up to 60 feet. (This opens up a huge and potentially most important new field for in situ observations--visual oceanography.)

e. Discovered such previously unknown facts about the Marianas Trench as that it has a wide flat floor; that currents are not active in it (at least not continuously); that it has little benthic animal activity. Also, determined the nature of sediments in the trench.

f. Proved the ability of high forms of life to exist at the greatest ocean depths.

g. Obtained data on the distribution of bioluminescence throughout the water column. At depths of over 2100 meters, bioluminescence appears as single or small groups of flashes; upon ascending to 700 meters the number of flashes increases rapidly (as much as 1000 times); at shallower depths bioluminescence remains high until "washed out" by daylight penetration.

h. Discovered that the submarine part of Guam is a thin coral cap on a massive volcanic structure having only a scattered veneer of sediments; discovered also that the island arc-trench structure of which Guam is a part has not subsided to any great extent.

i. Found that the value of acceleration of gravity g was 978.9331 cm/sec^2 on the bottom at 2286 meters depth, in comparison with 978.5376 cm/sec^2 at the surface.

RECOMMENDATIONS

Provide for increasing the knowledge available to the U. S. of the deep-sea environment. Specifically:

1. Continue and extend deep-sea research with the bathyscaph TRIESTE so as to take full advantage of the unique and proven capabilities of this vessel. Also, modify the TRIESTE to make it even more valuable for scientific work than at present.

2. Establish an enlarged scientific program, involving underwater acoustics and all oceanographic disciplines, for making observations and measurements vertically through water columns and in very deep water.

3. Develop improved acoustic and oceanographic instrumentation for use on the TRIESTE and on future deep submersibles.

4. Develop a deep submersible research craft more versatile than the TRIESTE.

5. Evaluate the usefulness of deep submersibles as

platforms for acoustic detection equipment and naval ordnance.

ADMINISTRATIVE INFORMATION

The work described was performed under S-R004 03 01, Task 0528 (NEL L4-2) from December 1958 to July 1960. The report was approved for publication 2 April 1962.

Special acknowledgement is due the team members who participated in the arduous NEKTON I and II projects. They were responsible for the success of an historical event.

The author also wishes to thank Dr. G. H. Curl, LT Don Walsh, USN, and LT L. A. Shumaker, USN, for their critical review of this manuscript.

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INTRODUCTION

Following the purchase of the bathyscaph TRIESTE by the Office of Naval Research in the spring of 1958, the vehicle was transported to the U. S. Navy Electronics Laboratory, San Diego, California. Reassembly of the craft was accomplished at the Naval Repair Facility, San Diego, by early October 1958.

The first dive of the TRIESTE in the Pacific was made on 20 December 1958 off Point Loma, San Diego. The diving schedule was then interrupted by a modification program which included the acquisition of a new sphere designed to permit safe dives to 36, 000 feet. All dives made in the spring (Nos. 51-56) and fall (Nos. 57-58) of 1959 were performed to test and evaluate the modified float, hardware, and equipment to be utilized in the Marianas Trench dives.

Project NEKTON I, a series of dives in the vicinity of Guam, began in 1959 and continued into early 1960. This series yielded three new depth records for a manned vehicle--a technological breakthrough of significant importance--plus the acquisition of valuable environmental data.

Project NEKTON II dives, which were also conducted in the Guam area, took place during June and July 1960. These tests were concerned with:

1. Precise determination of the velocity of sound throughout the maximum water column.

2. Determination of the temperature and salinity structure of the water column.

3. Water-current measurements.

4. Light penetration, water clarity, and bioluminescent measurements.

5. Observations of the distribution of organisms in the water column and on the sea floor.

6. Marine geological study of the trench environment.

7. Engineering tests of equipment at great depths.

Subsequent to the dives of NEKTON II in July 1960, the TRIESTE underwent an extensive period of modification, refitting, and rebuilding in preparation for further research studies.

SUMMARY OF DIVES MADE BY BATHYSCAPH TRIESTE (1958-1960)

DIVE NO. & DATE	LOCATION	LATITUDE	LONGITUDE	DEPTH WATER (ft)	DEPTH DIVE (ft) (m.)	DURATION	PILOT	OBSERVER	PURPOSE
49 12/17/58	San Diego Harbor	32°41.8'N	117°14.0'W	70	70 21 m.		Piccard	Rechnitzer	Test dive
50 12/20/58	Loma Sea Valley off San Diego	32°39.5'N	117°23.0'W	860	860 262 m.		Piccard	Light**	Demonstration photography
51 5/12/59	San Diego Harbor	32°41.8'N	117°14.0'W	50	50 15 m.		Piccard	Walsh	Test dive
52 5/19/59	Loma Sea Valley	32°40.2'N	117°23.1'W	720	720 219 m.	Down 1309 Up 1613	Piccard	Rechnitzer	Biological observations
53 5/22/59	San Diego Trough	32°37.6'N* 32°37.2N	117°29.7'W* 117°29.5'W	4100	4100 1250 m.	Down 1330 Up 1644	Piccard	Walsh	Technical
54 5/28/59	San Diego Harbor	32°41.8'N	117°14.0'W	60	60 18 m.		Piccard	Mackenzie	Test dive for underwater sound experiments
55 5/29/59	San Diego Trough	32°33.2'N* 32°33.0'N	117°27.0'W* 117°26.5'W	3970	3970 1210 m.	Down 1344 Up 1738	Piccard	Mackenzie	Underwater sound experiments
56 6/5/59	Loma Sea Valley	32°37.6'N* 32°37.5'N	117°22.2'W* 117°21.8'W	770	770 235 m.	Down 1318 Up 1445	Piccard	Rechnitzer	Test dive and biological observations
57 9/11/59	San Diego Harbor	32°41.8'N	117°14.0'W	62	62 19 m.		Piccard	Shumaker	Test dive after installing new sphere
58 9/15/59	Loma Sea Valley	32°40.2'N	117°23.1'W	590	590 180 m.		Piccard	Rechnitzer	Biological observations
59 11/4/59	Apra Harbor, Guam	13°27.5'N	144°39.0'E	70	70 21 m.		Piccard	Shumaker	Test dive
60 11/10/59	West of Guam	13°29.5'N* 13°29.1'N	144°38.2'E* 144°38.3'E	4900	4900 1490 m.	Down 1109 Up 1537	Piccard	Rechnitzer	Test dive and oceanographic observation
61 11/15/59	Southeast of Guam	12°52.8'N* 12°52.0'N	145°10.2'E* 145°10.0'E	18,150	18,150 5530 m.	Down 1015 Up 1550	Piccard	Rechnitzer	Test dive and oceanographic observation
62 12/14/59	Apra Harbor, Guam	13°27.5'N	144°39.0'E	65	65		Piccard	J. Cawley	Test dive
63 12/18/59	West of Guam	13°30.1'N* 13°30.0'N	144°37.1'E* 144°36.5'E	About 5900	5850 1780 m.	Down 1045 Up 1335	Piccard	Walsh	Test dive and pilot training

64 12/29/59	Apra Harbor, Guam	13°27.5'N	144°39'E	100	100 30 m.	Down 0925 Up 1037	Walsh	Jensen	Test dive and pilot training
65 12/29/59	Apra Harbor, Guam	13°27.5'N	144°39'E	100	100 30 m.	Down 1138 Up 1205	Shumaker	DeGood	Test dive and pilot training
66 12/29/59	Apra Harbor, Guam	13°27.5'N	144°39'E	100	100 30 m.	Down 1315 Up 1345	Walsh	Rechnitzer	Test dive and pilot training
67 12/30/59	Apra Harbor, Guam	13°27.5'N	144°39'E	100	100 30 m.	Down 0905 Up 1001	Walsh	Michel	Test dive and pilot training
68 12/30/59	Apra Harbor, Guam	13°27.5'N	144°39'E	100	100 30 m.	Down 1057 Up 1130	Shumaker	Rechnitzer	Test dive and pilot training
69 1/8/60	Marianas Trench	12°40.0'N* 12°40.1'N	145°21.5'E* 145°20.5'E	22,560	22,540 6870 m.	Down 0954 Up 1522	Piccard	Walsh	Test dive and pilot training
70 1/23/60	Challenger Deep	11°18.5'N* 11°19.0'N	142°15.5'E* 142°12.0'E	35,800	35,800 10,900 m.	Down 0822 Up 1658	Piccard	Walsh	Record dive
71 6/15/60	Apra Harbor, Guam	13°27.5'N	144°39'E	102	102 31 m.	Down 1430 Up 1501	Walsh	LCDR Winkler, ONR Code 466	Test dive and pilot training
72 6/15/60	Apra Harbor, Guam	13°27.5'N	144°39'E	100	95 29 m.	Down 1630	Shumaker	LCDR Kennedy ONR Code 466	Test dive and pilot training
73 6/21/60	West of Guam	13°30.7'N* 13°30.4'N	144°37.0'E* 144°37.0'E	5000	1070 326 m.	Down 1030 Up 1300	Walsh	Rechnitzer	Shallow sound velocity measurements
74 6/21/60	West of Guam	13°30.3'N* 13°30.0'N	144°36.4'E* 144°36.2E	5000	1455 443 m.	Down 1428 Up 1536	Shumaker	Kennedy	Test dive and indoctrination
75 6/25/60	East of Guam	13°26'N	145°31'E	8530	8530 2600 m.	Down 1239 Up 1713	Walsh	Rechnitzer	Sound velocity measurements
76 7/1/60	South of Marianas Trench	12°44.5'N	144°53.5'E	18,900	18,900 5760 m.	Down 0817 Up 1538	Shumaker	Rechnitzer	Sound velocity measurements
77 7/6/60	West of Guam	13°28.2'N* 13°26.8'N	144°24.5'E* 144°32.0'E	6840	1140 347 m.	Down 1145 Up 1625	Shumaker	Rechnitzer	Shallow sound velocity measurements
78 7/9/60	West of Guam	13°27.0'N* 13°26.6'N	144°32.1'E* 144°32.1'E	7500	7500 2286 m.	Down 1003 Up 1704	Walsh	Rechnitzer	Sound velocity and gravity measurements

*Locations of submersion and surfacing are both given wherever they differ appreciably.
**Mr. John Light of NBC News was aboard at the request of the Chief of Naval Information. With the exception of this dive, Navy Department personnel have been the sole users of the craft.

