NOTES AND OBSERVATIONS ON THE DANISH DEEP SEA EXPEDITION OF THE "GALATHEA" TO THE MINDANAO DEEP

By TEODORO G. MEGIA, INOCENCIO A. RONQUILLO and RICARDO R. MEDINA
Of the Bureau of Fisheries, Manila

OBJECTIVES OF THE EXPEDITION

The Danish research ship pulled into the port of Manila on July 6, 1951, and four days later it steamed away on its scientific mission to the Mindanao Deep. Among the most outstanding objectives of the Expedition to the Mindanao Deep were: To gauge by sounding the much disputed depth of the trench trawl for deep-sea animals and fishes, find how far below the surface living things can exist, determine the bottom configuration of the Deep, take bottom mud samples for bacteriological and sedimentation studies, and make organic productivity measurements. Last but not least was the spreading of Danish goodwill, wherever the work of the Expedition took the ship in its two-year round-the-world cruise of scientific discoveries.

THE BOAT AND ITS PERSONNEL

Constructed in 1933, the corvette "Galathea" had a war record of many years. Until it was commissioned for its oceanographic mission round the world, the ship plied between Denmark and England as a tourist ship. With a tonnage of 1,630 tons, it had a length of 79.9 meters and a draft of three meters. With a cruising speed of 12 knots, it was equipped with an automatic pilot and a Decca radar. Its twin-propeller drive, a feature little exploited by research ships in general, multiplied manifold the maneuverability of the boat which was of great help in hove-to operations.

Manned by a staff of 10 officers and a crew of 79, the "Galathea" carried 17 scientists in addition to a number of foreign scientists who came on and off in the course of her cruise round the world. The ship was under the command of Capt. Svend Greve and the Expedition under the leadership of Dr. Anton F. Bruun, an expert on flying fishes and one of the leading ichthyologists of the world. Dr. Torsten Gislen of the University of Lund, Sweden; Dr. Claude E. ZoBell of the Scripps Institution of Oceanography and the authors of these observations were among the foreign scientists, who joined the trip to the Mindanao Deep.

EQUIPMENT AND INSTRUMENTS

The most important equipment of the oceanographic vessel was the Hughes Recording Echo Sounder which in reality was the nerve center of all the boat's operations. The basic principles of the sounding machine revolved around the sending out of sound impulses from the bottom of the ship, measuring the time required for the resulting echo to return from the sea bed, and presenting the measurements in the form of a continuous graphical record of depth of water. The return of spurious echoes was reduced to a minimum by having the sound waves focused into a concentrated beam by a funnellike reflector, which projected the beam toward the sea bed. Soft bottom, air bubbles coming from the wake of the boat and creeping into the hydrophones, and the pitch and roll of the boat due to swells were the most important interfering factors, which introduced uncertainties in some of the recorded soundings.

The other important equipment used for deep-sea operations were the heavy dredge and hydrographic winches with tapered wires exceeding 12 kilometers in length. Both wire ropes contained a central core of hemp steeped in pitch. When payed out under load the wire stretched, thereby squeezing out the grease which under great pressures at ice-box temperatures congealed to form a thick coating of viscous material clinging around the wire. When a messenger was released to reverse the bottle clamped to the hydrographic wire, the speed of descent was greatly reduced by the clinging grease and by the progressive increase in viscosity of the successive layers of water, due to decreasing temperature and increasing pressure. Consequently, at the time the messenger hit the bottle, the force of impact was not sufficient to trip the mechanism that reversed the bottle. Seven successive failures in water sampling were believed due to such difficulty.

The dredges and trawls were of different types and sizes. A variety of types of trawl constituted the bulk of collecting gear. These were the sledge trawl, lobster trawl, shrimp and herring otter trawl, and the general purpose triangular otter

trawl. Most of the trawls had simple rectangular iron frames to which the collecting nets were attached. The nets tapered to collapsible cod ends, which were made of heavy canvass and supported by a pair of iron rings distanced a few inches apart. The dredges were smaller and had serrated iron frames.

The bottles, used for securing water samples, were of the modified Nansen type whose valves, when closed, sat on rubber gaskets. Heavily plated, each bottle carried a one-piece frame which housed the two deep-sea reversing thermometers. A number of the thermometers resisted pressure exceeding 1,000 atmospheres, while the others collapsed under those pressures. A number of the Watanabe (Japanese) thermometers of the Bureau of Fisheries tested during the trip withstood a pressure of 815 atmospheres.

For examining minute specimens, they had a special research microscope, whose construction was radically different from those in general use. The arm was at the front to give free access to the object, stage, objectives, substage and mirror, thus offering greater comfort and convenience to the user. The optical elements were Balcoted to avoid objectionable reflections which might interfere with the instrument in producing a sharper, clearer image most truly interpretive of the tonal characteristics of the specimen.

