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REPORT OF OCEANOGRAPHIC WORK WITH SCRIPPS INSTITUTE OF OCEANOGRAPHY, INDIAN OCEAN DECEMBER 1960 - JANUARY 1961.

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SUMMARY

The research vessel "Argo", the oceanographic equipment and techniques in use and the results of Leg IV of Expedition Monsoon (Mauritius to Fremantle) are briefly described. Continuous depth sounding, bottom photography and sediment coring, heat flow, magnetic and gravity measurements were carried out on three crossings of the Mid-Indian Ocean Rise, on the St. Paul-Amsterdam plateau and the South-east Indian Basin. Hydrographic and biological samples were taken and a detailed bathymetric survey was made of the Diamantina Deep area.

INTRODUCTION

Expedition Monsoon was organised by the Scripps Institute of Oceanography as a preliminary cruise to the Indian Ocean in preparation for the international Indian Ocean Expedition planned for 1962-63. The research vessel "Argo" reached the Indian Ocean by way of the Pacific and northern Australia, and arrived at Mauritius, the most westerly point of the cruise, on December 7th, 1960.

At the invitation of the Scripps Institute the writer joined the "Argo" at Mauritius and took part in Leg IV of the expedition, Mauritius to Fremantle, from 9th December 1960 to 2nd January 1961. During this part of the cruise most of the modern oceanographic techniques were used and much valuable experience was gained in the handling of equipment, the organization of oceanographic research and in the marine geology of the southern part of the Indian Ocean.

THE RESEARCH VESSEL "ARGO"

The research vessel "Argo", a converted naval salvage vessel of a little under 2,000 tons, was recently acquired by the Scripps Institute mainly for work in high latitudes where heavy seas can be expected, making the handling of heavy equipment on the more usual smaller vessels a hazardous business. Although minor difficulties were experienced with the equipment and layout of the ship on this, her first long research cruise, the vessel proved to be a steady, stable platform for oceanographic work, free from vibration and with ample laboratory, storage and working space.

Almost the entire after part of the ship was given over to scientific work. The large after deck or "fantail" had a very low freeboard to facilitate equipment handling. A hydraulically controlled A-frame overhanging the stern carried the tapered wire from the main (dredging) winch situated below the after deck and equipment on this winch was handled from a basket low down on the stern below the A-frame. Hydrographic winches were situated at the after end of the upper deck on port and starboard sides, equipment being worked from a bucket swung overside from the lower deck.

Laboratory space is amidships on the lower deck. The air conditioned inner laboratory, in the centre of the ship, housed magnetic, gravity, and seismic recording apparatus and miscellaneous electrical equipment. A small, fully equipped photographic darkroom adjoins this laboratory. The outer laboratory, surrounding the inner laboratory on three sides and extending the full width of the ship, housed the depth recorder, Nansen bottle racks, salinimeter, chemical and biological apparatus, battery chargers etc. It was equipped with adequate working benches and storage cupboards for chemical, biological and sedimentological work, with running water, deep sinks, power plugs etc. Both laboratories had intercommunication with bridge, winch operators and all parts of the ship and were fitted with navigational instruments - repeater gyro compass, speed indicator, log, chronometer, and wind speed and direction indicator.

A small laboratory was fitted up in the forward hold which also housed the Edo head (depth sounder) column, diving gear and a decompression chamber, and was used for storage of equipment, spares and stores. Explosives were stored in a separate store aft of the main winch.

OCEANOGRAPHIC EQUIPMENT

(a) Winches. Technical details of the winches are not available. All were equipped with accurate meter wheels which are regularly checked for wear, accumulator spring and spreader. The hydrographic winches were electrically driven and carried up to 6,000 fathoms of ¼" 7 x 7 steel wire. The dredging winch, which was set athwartship under the after deck, carried ¾" to 7/16" tapered wire rope on a storage spool, the driving wheels being hydraulically operated.

(b) Precision Depth Recorder. This instrument, which was in continuous operation, was virtually the focal point of the ship. Manufactured by Westrex, New York, and costing around $5,000, the instrument was used with the normal Edo Depth Sounder and provided a continuous bottom trace with an accuracy of better than one fathom to a depth of 6,000 fathoms. The recording paper represents 400 fathoms depth and scale change is automatic, but continuous monitoring was necessary to keep interference from surface turbulence and the deep scattering layer to a minimum and to make frequent audio checks for scale changes.

Gravity and Magnetic Work

Both gravimeter and magnetometer were on continuous recording while the ship was under way. The La Costa surface sea gravimeter, mounted in gimbals in the forward hold, had to be secured only during very rough weather. The proton precession magnetometer was towed astern on a special conducting cable connected through the winch drum to the recorder in the inner laboratory.