SEA FLOOR STUDIES

Water Currents on the Sea Floor

Water current measurements on the sea floor have been made by direct observation from the bathyscaph TRIESTE. Electromechanical devices were not used to sense horizontal current and direction during the period of this report. However, rather accurate measurements of low velocities can be easily made using the bathyscaph. Suspended particles illuminated by the strong external light source of the bathyscaph can be readily seen by the strong Tyndall effect. When the craft is oriented at right angles to the prevailing current, these suspended particles serve as reference points that drift along with the current. A simple determination of velocity is made by measuring the time required for the particles to traverse a 10-cm path, the internal diameter of the window. Current velocities below 10 cm per second are easily measured.

Observations off San Diego at depths of 700 to 1000 feet revealed conditions to be highly variable from dive to dive. On Dive No. 52, current velocity was found to be between 3.3 cm per second and 5 cm per second (0.06 and 0.1 knot respectively). On Dive No. 56 at approximately the same location, the current was estimated from motion-picture records to be approximately 0.5 knot. This relatively high-speed current had produced 6- to 8-inch scour holes around scrap-iron tubing 4 inches in diameter that was resting on the sea floor. At this time, the bathyscaph rolled gently from side to side while resting on the sea floor, a characteristic never experienced before. Sea pens, 8 to 10 inches long, that normally stand erect were bent over to within 3 inches of the bottom. There was also an indication of ripple-mark formation and suspended particles were flowing rapidly past. The water mass above the sea floor was turbid from the suspended sediment, and visibility was limited to 25 to 30 feet. Hermit crabs in shells 0.5 to 0.75 inch in size were tumbled along the bottom, unable to gain footing for more than an instant. The swimming actions of sablefish were recorded as the animal swam "upstream." During this dive, the operator took advantage of the water currents to carry the bathyscaph across the sea floor.

K. V. Mackenzie (personal communication) observed similar current velocities in the San Diego Trough (Dive

No. 55) at 4200 feet (estimated 0.5 knot). However, notes by LT Don Walsh reveal variability in current velocity at this location also. He reported no current on Dive No. 53 and stressed the observation by stating that a 15-minute wait was required to allow the sediment to settle following the bathyscaph landing.

On the deeper dives in the vicinity of Guam, water currents were found to be less than 1 cm per second (Dive Nos. 61, 70, 75, and 76). At approximately 7000 feet, at locations west of Guam (Dives Nos. 76 and 77) water current appeared to be variable in direction and velocity. However, Dive No. 77 revealed the sea floor sediment to be formed into distinct ripples with a crest-to-crest distance of 18 inches and a vertical amplitude of 0.5 to 1.5 inches. Illumination was not adequate during these two dives to acquire a good measure of water current velocity.

Below 18,000 feet, water current velocities were virtually nil. The bathyscaph did not reach the sea floor on Dive No. 69 when it descended to 22,540 feet, so there was no chance to make a current observation. At 35,800 feet on Dive No. 70, sediment forced into suspension by the landing remained as a dense cloud for the duration of the stay.

Geology and Biology of the Sea Floor

Ocean dives to the sea floor in the San Diego area were all made either in the Loma Sea Valley or in the San Diego Trough (fig. 1). In the interest of safety, such dives were limited to the relatively level and obstruction-free basins of these areas. The majority of dives were made to permit U. S. personnel to become acquainted with the operational techniques involved and to survey the environmental conditions present in these areas, particularly those that could be expected to influence the safe movements of the TRIESTE while submerged.

In both areas, the sedimentary overburden is predominantly olive-green clay-silt. Observations of the Loma Sea Valley, as recorded for Dive 52, are typical for both the Loma Sea Valley and the San Diego Trough, except for the biological constituents occupying each ecological environment. The soft sediment was found to be heavily

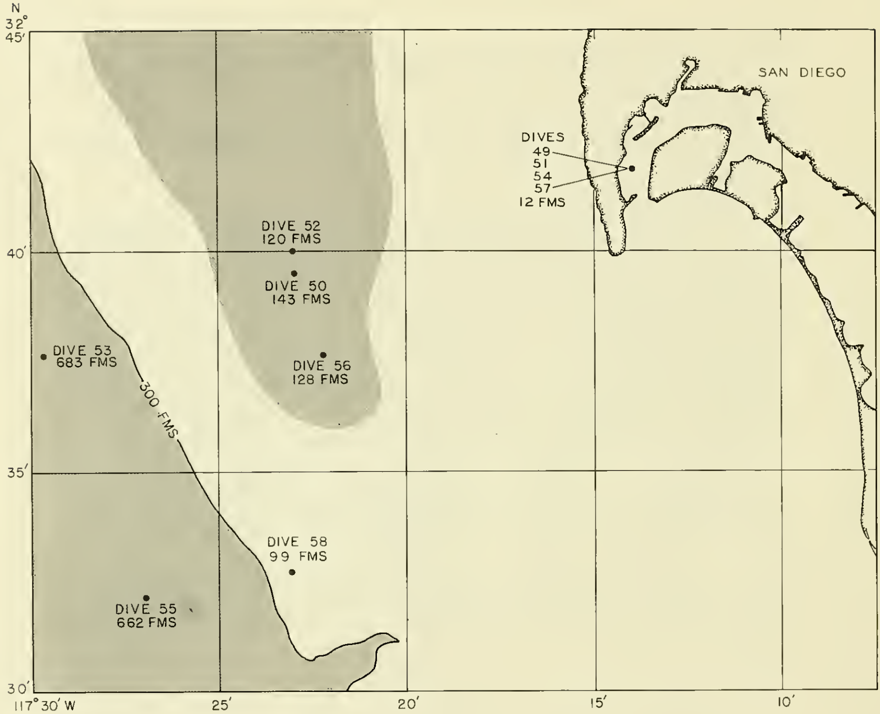

Figure 1. Location of dives made off San Diego. Dots indicate descents. Depths are indicated in fathoms.

populated with burrowing worms of several types. Surface-dwelling organisms were represented by several invertebrate phyla and fishes. All of these influence sedimentation processes through their feeding and burrowing or locomotion. A myriad of invertebrate forms were also observed to occupy the water mass immediately above the sea floor. Certain fishes appeared to be restricted to an area about 15 to 25 feet above the bottom.

Microtopographic features such as volcano-shaped mounds, funnel-shaped depressions with a terminal hole, burrow trails, mold depressions, and sculpturing attest to the presence or recent presence of animals. Shell fragments of deceased mollusks were found strewn about the sea floor. Artifacts of man, such as discarded metal, paper, glass containers, and other materials have also been viewed on the sea floor.

DIVE NO. 52

Approaching the bottom at 720 feet, the sea floor was first seen at a range of approximately 25 feet. Heavy concentrations of suspended material and living forms restricted visibility to approximately this range. On landing, a small cloud of sediment was forced into suspension by the water displaced around the descending sphere. The cloud was quickly dispersed and carried out of the viewing area by the water current present. A check of the time required for suspended particles to drift across the 10-cm diameter of the inner frustule indicated a water current flow of 5 cm/sec. During the time the bathyscaph was fixed on the sea floor, the suspended matter was seen to include not only inanimate particles but a myriad of biological forms that included medusae, arrow-worms, ctenophores and mysids.

Microtopographic relief such as sculpturing, furrow trails, mounds, and depressions appeared at a minimum despite the wide variety of living forms present. However, as the bathyscaph moved across the sea floor, a changing panorama of microrelief was observed that included such features in varying degree and quantity. The largest feature seen was a depression 6 feet across and 2 feet deep. The channel (?) extended beyond the visual range made possible by the external illumination. It was not bordered by levees despite the rather steep slope bordering each side of the long depression. Sediment appeared to be at a maximum angle of repose. However, the condition of the slope indicated a prolonged period of exposure to the velocity of currents present and sedimentation of particles on the sea channel slopes.

Artifacts of man observed included two tin cans, an old shoe, and a sheet of newspaper. These artifacts all rested on the surface of the sea floor. Settling into the sediments appeared to be at a minimum. No scouring about the artifacts had been effected by the water current flow present.

DIVE NO. 53

The sea floor at 4100 feet (the San Diego Trough) appears to be a grey-green clay-silt. Microtopographic relief features are predominantly the result of biological burrowings and digging activities. Small holes, small cones of discharged sediments, brittle stars, fish trails and sculpturing of the upper 0.25 inch of sediments predominate throughout the area (fig. 2 and 3).

Upon landing, a small amount of material was brought into suspension. The bearing strength of the sea floor was adequate to sustain the weight of the bathyscaph. Suspended sediment was carried rapidly out of the viewing area by the water current. Water current velocity was estimated to be less than 0.75 knot. Living forms in the water immediately above the sea floor were abundant and apparently involved a myriad of invertebrate forms. During a horizontal traverse over the bottom using the bathyscaph propulsion system, a half-pint milk carton, numerous brittle starfish, and several sea cucumbers were observed.

Ocean dives to the sea floor in the vicinity of Guam were made in the basin west of Apra Harbor and in the Marianas Trench east and southwest of Guam (fig. 4). In contrast to the Mediterranean dive locations and those off San Diego, the sea floor off Guam was observed to be predominantly exposed bedrock with only a thin layer of sediment.