It is worthy to note at this point, that all the specimens collected were separated into phylogenetic groups soon after they were killed and then preserved and labelled accordingly. This was the first time that such practice was adopted in a long-range biological expedition.

ACHIEVEMENTS AND DISCOVERIES

In fulfillment of its first objective, the "Galathea" on July 29, 1951, at about 0024 hours, sounded a depth of 10,628 meters some distance away from the Snellius Deep, located approximately at 9° 42′ N and 126° 51′ E. It is interesting to compare it with soundings taken by other research vessels in previous years. The following table is a list of such soundings.

Nationality	Vessel	Year	Depth in meters
German	Planet	1912	9,789
German	Emden	1927	10,791
Dutch	Snellius	1930	10,160
American	Cape Johnson	1945	10,498
Danish	Galathea	1951	10,628

The Emden figure of 10,791 meters was the result of a spurious return signal, and therefore could not be accepted as a valid sounding (Hess and Buell, 1950). The sounding was made on a traverse nearly parallel to the axis of the trench using a non-directional echo sounder. In the sounding of the Japan Trench, a depth of 10,907 meters was recorded by the U. S. S. "Ramapo", using an audible frequency echo sounder. Hess and Buell re-analyzed the "Ramapo" data and found the maximum depth of only 9,803 meters. Allowing an error of 110 meters due to the average error in reading the echo sounder, deviation in frequency of the power current and error in the correction tables due to variations in the velocity of sound in water of varying degrees of temperature, salinity and pressure, the "Galathea" figure of 10,628 meters remains to be one of the deepest soundings ever made to-date. If the original figure is finally accepted, its corrected value thus estimated, leaves the Mindanao Deep in the same position of eminence as before, namely, that of being one of the deepest spots in all oceans.

The first attempt of the "Galathea" to trawl and dredge the narrow sea bed of the Mindanao Deep yielded results which occasioned a flood of congratulatory messages from people in Europe, who kept themselves posted with the activities of the ship. On July 21, 1951, at about 1845 hours the trawl with the two dredges brought up animal life from a depth exceeding 10,000 meters, the deepest part of the combed area being 10,462 meters. Two lamellibranchs, which showed evidence of life when hauled aboard, eight actinians and several holothurians came up with the collecting gear to create biological history. Subsequent operations added several amphipods and tanaidarians which increased the total number of species collected from the area.

Following the collection of these deep-sea forms, there had been lively speculations on how the organisms came to settle upon the deep sea bed. Being sessile, these animals could not have been caught from anywhere else except from the bottom or the walls of the trench. It was difficult to believe, however, that the pieces of stones to which the organisms were found attached could have been scraped from the steep slopes and entrapped by the heavy collecting gear dragging at the rate of 1.5 to 2.0 knots. The wire was taut and parallel to the axis of the keel, and the boat methodically and patiently positioned [illegible] The presence of stones

scientists, the results of recent seismic disturbances. The Mindanao Deep, being the epicenter of most of the earthquakes occurring in Eastern Visayas and Mindanao (Selga, 1931), must have a foundation that is geologically unstable. Consequently, some recent crustal displacements there might account for the peeling off from the steep slopes of the stones which, together with their load of sessile animals, rolled down to rest upon the soft stratum covering the sea floor. If this assumption is true, the animals collected indeed must have been able to adjust themselves to their new and unusual environment.

In the light of the work of the "Galathea" the concept of an azoic zone in the abyssal depths is now a thing of the past, although earlier, this has been dubiously disproved by the plankton collections taken from comparatively shallower depths using the self-closing Palumbo net.

That other forms of life do exist in the cold, disphotic and quiet waters of the Mindanao Deep was conclusively demonstrated by Dr. Claude E. ZoBell, one of the guest scientists aboard, who found viable bacteria from the deepest layer of water sampled. Collecting the samples under sterile conditions, the American microbiologist was able to culture them successfully under simulated *in situ* conditions. Most of the bacteria observed were rodlike in shape and of the nitrifying type. The presence of nitrifying bacteria in the water and mud samples indicates that the mineralization of organic matter occurs within the entire water column and in the layer of sediment immediately below it. This is considered significant, as more importance can now be ascribed to the known slow process of diffusion which returns the regenerated plant nutrients to the euphotic zone to maintain the tropho-dynamic equilibrium in the sea.

Mud samples were taken by the Pettersson grab and the Kullenberg core samplers. The only core sample collected was taken from a depth of 10,328 meters. The sample which was 75 cm. in length was preserved in a plastic glass tube for further study in Copenhagen. From the sample, they hope to find radioactive substances which may throw light on the rate of sedimentation. For isotope determination, several samples of bottom water were preserved in heat annealed glass ampules.