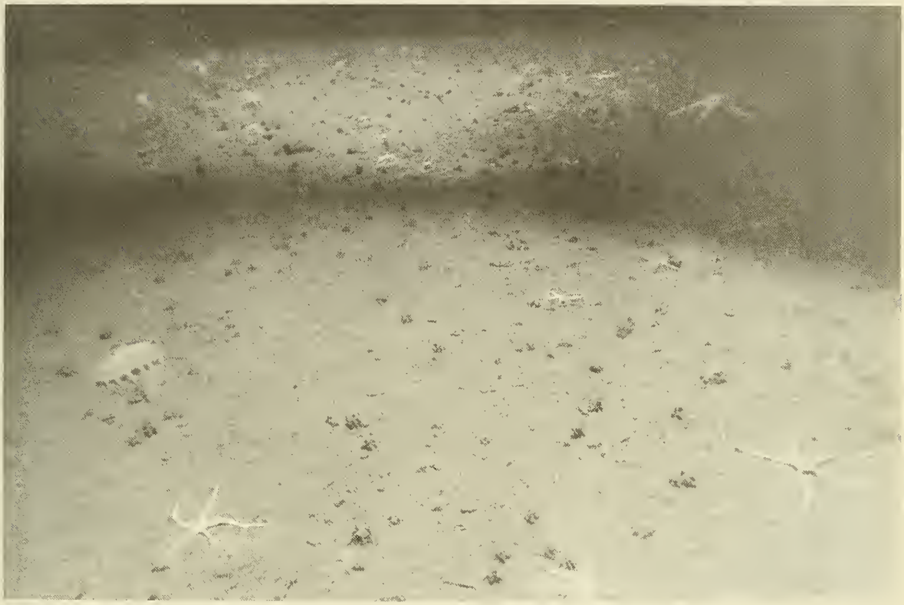

Figure 2. A common inhabitant of the San Diego Trough at 4100 feet is the brittle starfish, probably Ophiomsium lymani or Ophiotrix sp. Many such starfish were observed to be buried with only the tips of their arms protruding from the sediments. These are believed to be a species other than those observed on the surface. An unidentified lavender sea cucumber (Holothurian) with well-developed pseudopods moves slowly across the green sediment. Numerous worm tubes are terminated by a palmate-form exposed end (probably achaetopteran). They extend up from the sediments and appear as dark clumps throughout the figure. A puff of sediment is being extruded from a mound in the far background. Numerous lavender and white heads of nontube dwelling worms were also observed but are not recorded by the film. The large starfish, upper right, is the only one seen at this location.

Figure 3. A sablefish, *Anoplopoma fimbria*, rests on the sea floor (4100 feet) within the area illuminated by the mercury-vapor lamp. Brittle starfish and chaetopteran worm tubes are abundant. An unidentified shrimp, lower left, moved slowly out of the illuminated area while the bathyscaph remained in a fixed position. The carcass of the pelagic crab, *Pleuroncodes planipes*, appears only as a diffuse whitish mass above the two small brittle starfish, lower right. At one time five sablefish appeared in the illuminated areas.

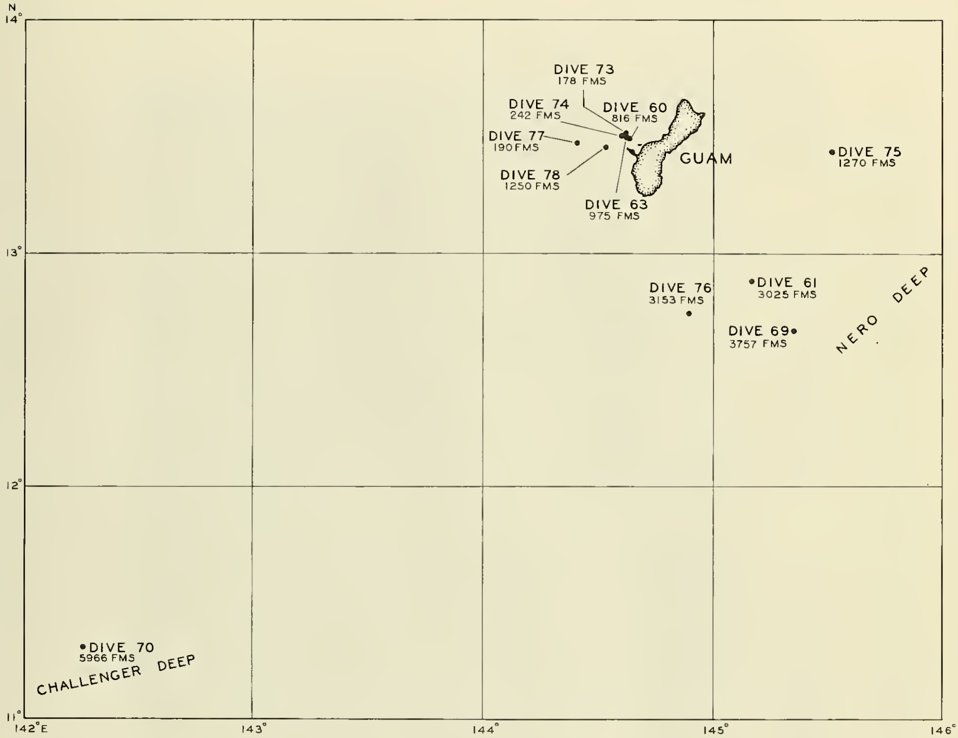

Figure 4. Location of dive descents off Guam and in the Marianas Trench between the Nero Deep and the Challenger Deep. Dots indicate descent. Depth is indicated in fathoms.

DIVE NO. 60

The sea floor at 4900 feet on the steep slope just west of Apra Harbor, Guam, was a unique area for bathyscaph operations because of water currents and the magnitude of the rugged outcrops. Outcrops were identified as the predominantly exposed bedrock of a regular size and form. Interspersed among the outcrops was an off-white sediment.

A conspicuous feature was the ubiquitous distribution of unidentified "black pebbles" that were strewn about the sea floor (fig. 5): The mantle of sediment overburden appeared to be thin and subject to transfer by water current. Although not clearly defined, the sediment appeared to be banked against the north (?) slope of the rock piles (fig. 6). The exposed bedrock varied from eroded and partially dissolved masses of bedrock (fig. 7) to relatively unaltered materials, possibly of igneous origin. Although the sediment yielded all appearances of being skeletal remains of deceased animals, it is possible that a portion of it was from terrigenous sources, particularly the coral fringing reef of Guam.

Although landing conditions were obviously hazardous, a bottoming was accomplished among significant rock outcrops (fig. 6). Sediment brought into suspension by the landing rapidly settled to the sea floor or was carried out of the viewing area. The bearing strength of the sea floor was adequate to sustain the weight of the bathyscaph well above the bottom. The penetration of the sphere was estimated to be no more than 3 inches. A rock outcrop 4 or 5 feet high of varied form was seen through the observation window (fig. 6). The outcrop material appeared to be pillow lava covered with a thin layer of recently deposited sediments. The crustal bedrock (of igneous origin?) had undergone some chemical and physical erosion (fig. 7). As the bathyscaph drifted across the sea floor, photographs were taken using the external 35-mm camera and electronic strobe light.

Biological activity was at a minimum. However, three eels about 3 feet long were observed swimming 4 or 5 feet above the rocky outcrops. They showed little response to the high-intensity lamp illuminating the area. During the bathyscaph cruise across the sea floor, scouring was noted to be minimal. A few depressions and the perimeter of 0.5-inch holes were obviously of biological origin, but their occupants were not observed. A single, living "whip coral" was noted to be attached to an exposed sheet of bedrock (fig. 8).

Figure 5. The scattered distribution of "black pebbles" was common at 4900 feet. The pebbles are not ballast from the TRIESTE. Diameter of the particles ranged between $\frac{1}{4}$ inch and $\frac{3}{4}$ inch. Dive No. 60.

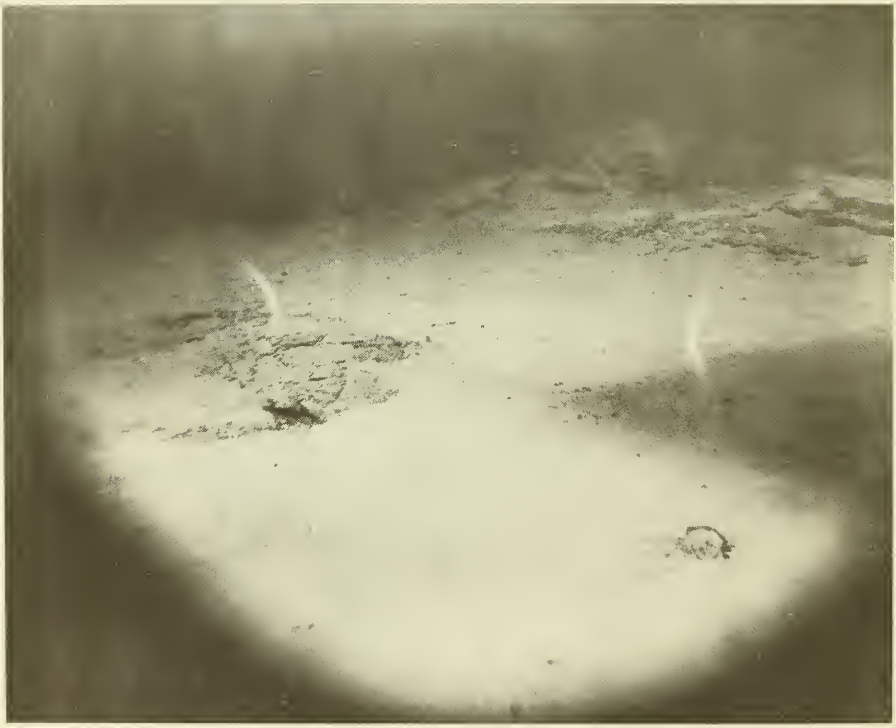

Figure 6. Approximately 50 per cent of the bedrock at 4900 feet was exposed. Pillow lava appears to be covered with a thin mantle of off-white sediment that includes a ubiquitous distribution of black pebbles. Crustal bedrock that has undergone erosion appears in the right background. Maximum microrelief of rock pile in background was about 4 feet. Water current was observed to be toward the background. However, no ripple marks or scouring are evident. The two white crescents to the left and right of photograph center are photoprocessing faults. Dive No. 60.

Figure 7. The sea floor at 4900 feet on the west slope of Guam was approximately 50 per cent exposed basement rock with a thin mantle of sediment. The bedrock was finely sculptured by erosion and dissolution of the softer portions. A partially disintegrated palm frond (?) appears in the lower third of the figure. Dive No. 60. (35-mm electronic flash photograph)

Figure 8. A living single ship coral is found attached to an unidentified substrate that is either an eroded piece of sheet steel or exposed crustal bedrock. Sprinkled about on the surface of the off-white sediment are small black pebbles. At the lower center a heavy concentration of the pebbles surrounds a depression of biological origin. Dive No. 60.

DIVE NO. 61

Man's first direct viewing of the sea floor at 18,150 feet was achieved on this dive, which brought the manned deep-diving record back to the U. S. Upon landing, the bottom was noted to be uniformly level, but pock-marked with numerous white circular areas on a tawny substrate (fig. 9). Closer examination revealed that biological activity was responsible for these marks. The lighter subsurface sediment had obviously been brought to the surface by burrowing animals. The sediment had subsequently spread circumferentially about the penetration without creating a mound. The bearing strength of the sea floor was adequate to sustain the weight of the bathyscaph satisfactorily. Maximum penetration was estimated to be no more than 3 inches.

Figure 9 illustrates the numerous particles that were present in the water immediately above the bottom. Biological entities and suspended particles above the sea floor were conspicuous and a definite turbid condition existed. The brownish tinge of the sea floor was thought to be caused by the settling of the inanimate materials and organic substances present in the water mass directly above the bottom.

The sea floor downgrade slope was evident and estimated to be about 1 degree. Upon leaving the sea floor, the observers noted a vertical drop of 4 to 5 feet that interrupted the gentle slope to form a "berm" running perpendicular to the downslope gradient. Beyond this drop, the sea floor appeared to have approximately the same depression angle. The upper discontinuity of the break in the slope clearly revealed an exposed rock outcrop. Maximum exposure of rock was 6 inches.

Evidence of ripple marks or scouring formations was absent. The funnel-shaped depressions and/or volcano-shaped mounds found at shallower depths and at all locations where bathyscaph operations had been previously conducted were absent. Water current was negligible and apparently had been in recent time insufficient to produce ripple marks or contribute significantly to the alteration of the microrelief. A few pebbles, about 0.5 inch in diameter, similar to those seen at 4900 feet, were scattered irregularly throughout the area.

Upon leaving the bottom, it was possible to see that the sphere had been supported during the bottoming by a ridge of exposed rock 8 to 10 feet long.

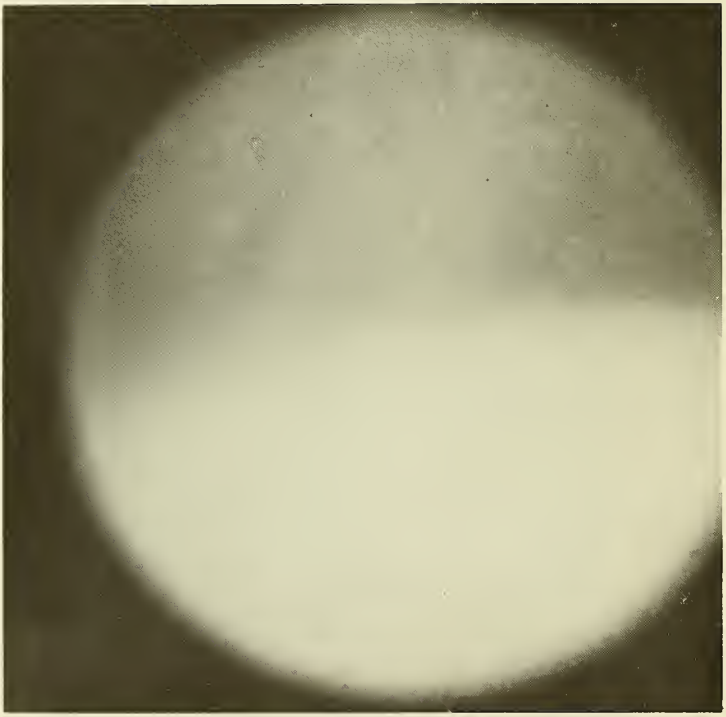

Figure 9. The sea floor at 18,150 feet reveals evidence of biological activity, such as the whitish sediment brought to the surface by burrowing animals. The "pock-marked" light-brown sea floor was noted to slope downward slightly to the left. The heavy concentration of suspended matter near the bottom can be noted in the figure. Dive No. 61.

DIVE NO. 69

Upon approaching the bottom, the fathometer readings were questionable and, in an attempt to make a "soft landing," too much shot was dumped. Consequently the sea floor at 22,540 feet was sighted only briefly. The dive yielded a new depth record and a test of the craft and its components.

DIVE NO. 70

The ultimate in depths--the Challenger Deep--was found by explosive echo-ranging to have a flat-surfaced full plane approximately 0.5 mile wide and 3 miles long. The long axis of the plane was parallel to the Marianas Trench axis. The geographical location of its center was determined by Loran sea fixes to be 11°18.5'N latitude, and 142°15.5'E longitude.

Upon landing, sediment was brought into suspension where it remained for the duration of the 20-minute stay. The sea floor was remarkably white and of extremely fine material. It was uniformly flat and there was no evidence of burrowing animals. Water current was virtually nil. Microrelief was observed to be minimal. However, only the area immediately adjacent to the touch-down point was observed.

Near the bottom, a jellyfish approximately 3 inches in diameter was observed pulsating 6 to 8 feet from the sea floor. Just prior to landing on the bottom a red shrimp swam through the cone of light.

At the bottom, Piccard reported observing a flat fish "looking like a sole." Since flat fish are vertebrates and teleosts, this demonstrates the capability of high forms of life to exist at the greatest depths. Apparently a satisfactory amount of oxygen and food replenishment exists even there.

The previous record depths for fish were about 7000 meters, where they have been trawled by both the Danish Galathea Expedition and by the Soviets from the Vityaz. It is known that certain proteins coagulate at pressures considerably less than those of the deep trenches--for example, a sea urchin egg will coagulate. Hence these great depths might have been entirely without higher forms of life for such barochemical reasons.

The TRIESTE depth was determined to be 35, 800 feet following calibration tests of the Bourdon tube-type hydraulic pressure gauges by the Eastern Standards Laboratories, U. S. Naval Weapons Plant, Washington 25, D. C. Additional calculations of the depth attained were made and offered to the author by Dr. John A. Knauss, Scripps Institution of Oceanography, Dr. John Lyman, National Science Foundation, and Dr. Ernest R. Anderson of the Navy Electronics Laboratory. These calculated values varied from 34, 931 to 35, 805 feet depending upon the calibration data used. The "best value" for the depth may be a few hundred feet less than the figure 35, 800 used throughout this report. Further investigation of the temperature corrections to the pressure gauges may resolve the difference.

DIVE NO. 76

Dive No. 76 was made primarily to acquire sound-velocity measurements. The ultimate depth reached for these measurements was 18, 900 feet. The bottom was obviously bedrock covered by only a thin mantle of whitish sediment (fig. 10). The greater portion of the exposed black bedrock was clearly rounded and appeared encrusted, as if by accretion. Some individual small rocks, also rounded and no more than 2 to 3 inches in diameter were strewn about the sediment cover. The sea floor beneath the mantle of sediments appeared to be a solidified material with long ridges of outcroppings. The ridges formed at the boundary where a minor drop in the downslope profile existed.

The bedrock was exposed for long sections at this nominal break in the slope. The slope gradient was estimated to be 2 to 3 degrees. From a viewing vantage point 60 feet from the bottom, a distinct ridge of exposed rock extended for more than 100 feet; it apparently ran parallel to the axis of the trench. Isolated clumps of rocks were for the most part flat, about 1 foot in diameter. They protruded out of the bottom about 3 inches. Smaller fragments, about 0. 25 inch thick and only 2 to 3 inches in diameter were also distributed at random on the sea floor.

A few worm tubes protruded out of the sediment. These tubes were approximately 0. 25 inch in diameter and 2 inches high. Within the thin sediment mantle, several conical hummocks of sediment with a distinct aperture in

Figure 10. Photograph of the sea floor. Dive No. 76.

the center were noted, but there was no evidence of a biological inhabitant.

Upon landing, sediment was elevated into suspension by the displaced water. The majority of the heavy material remained in a suspended state only a matter of seconds and then settled. The remaining material offered an index to the prevailing water current velocity. The current was measured visually to be less than 1 cm per second moving parallel to the ridges of exposed bedrock. The water immediately above the sea floor was clear and virtually devoid of marine life and suspended particles.

A coil of material that had formed a 6-foot double S was noted on the bottom. It was apparently a piece of cable.

Visual observations of the sea floor at this location were comparable to those made at 18,150 feet (Dive No. 61). A definite sea floor slope of about 1 degree with discontinuities involving abrupt breaks in the slope exposing bedrock were present. Bedrock covered with a thin mantle of whitish sediment was noted in both dives. The mantle gave all appearances of being relatively thin. Bearing strength, however, was again adequate to sustain the weight of the bathyscaph and only a modest penetration of the sphere was experienced.

DIVE NO. 75

The sea floor at 8530 feet revealed coarse sediment cover of at least several inches. Here well-developed ripple marks were observed. The average crest-to-crest distance of all the ripple marks was estimated to be 18 inches with an amplitude of 0.75 to 1 inch (from motion picture footage and fig. 11). Water current at that time was 0.7 cm per second. It appeared that the water current flow rate, which was not oscillatory, would be too slow to form such ripple marks, which were continuous and parallel. They showed no signs of cross-rippling and were well formed, as though of recent origin. No thin layer of dark material was present on the surface. Some dark pebble-like particles on the bottom were scattered at random about 2 to 3 inches apart. The particle size was only slightly larger than the ballast (i.e., estimated to be 4 to 5 mm in maximum width).

Figure 11. Photograph of the sea floor, showing bottom ripples.

Sediments brought into suspension were observed to drift rapidly past the bathyscaph port. Water particle movement through the illuminated area was at the rate of 0.7 cm/sec. Water flow was perpendicular to the long axis of the ripple marks. An attempt to obtain sediment samples for correlation of water current velocity and the physical dimensions of the ripples was thwarted by the accidental loss of the sampler. There was no evidence of burrowing or benthic organisms. Some pelagic invertebrates were seen in the water immediately above the sea floor. Suspended inanimate particles were also present, but in such quantities that visibility was not seriously affected.

DIVE NO. 78

While this dive was made about sixty miles from Dive No. 75, the materials making up the sea floor sediments at this location appeared to be the same as in Dive No. 75. However, ripple marks here were definitely crossed and deteriorating. A thin mantle of dark substance had settled on the bottom, occluding the clean white sediment observed on Dive No. 75. The bearing strength of the material was comparable to that of the previous sea-floor sediment encountered. Biological life was limited to one starfish and possibly a few tube-dwelling worms.

An artifact of man that caused great concern was an unexploded 5-inch projectile that was located directly in the circle of light provided by the bow lamp. Ironically, a beer can was leaning against the base of the projectile. Both objects were supported high on the surface of the sea-floor sediment. There was no evidence of scour or settling of these two artifacts (fig. 12). Water current flow here was very slow and seemed to vary in direction. Poor illumination vitiated any attempt to determine the precise velocity of the current.

Figure 12. Photograph of the sea floor, showing bottom ripples and artifacts (projectile and beer can). Dive No. 78.