In collecting bottom samples and specimens, the Danish scientists were faced with the problem of determining just necessary, the excess length looped over and possibly fouled the gear and prevented it from functioning normally. As the damaged wire was hauled in to raise the gear, the sudden increase in the tension of the wire snapped it at its weakest point, thereby losing valuable equipment. The dynamometer, which recorded the varying tension on the wire, was of little use, as it failed to register easily the resulting slack in the wire when the gear touched bottom. This was due to the light weight of the gear compared with the weight of the wire out.

To meet this problem in future deep-sea operations, Dr. ZoBell hatched the idea of conducting glass ball breaking experiments. If a gear carried a glass ball which was made to explode when the gear hit bottom, the resulting sound could probably be heard in the hydrophone. Surprisingly, the experiments yielded results which, among other things, satisfactorily explained the crushing of several deep-sea reversing thermometers used in the hydrographic work. Of the 58 glass balls lowered at different times to depths ranging from 9,000 to 10,418 meters, 28 were broken, 22 water-filled and the rest unbroken. The discordant results taken from the balls lowered at the same level were attributed to the fact that the balls were not made of uniform quality. However, it should be noted that these glass balls withstood pressure at 6,000 meters in previous experiments.

The information gathered from these glass balls breaking experiments promises to be of outstanding importance in the design and use of deep-sea instruments. The American scientist explained the phenomenon of breaking by saying that the glass was compressed until it failed. When the ball finally broke, water must have rushed suddenly to fill the void space, thus creating a region of greatly reduced pressure in the vicinity of the broken ball. The accompanying equalization in hydrostatic head resulted in what he termed an implosion. The penetration of water into some of the unbroken balls was explained by saying that it might have been due to some molecular phenomenon of an astonishing kind.

In the light of these experiments Dr. ZoBell's theory of implosion appears to be the only valid explanation for the pulverization of the glass of which the thermometers were made. The effect of the implosion was manifested by the

A new concept on the behavior of oceanographic gear at subsurface depths was evolved when a bathysphere was sent down with a load of instruments, and returned with a record of its movements while in suspension in a mobile medium. With an inside diameter of about 22 inches, the metal ball was divided into two hemispheres flanged tightly together by closely spaced stud bolts. An aluminum frame of approximately two feet in width and eight feet in length was clamped to the wire a few feet above the shackle that linked the upper hemisphere with the end of the wire. In spite of the frame, a rotation of about 270 turns was recorded in one trial. One wing of the frame was bent, while the other had its distal end sliced off as if a sharp heavy knife had cut it. A maximum vertical displacement of about a meter was recorded.

On the basis of the bathysphere data, it may now be assumed that oceanographic gear lowered to great depths by a steel wire, composed of twisted strands, behaves in a similar manner. Thus, the number of failures experienced by the "Galathea" in her deep-sea operations can be ascribed to this fact.

One important aspect of the work of the "Galathea", which will influence greatly fishery researches of the future, pertained to organic productivity measurements. Outstanding in the principles involved and of far-reaching significance in the assessment of the fertility of surface waters, organic productivity measurements appear to afford the only direct approach to a quantitative study of the food cycle in the sea. With the method of using an artificially radio-activated carbon as a tracer in organic productivity studies, oceanography comes close to the threshhold of being able to assess fish production in terms of available plant nutrients in sea water. Where before the routine analysis of dissolved nutrient salts in sea water merely gave an indirect index to the fertility of a given area, now a direct correlation exists between hydrographic and biological data.

REMARKS AND RECOMMENDATIONS

On the whole, the work of the "Galathea" may be regarded as the starting point in unraveling the mysteries shrouding the Mindanao Deep. A repeated survey of the area with a reasonable interval of time may yield information important to the understanding of the capricious climatic changes around us. Now unknown to anyone, it may be playing an important oceanic circulation in the Western Pacific. Given active support by the public, which in Denmark made possible the "Galathea" Expedition, a similar undertaking, sponsored by the Government, can add to our knowledge of the Mindanao Deep, which lies sprawled just behind our backdoor.

At the behest of the writers, Dr. Bruun, head of the scientific staff, gave his views on problems which he thought should engage the attention of marine investigators in the Philippines. He specifically suggested the statistical study of important fisheries however faulty the data might be in the beginning. For the census of fish populations, tagging experiments should yield first-hand information on the state of our fisheries. This will ultimately lead into an understanding of conservation problems.

He would recommend the establishment of a deep-sea research laboratory preferably in a protected town in Surigao.

REFERENCES

HESS, H. H., and M. W. BUELL, Jr. 1950. The greatest depth in the oceans. Trans. Sm. Geo. Union. 31 No. 3: pp. 401–405. 1950.

SELGA, MIGUEL. 1931. The deeps of the Philippines. Pubs. of the Manila Obs. 3 No. 8:189–195.