ACOUSTIC MEASUREMENTS

Sound-Speed Measurements

The primary purpose of the scientific program using the TRIESTE during Project NEKTON II was to obtain sound-speed measurements *in situ*. Table 1 gives some of the data obtained.

TABLE 1. MEASUREMENTS OF SOUND SPEED, TEMPERATURE, AND SALINITY FROM TRIESTE.

Dive Number	Depth (meters)	Latitude (°N)	Temperature (°C)	Salinity (°/oo)	Sound Speed Meter No. 1 (m/sec)	Sound Speed Meter No. 2 (m/sec)
77	105	13.5	26.92	34.79	1540.78	1540.78
77	140	13.5	25.83	35.01	1538.86	1538.87
54	191	32.5	9.06	34.08	1488.7	----
77	330	13.5	13.77	34.47	1507.79	1507.75
76	1180	12.7	4.15	34.67	1485.60	1490.23
55	1209	32.5	3.38	34.53	1480.40	----
75	1302	13.4	3.54	34.50	1485.00	1484.86
75	2504	13.4	1.77	34.69	1498.00	1494.20
75	2598	13.4	1.75	34.66	1499.67	1495.93
75	2598*	13.4	1.72*	34.66	1499.42	1495.64
76	5120	12.7	1.46	34.67	1542.43	----
76	5760	12.7	1.44	34.66	1554.68	----

*30 minutes later.

In general, the measured values of sound speed at great depths were found to be less than those computed. Measurements for depths greater than 8000 meters would be very valuable to obtain or verify the depth dependence of sound speed.

Reference 1 (see list of references at end of report) presents a detailed discussion of sound-speed measurements made from the TRIESTE during NEKTON II. Earlier experiments using the bathyscaph in a similar manner are reported in reference 2.

Sonar Tests

Dives Nos. 61 and 69 furnished opportunities to test the effectiveness of the AN/SQS-4 and the AN/SQR-8 Mod 4 sonars in detecting and following the bathyscaph on its descent and ascent, while maintaining voice communications through the bathyscaph acoustic telephone and two AN/UQC-1B's. Results are omitted because of classification.

GRAVITY MEASUREMENTS

To test the usefulness of the bathyscaph as a platform for obtaining gravity measurements at great ocean depths, K. V. Mackenzie obtained a LaCoste-Romberg Company geodetic gravimeter, model G, to measure the value in situ. This instrument has a range of 6.000 cm/sec^2 with a sensitivity of 1×10^{-5} cm/sec^2.

During Dive No. 78, gravity measurements at mid-water were attempted. However, the vertical stability and control were insufficient to permit a satisfactory reading.

Success was achieved on the sea floor at a depth of 2286 meters. The value of g was found[2] to be 978.9331 cm/sec^2. This compares with a reference value of g at the Ship Repair Facility, Apra Harbor, of 978.5376 cm/sec^2. Although this isolated measurement does not contribute significantly to knowledge of the variations of g with depth, it does show the suitability of a manned deep submersible to serve as a stable platform for such delicate instruments.

VISUAL OBSERVATIONS IN MIDWATERS

Bioluminescence

Beebe[3] (1934) using the bathyscaph and Monod[4] using the French bathyscaph FNRS-3 observed bioluminescence down to the greatest depths reached (1400 meters). Monod found that the bioluminescence was much less near the bottom.

In Project NEKTON I, the bathyscaph descended to the maximum known depth in the ocean (35, 800 feet in the Challenger Deep). During this descent and others made to the bottom at shallower depths, bioluminescence was found to be present at all depths, but was not necessarily continuous from surface to bottom. However, the greatest abundance of bioluminescence was observed between the base of the sunlit zone (the depth near the surface where the intensity of daylight masks out the weak light generated by marine organisms) and 10, 000 feet.

The common pelagic and bathypelagic sources of bioluminescence are found among the protozoans, coelenterates, ctenophores, euphausiids, decapod crustaceans, salps, and fishes. Both intermittent and steady luminescence can be found among these animal groups.

Observations made by lowering bathyphotometers[5] and by direct visual observations reveal that deep-sea faunas predominantly display intermittent flashing. Until the work of Clarke and Backus[6] very little was known about the absolute magnitude of the luminescent flashes of oceanic animals under natural conditions. Relatively few laboratory studies have been conducted on the subject other than those by Nichols[7] (1924) and by Clarke and Backus[6] (1956). In both laboratory and sea conditions, the intensity of a luminescent flash at 50 centimeters was found to be approximately 0. 00005 to 0. 000075 microwatt per cm^2.

An inherent difficulty in the system employed by Clarke and Backus, or in any cable-lowered photometer, is that it is difficult to determine the distance of the luminous source from the photometer. This problem can be partially resolved by having bathyscaph observers conduct direct visual observations along with estimates of the intensity. Intensity of a luminescent flash can be qualitatively estimated using the scale employed by astronomers in describing star brightness, a technique readily adaptable to a scientist using the bathyscaph. Distance to the emanating source can also be approximated.

Clarke[8] has, in view of the above problem, considered the light intensity of a given flash of point source in relation to its possible distance from a sensing instrument. His experiments and deductions reveal, as a best estimate, that the maximum possible sensing range of a photometer is about 10 meters. His calculations and conclusions seem correct, as 10 meters represents the maximum estimated distance that such sources can be seen by the human eye from within the bathyscaph. This assumes equal sensitivity between instrumental sensors and the human eye.

Virtually continuous observations to determine the presence of bioluminescence throughout the large water column have been made during ascents of the TRIESTE (Dives Nos. 61, 76, 77, 78). Results are shown in table 2. It appears that bioluminescent flashes are normal at great depths and do not necessarily require tactile stimulation by a source such as the moving bathyscaph. Although Dietz[9] reports that it is an advantage to have the eddy current behind the bathyscaph, as during the ascent, because this stimulates organisms to luminesce; subsequent observations have revealed that this contributes only modestly to the flashing rate. A burble or knuckle of water does follow behind the bathyscaph on the ascent and this usually does elicit a small increase in the the amount of bioluminescence. As the maximum ascent rate of the TRIESTE is never more than 2 meters per second, the water current activity behind the bathyscaph is relatively slight.

The quantity of bioluminescence remained substantially the same for conditions of descent and ascent. Exceptions noted were the breakup of strings of point flashes and entanglement of medusae in the external rigging of the TRIESTE during ascent. It is well known that tactile stimulation will elicit significant increases of bioluminescence in surface "burning water." (However, dropping of ballast, which should be a potent tactile stimulus in a limited area, resulted in little bioluminescence.)

By analogy, the concentration of bioluminescence at any one time rarely exceeds the number of stars that can be seen in the heavens on a clear, dark night. Evidence of virtually incessant flashing in the viewing area was observed by Piccard (personal communication) in 1956.

TABLE 2. BIOLUMINESCENCE OBSERVATIONS.

DIVE NO. 61 (DESCENDING AND ASCENDING)

Depth (feet) (Uncorrected gauge readings)	
4200	Approximately 1 flash per 1/2 meter^3. Usually single points. One fairly large disc-shaped object with numerous points of light.
4800 & 5400	Amount of bioluminescence remains approximately uniform.
6000	Bioluminescence much reduced; only isolated points observed.
6900 to 10, 500	Virtually no bioluminescence present.
12, 300	Single point, water virtually clear of suspended material.
13, 800	No bioluminescence observed since 12, 300 feet. Release of ballast incites no bioluminescence.
17, 400	Amount of suspended material has increased to a high quantity. Particles reflect white. Most are inanimate. Size average 1/8 inch, two are 3/8 inch. One pteropod observed.
17, 700	One mysid. Considerable amount of material in water. Isopod (?), white, 1/2 inch, swimming while in vertical position.
18, 000	Pelagic annelid, *Tomopteris* sp., 2 1/2 inches, 1 inch wide including parapodia, body 1/2 inch or less. Two pteropods.
18, 450	One mysid, 1 inch long, resting quietly in suspended animation, 1 1/8 inch medusa.

18,540	Amount of suspended matter has approximately doubled over what it was earlier. Many of the particles appear to be about 1/4 inch in diameter and very light in color. Nearly white. One mysid, one *Tomopteris*.
18,600	Sea floor clearly shows the presence of burrowing organisms. White patches mottle the tawny sea floor, and represent sediment brought to the surface by burrowing animals. One mollusk shell, similar to *Astrea* of shallower water; 2 inches in diameter at the base and about 1 1/2 inches high. Water current virtually nil.
18,600	(On leaving the bottom.) One mysid, one *Tomopteris*.
18,150	One *Tomopteris*.
15,300	Some bioluminescence; four sustained greenish-white flashes. Observation followed by a period of no bioluminescence.
15,060	Two bursts of bioluminescence that remained evident until the bathyscaph passed away from the object (30 seconds).
13,500	Three greenish-white flashes.
12,600	Two flashes.
7200	A number of pieces of bioluminescence observed. One unit appeared as a cluster until it was broken into fine pieces in the turbulence of the bathyscaph. Perhaps it was a siphonophore. Several other points of light evident.

DIVE NO. 76 (ASCENDING ONLY)

Depth (feet)	
18,920	Euphausiid or crustacean. Visibility 70 to 80 feet.
10,840	Ten small white flashes.
10,350	One flash - none between 10,800 and 10,400.
10,300	Four flashes.
9760	Six flashes. One 15-second duration flash.
9270	Flare-up of flashes. Quantity increasing. Five or six of 30-second duration.
9075 8830	200-foot interval, none; then four to five. One sustained big mass of light. Adequate to permit viewing of grating inside antechamber.
8780	Strings of bioluminescence being broken up in burble. Too many to count. Four-inch chain. Big points of 30-second duration. Much suspended matter.
8185	Continuous bioluminescent flashing.
7990	Slight decrease. Water temperature, 3.5°C.
7841	Short chain that appeared to be a fish with lights on. Many other small points.
7495	String broken up.
7346	Increase. Double of amount at 8000 feet. Full sky density. Some first magnitude.
7100	About same density. Several appear as three points in a cluster.
6900	Increasing. No void periods. Full sky.

6600	Broken animal. Bioluminescence not as bright as isolated flashes. Weaker lights are about one-third intensity of first magnitude star. Majority second magnitude.
6180	No change. Short periods of no flashes. More breakup. A single 60-second sustained glow.
5900	Ballast release caused no excitation.
5500	Increasing.
5300	Marked increase since 5500 feet.
4800	Tenfold increase over 6600 feet.
4250	100-200 points present at all times. Water temperature 5.0°C.
4100	Same as above.
3600	Bright points increasing slightly.
3000	Same as above.
2150	Bright points increasing slightly.
2000	Twofold increase over 4000.
1500	Detect contrast color of hull fittings. Bright bioluminescence still visible.
1150	Bioluminescence detectable over ambient sunlight. Magnetic value clearly white now. Dark red paint appears black.
1000	No longer possible to see bioluminescence due to daylight.

DIVE NO. 77 (DESCENDING ONLY)

Depth (in feet)	
620	Few faint points.
640	Organisms transparent in searchlight.
800	Several small black fish 4 inches long; silver blue, dark circle around eye.
1070	Numerous animals. Occasional flash. Jellyfish 1 1/2 inches long, 3/4 inch wide.
1100	Hint of daylight. Very little bioluminescence. Long yellow unidentified pelagic worm.
1125	Ballast release excites three flashes.
1140	A phyllasome larva.

DIVE NO. 78 (ASCENDING ONLY)

7000	Few isolated points second magnitude. 0 to 4 points in total viewing area.
5500	Moderate increase. Long period of blackness.
4800	Increasing; one-fourth full starry sky.
4600 to 4400	Patchy. One-third full starry sky. Continuous stream of light sources.
4000 to 3500	Continuous stream. Second magnitude brillance.
3000	Continues about same.
3000 to 2800	Increasing patterns of light. Small circles, 1 inch in diameter. Periphery dotted with small points of light.
2500	First magnitude increasing as is second magnitude.
2150	Strong swimmer.
2000	Big flashes. Exceed first magnitude star brilliance.
1400	Arrays of off and on lights.

The observation was published in more subdued working in a report by Piccard and Dietz[10] which stated that, "with the lights extinguished in deep water, a small point of bioluminescence was seen every few seconds." At this time, a situation comparable to "burning water" was also seen at the surface.

Attempts to identify the emitting sources have been made. Illuminating the area with the external lights has revealed either no discernible source or only heavy concentrations of suspended matter. The majority of light sources are presumed to be protozoans that are too small for the human eye to resolve.

The only color of bioluminescence observed during the descents of the TRIESTE has been greenish-white, although other luminescent colors are known to be present in marine organisms.

Most descents with the bathyscaph have been to the sea floor. It is of interest to note that although benthic members of the several phyla are known to possess bioluminescent species, no benthic bioluminescence has been observed. These benthic forms include sea pens, nemertean worms, chaetopteran worms, and coelenterates.

Water Clarity

One of the intriguing phenomena revealed during bathyscaph dives has been the prevalence of marine "snow." Particles in the water are easily detected if exposed in a beam of light. As the scatterers are made apparent by such a source, a Tyndall effect can be created.

Bathyscaph observers have only a qualitative index of the amount of material present in this "snow." The identity of these suspended materials is still poorly understood. However, they are believed to be largely inanimate. They are distributed throughout even the largest known water column in the ocean.

During a bathyscaph traverse of a water column or a lowering of photometric device, suspended materials have been found to vary in quantity. Analysis by Jerlov[11] of data from several deep oceanic locations indicates that there is definite particle stratification that suggests a means of identifying water mass movement. His determination of variability has been confirmed by observations from the TRIESTE.

Although particles are conspicuous in the "Tyndall beam" of the external lamps, there has been little evidence to suggest that they are alive. It is highly probable, of course, that the particles are of microscopic size and beyond the resolution of the human eye. Despite the conspicuousness of these particles during deep water observations, the water was still relatively clear compared with surface coastal water.

Kalle[12] and others have noted that in sea water water-soluble pigments of yellow color are present. This yellow substance has been found in the ocean as well as in coastal waters. However, it has not been observed on bathyscaph dives.

Deep water has nearly the clarity of clear oceanic surface water. On one occasion, the author and another observer were able to see the sea floor at 5678 meters clearly as it was illuminated by the outside lights at a maximum range of 60 feet. The observations were made both approaching the off-white bottom and later as the ascent commenced.

By contrast, in the highly productive waters off the San Diego coast visibility may be reduced to less than 25 feet. However, three TRIESTE dives made in virtually the same location off San Diego on different dates revealed that there can be significant difference in the quantity of suspended matter present on different days. These variations are obviously due to the horizontal transport of material and organisms into the area by deep water currents. On one occasion, the water was a puree of suspended particles and living forms, primarily chaetognaths, ctenophores, medusae and mysids. As the majority of these animals are clear and relatively transparent, they did not reduce the maximum range of visibility as much as might be expected.

Observations made during several dives of the bathyscaph FNRS-III revealed the presence of a crystalline clear layer near the sea floor. In no instance has this observation been duplicated by the TRIESTE dives either in the Mediterranean or in the Pacific.

Water clarity near the sea floor in deep water is reasonably adequate to permit good photography and clear observations. On Dive 56 (in Loma Sea Valley) an appreciable flow of sediments immediately adjacent to the bottom was noted. A relatively strong current was present of approximately 5 centimeters per second. This flow was adequate to tumble shells inhabited by hermit crabs along the bottom; fishes were noted to swim "upstream"; sea pens, normally rigid and vertical, were swept over to an angle of approximately 45 degrees.

In the Mediterranean, clouds of suspended matter passed through the illuminated area as the bathyscaph remained in a fixed position. These were probably generated by fishes grubbing in the sea floor sediments. On two occasions, fishes were observed to stir up the sediment apparently in search of food, such suspended clouds were noted to drift in a fixed direction at 1 centimeter per second.

Daylight Penetration

Visual observations from the bathyscaph TRIESTE indicate that daylight penetration down to 600 meters (maximum) can be expected in clear ocean water. Table 3 compares these results with those obtained by other investigators either through direct observation or by the use of cable-lowered bathyphotometers.

Reasons for the extinction of daylight at 600 meters or less during bathyscaph dives are supplied by Clarke and James[13] who conclude from their examinations that ocean waters contain suspensoid and filter-passing materials that are effective in increasing absorption, so that sea water is always less clear than pure distilled water. Such suspensoids have been almost invariably observed above and below the depth of daylight penetration on each bathyscaph dive.

During 1957, Jerlov and Piccard[14] descended 600 meters in the Mediterranean with the TRIESTE for the purpose of measuring daylight penetration. Unfortunately, malfunctions of the photometric equipment made it impossible to obtain light-level readings to the maximum depth obtained. This dive represented the only specific attempt with the bathyscaph to obtain photometric readings concurrently with visual observations of daylight extinction.

TABLE 3. OBSERVATIONS AND MEASUREMENTS OF DAYLIGHT EXTINCTION.

AREA	OBSERVER(S)	EXTINCTION OF DAYLIGHT (DEPTH IN METERS)	REMARKS
Sargasso Sea (off Bermuda)	Beebe[3]	593	First deep-sea direct visual observations of daylight extinction.
Sargasso Sea	Clarke[15]	430	Used light-sensing equipment.
(Very clear waters; area not specified)	Clarke	520-580	Estimate based on comparison of Clarke's photometric results with Beebe's observations.
Bronson Deep (North of Puerto Rico)	Clarke	700	Estimate.
Off Portugal	Peres, Piccard and Ruivo[16]	430-450	Visual observations from FNRS-III.
Mediterranean	Dietz, Piccard and Rechnitzer	500-(Dietz) 525-(Piccard)	Visual observation from TRIESTE.
Mediterranean	Piccard	600	Visual observations from TRIESTE. Used subdued lighting within sphere to increase visual sensitivity.
Off Guam	Rechnitzer	600	Visual observations from TRIESTE.

Supplemental data on this subject from French bathyscaph operations are also lacking. This is probably because the French have had unusual success with their underwater illumination system. In lieu of measuring light penetration, they have concentrated on obtaining information about plankton distribution and the quantity of suspended particles in the water.

Preparation for the daylight penetration observations by the author in the Mediterranean[17] (1957) included a reduction of ambient light within the sphere and a short dark adaptation period. Only a minimum amount of light was used within the sphere for operating the craft. This precaution was supplemented by the use of a tight-fitting rubber face mask with glass removed, which excluded all ambient sphere light when the front edge of the mask was held firmly against the hull of the sphere around the window. External illumination was not employed during the descent until after the extinction of daylight was observed.

Dark-adaptation time on this dive was limited to that required to reach depth after the start of the dive (about 30 minutes). To extend capability for visual detection of daylight penetration, an investigator should have a one-hour dark-adaptation period.

Marine Biology

During the 1958-1960 bathyscaph diving program, a variety of habitats were encountered. Within the Loma Sea Valley, a fauna of fishes and invertebrates was encountered that varied with time and space both on the sea floor and in midwater. Temporal changes were striking. Invertebrate populations in particular were noted to vary tremendously in species, quantity, and distribution. The extreme variability in this area appears to be caused by variations in water mass movement.

There are significant differences in species occupying the region of the Loma Sea Valley (about 800 to 1000 feet) as compared to the San Diego Trough (about 3600 to 4200 feet). The San Diego Trough fauna is dominated by brittle starfish, tube worms, holothurians, and sablefish.

The sea floor fauna in the Guam area was depauperated. Living organisms were found to be abundant down to 10, 000 feet. Suspended matter, yet unanalyzed as to animate and inanimate constituents, may contain many forms too small to be recognized without optical magnification.

Sampling has been limited due to sampler failures. However, prototype sampling devices are under development and test (fig. 13-16).

Biological entities and their remains appear to constitute an important interference factor in the propagation of sound through long deep-water paths. It is planned to explore the effects of these organisms on sound propagation using equipment carried aboard the TRIESTE.

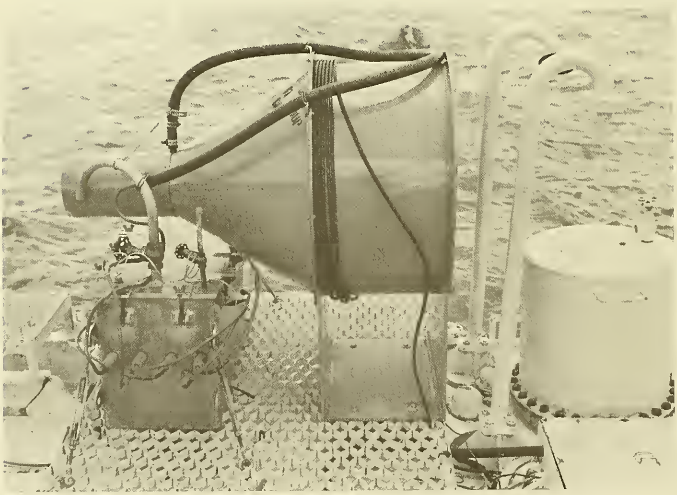

Figure 13. Prototype multiple plankton sampler. Twenty individual samples are selected on command by remote control and held in storage under sea water until removed for analysis or preservation. Water is pumped through standard plankton netting by an ambient-pressure-compensated 6- or 12-volt dc motor-driven propeller located in a stainless steel cover at the apex of the conical shroud. Beneath the conical shroud is the prototype system wherein a set of standard lead-acid batteries were compensated to ambient pressure.

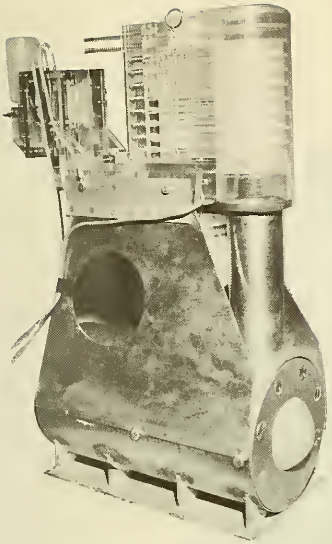

Figure 14. Another prototype multiple plankton sampler. Ten individual samples are selected on command by remote control and held in storage under sea water until removed for analysis or preservation. Water is pumped through standard plankton netting by an ambient-pressure-compensated 24-volt dc motor-driven propeller located in a stainless steel cover below the acrylic plastic sampling unit. An ambient pressure compensated solenoid, located upper left, is used to release sampling discs into the storage position. Additional sampling units can be easily added to the "stack" of ten shown.

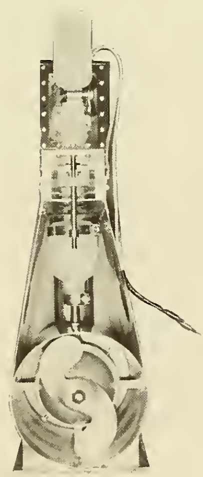

Figure 15. End-on view of sampler of figure 14. Polyethylene bottles serve as reservoirs for the electrically non-conducting fluids used to compensate for ambient sea pressure and to prohibit the entry of sea water into the electrical circuits. This sampler was successfully operated to depths of 18,900 feet. Power for the motor was taken from the prototype system used for operating standard lead-acid batteries at ambient hydrostatic pressures.

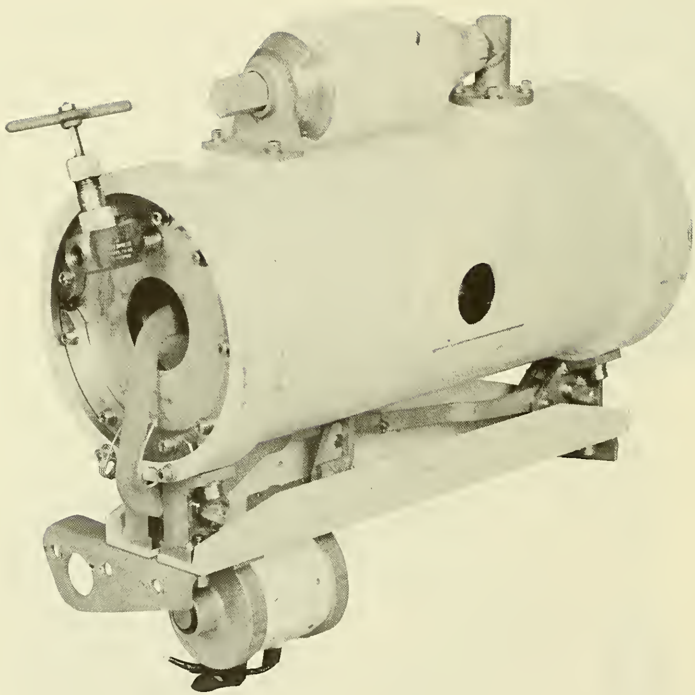

Figure 16. Prototype ambient pressure water and plankton sampler. This unit is adaptable to bathyscaph or cable-lowered use. A single water and filtered plankton sample can be acquired by remote control. Pressure within the chamber can be maintained up to a maximum pressure of 1000 psi. Closure of the apertures can be effected either mechanically by messenger or by an electrical solenoid. Two viewing ports and openings for internal lighting are available for viewing the contents while under pressure. Exchange of water after closing can be effected in the laboratory through high-pressure gates located on each end of the pressure vessel.

WATER TEMPERATURES IN THE MARIANAS TRENCH

Above a deep trench, a unique characteristic of the water column is the adiabatic increase of the temperature. Wurst[18] (1929) has shown that a slight increase in temperature can be anticipated below about 3000 fathoms. At this depth a minimum temperature level occurs for water masses of constant salinity.

The temperature profile obtained during bathyscaph Dive No. 70 (fig. 17) shows this minimum temperature level followed by a gradual increase as the bathyscaph descended. The recorded temperature values were acquired using a resistance bridge. The accuracy of this bridge and its calibrations were not adequate to permit the values to be considered absolutely precise.

The temperature at 3100 fathoms on Dive No. 76, as determined by a reversing thermometer, was $2.12 \pm 0.08°$ C. A chart reading of $2.3°$ C at the same depth in the same dive was recorded.

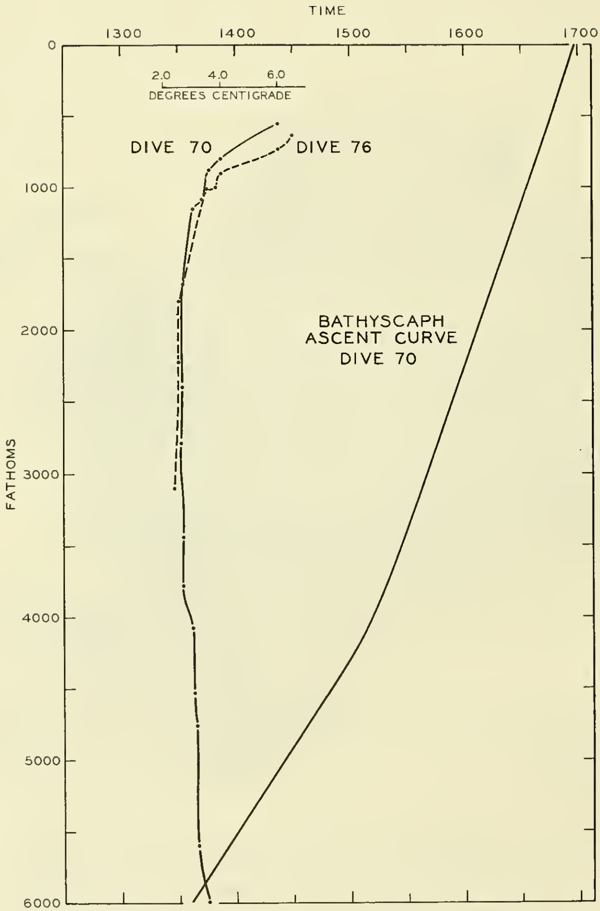

Figure 17. Sea water temperatures obtained by a resistance bridge, illustrating adiabatic cooling at mid-depths. Absolute accuracy of recorded values is not intimated by this curve.

BIOLOGICAL FOULING OF TRIESTE

Fouling of the exterior of the bathyscaph within San Diego Bay has been spectacular and a nuisance (fig. 18). Profuse growth of *Obelia, Tubullaria,* barnacles, tube-forming worms such as *Spirorbis,* and even the young of the giant kelp *Macrocystis* have formed dense fouling covers to the extent that the paint was no longer visible after a few weeks. It is of interest to note the preferential settling of the organisms on the white painted surface rather than on the blue band.

The first antifouling white paint, Amercoat 85 and 33, was applied following the March-April 1959 overhaul of the TRIESTE (fig. 19). This paint was also fouled in a short time (fig. 20). As indicated by this photograph, the exposure to high hydrostatic pressure and low temperature during the bathyscaph dives had no apparent detrimental effect on the living organisms; Dives 53 (to 4100 feet) and 55 (to 4200 feet) applied pressures of over 1800 psi to the growing organisms.

Prior to the initiation of NEKTON I, a standard stock antifouling paint, vinyl red formula 121, was substituted for the white paint (fig. 21). Good antifouling characteristics were noted. However, biological growth in Apra Harbor is always negligible.

Controlled tests with Laminar X-500 conducted off the NEL pier indicated that this paint would be a good antifouling covering for the craft. However, following two months' immersion in 1961, the craft was again heavily fouled and now requires weekly cleaning by divers.

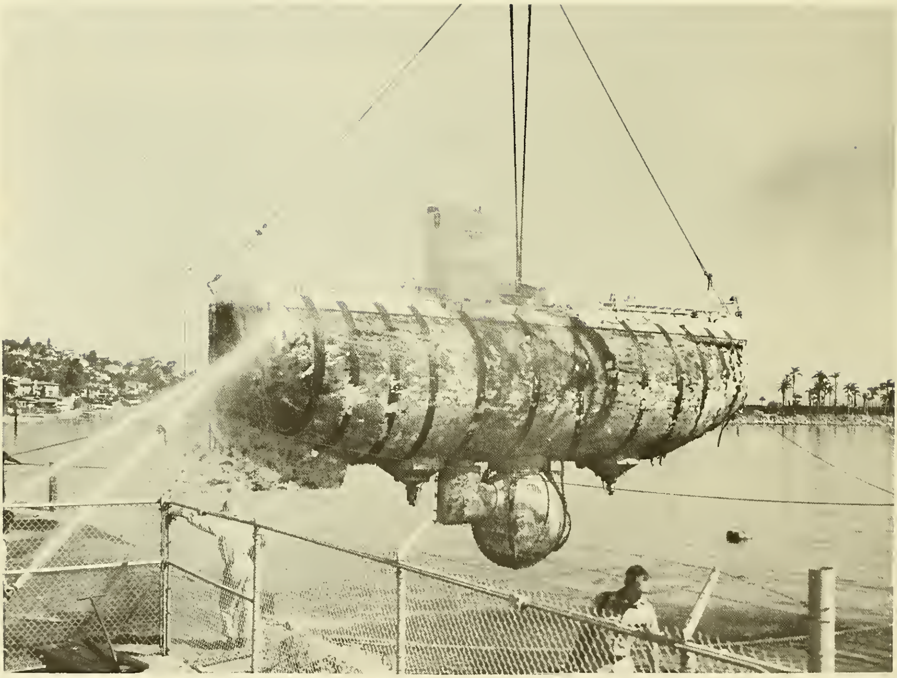

Figure 18. Biological fouling on Italian paint after 4 months' immersion, November 1958 - March 1959.

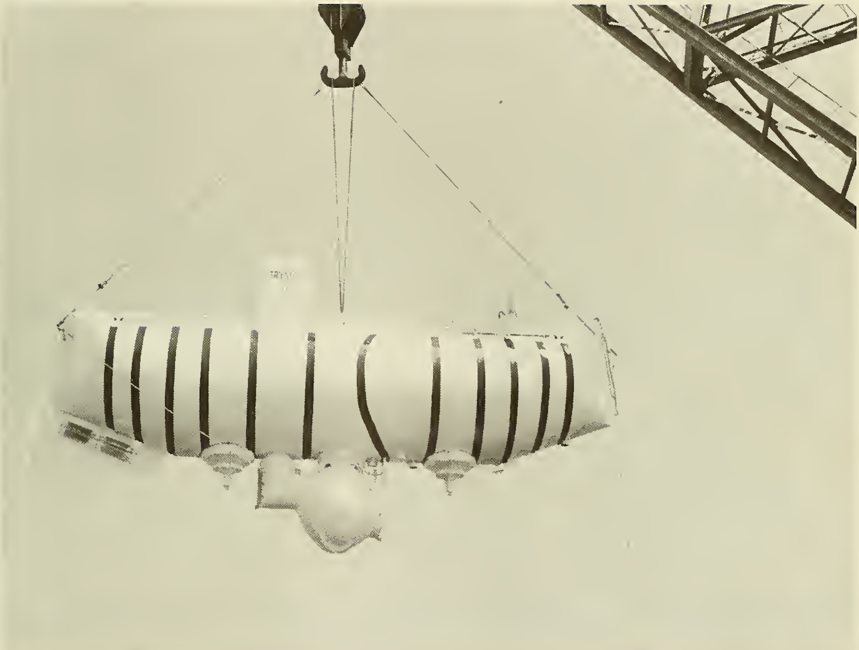

Figure 19. TRIESTE painted with Amercoat 85 and 33.

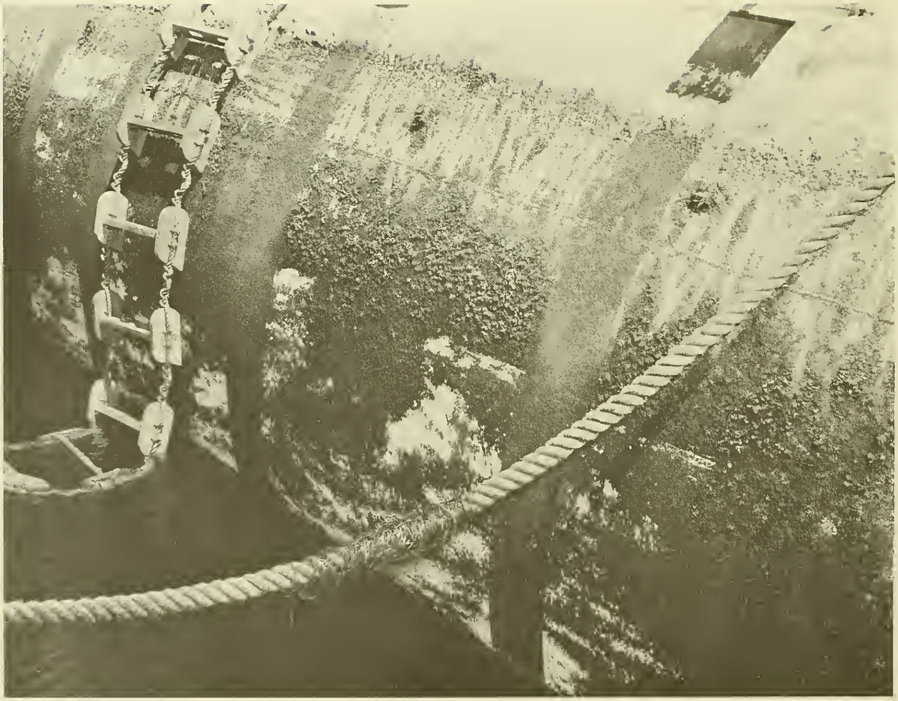

Figure 20. Biological fouling on Amercoat 85 and 33 after 2 months. The fouling showed no apparent changes following exposure to reduced temperatures and marked pressure increases to over 1800 psi.

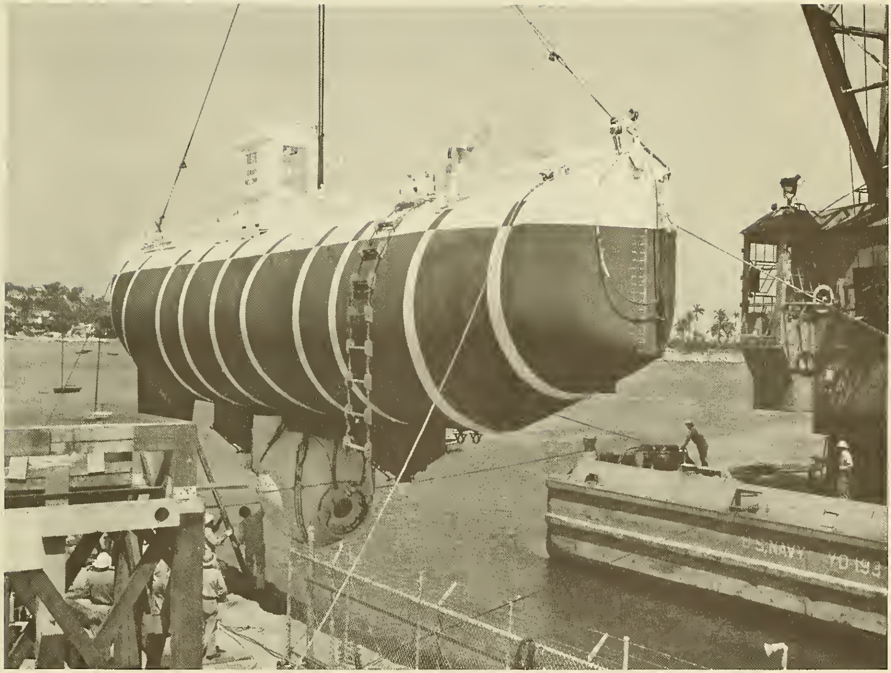

Figure 21. TRIESTE painted with vinyl red formula 121.

CONCLUSIONS

1. Oceanic environmental research has been successfully conducted to the maximum known depth in the oceans using a manned vehicle, the bathyscaph TRIESTE.

2. The validity of the concept of sending man and machine as a team into the depths for oceanographic research has been proved by successful scientific observations and measurements of water clarity, bioluminescence, water currents on the sea floor, gravity, sound velocity, water temperature, sea-floor studies, and other facets of marine biology, marine geology, and physical oceanography.

3. Observations at the sea floor using the bathyscaph lead to several important conclusions:

a. The presence of currents along the deep-sea floor of sufficient magnitude to cause the coarser sediment to form ripple marks had been previously noted by deep-sea camera studies. Inasmuch as no current measurements can be made during camera studies, it was not known whether these were intermittent or continuous currents. The bathyscaph observations have confirmed the presence of these deep ripples, and have further established that the current present in the area at the time was not strong enough to cause the rippling. The currents are therefore intermittent. The presence of such deep currents heretofore unknown (before camera and bathyscaph studies) is an important oceanographic phenomenon which, at present, physical oceanographic theory cannot explain.

b. The TRIESTE has found abundant evidence of biological churning of the bottom. The marked variance and dispersion of these minor features has been especially augmented and compared to sea floor photos.

c. An important contribution was made to knowledge of the topography and structure of the sea floor by the dives off Guam which demonstrated that the submarine part of the island is a thin coral cap on a massive volcanic structure having only a scattered veneer of sediments. This not only demonstrated the actual structure, which was previously unknown, but also showed that the island arc-trench structure of which Guam is a part has not subsided to any great extent.

d. Important contributions were made to studies of the topography and structure of the great trenches of the

Pacific in the diving into the Marianas Trench. Echo sounding does not show the configuration of the floor along the axis of these trenches because of the broad-beam of the sounders, the depth of water, and side echoes. As a result of the TRIESTE program, it is now known that the trench (and probably others) has a wide flat floor; that currents are not active in it (at least not continuously); and that it has little benthic animal activity. Furthermore, the nature of sediment in the trench was ascertained. The sediment of the trench previously was known from only one small sample taken by the HMS CHALLENGER in 1952, and in another portion of the Trench.

4. Other conclusions are:

a. Particulate matter exists to some degree to all depths in the oceans.

b. Water clarity in the deep oceans generally permits observation from the bathyscaph to distances up to 60 feet, when lighting conditions are suitable. A new arc for *in situ* observations on "visual oceanography" is indicated.

c. For the bathyscaph observer, extinction of daylight in the ocean generally occurs at approximately 600 meters.

d. At depths of over 2100 meters, bioluminescence was observed only as single, or small groups of flashes. Upon ascending to 700 meters, the number of flashes increased rapidly as much as 1000 times. At shallower depths bioluminescence remained high until "washed out" by daylight.

RECOMMENDATIONS

Provide for increasing the knowledge available to the U. S. of the deep-sea environment. Specifically:

1. Continue and extend deep-sea research with the bathyscaph TRIESTE so as to take full advantage of the unique and proven capabilities of this vessel. Also, modify the TRIESTE to make it even more valuable for scientific work than at present.

2. Establish an enlarged scientific program, involving underwater acoustics and all oceanographic disciplines, for making observations and measurements vertically through water columns and in very deep water.

3. Develop improved acoustic and oceanographic instrumentation for use on the TRIESTE and on future deep submersibles.

4. Develop a deep submersible research craft more versatile than the TRIESTE.

5. Evaluate the usefulness of deep submersibles as platforms for acoustic detection equipment and naval ordnance.

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