Sonar Pinger

This is a relatively new piece of equipment in oceanographic practice although one which has been under development for some time. It is, however, one which must undoubtedly become an essential in all oceanographic work.

The sonar pinger consists simply of a normal Edo transducer mounted on a light framework with a 6 volt battery power supply and an electronic circuit capable of stepping up the voltage to 9,000 volts. The transducer gives a signal every second which, as the pinger is lowered to the bottom, is received on the precision Depth Recorder both as a direct signal and as a reflected bottom echo. The separation of these two traces on the P.D.R. then is a measure of the height of the instrument above the bottom.

Sediment Corers

Coring was carried out on all stations using either gravity corer or Kullenberg piston corer. The gravity corers used were of 2" diameter with a 6 ft. long core barrel and plastic liner and a 100 lb. driving weight. They were used without a trip arm and were lowered on the hydrographic winch at approximately 100 meters per minute, with the sonar pinger 100 fathoms above the corer. There were very few failures and cores 4 to 5 ft. long were obtained regularly. After draining off surplus water the cores were stored in an upright position in the freezer.

A modified Kullenberg piston corer was used with a 30 ft. barrel weighted by 300-400 lbs of steel plate weights. This corer was lowered from the dredging winch, and a trip arm release, using a normal 6 ft. gravity corer as a trip weight was arranged to give a free fall of 10 feet. The extruded core was sealed in 3 ft. lengths of split plastic tube and stored at 4^{o} centigrade. The gravity core obtained is used to interpret the upper portion of the piston core which is distorted during extrusion.

Bottom dredges

The rock dredge, consisting of a stout steel frame with a heavy chain bag, was used on the dredge winch. A small pipe dredge was attached to retain finer sediments. The Otter Trawl was also used on the bottom, mainly for biological work and to obtain specimens of bottom dwelling and burrowing organisms. Both dredges were towed at 2 to 3 knots for several hours.

Bottom cameras

Two submarine cameras were in use. The heavy NEL Mk. 7 camera was used on the dredging winch, the smaller camera on the hydrographic winch.

Both cameras are fully automatic, film transport being by a battery powered 6 volt electric motor set in action by a timer. A 2,000 watt/second electronic flash unit is operated by the motor to provide a short duration flash every 30 seconds. A fixed aperture f.11 lens was used in the NEL Mk.7, and a f.2.8 variable aperture lens in the smaller camera, both pre-focussed on the target distance. Both cameras and flash units were contained in water-tight pressure housings mounted on a tubular framework designed to allow pictures to be obtained whatever the attitude of the apparatus. In the upright position the camera was set to take oblique photographs (at 30°). Both cameras were used with the sonar pinger.

A vertical stereo-camera had been tried out earlier in the cruise, but was lost in the Java trench.

Temperature Probe

This apparatus consists of a recording mechanism, in a pressure container connected to two thermisters at either end of a long metal probe. The probe is lowered into the bottom sediments and the temperature differential between the thermisters measured. The heat flow is then calculated from the conductivity of the sediments, measured by means of needle probes inserted into the sediment core.

Seismic Reflections

The standard marine geophones and recording equipment were used for seismic reflection work. Seismic refraction programme had been completed before Mauritius.

Hydrographic Equipment

Hydrographic casts to the bottom were made on all main stations using the normal Nansen bottles with one unprotected and two protected reversing thermometers. Large volume water samples for C14 dating were taken in a specially constructed sampler from which the water could be pumped into suitable containers.

Bathythermographs, to 800 feet were taken while underway, using standard B.T. equipment on a light winch reserved for this purpose.

Biological Equipment

The standard biological equipment was used including the mid-water trawl, otter trawl, plankton trawl (meter net) and surface plankton nets.

ORGANIZATION OF THE EXPEDITION

The scientific party on this leg of the cruise numbered 16 and was under the leadership of Dr. R.L. Fisher. A continuous watch was maintained in both laboratories. The inner lab. watch maintained the gravimeter and magnetometor, the outer lab. watch being responsible for monitoring the Depth Recorder and for the bathythermograph programme.

On station, winch operators were drawn from the engine room staff, but otherwise the entire operation of handling, lowering and raising equipment was carried out by the scientific party. For this reason the scientific party included two experienced riggers, one of whom was also experienced in the handling of explosives for seismic work and in skin diving. The party also included an electronic technician for the maintenance of the instruments.

The critical factor in maintaining the ship's schedule was the ratio of station time to running time. By using the hydrographic and dredging winches alternately, station time was kept to a minimum but even then the main stations occupied from 17 to 24 hours. During this time a close liaison was maintained between laboratory and bridge to keep the ship in position and ensure that the wire angle was kept to a minimum while equipment was being lowered. A typical station programme is given below:

Station IV - 5. 15th December 1960

Position - 23°54.5'S; 73°50'E. Uncorrected depth 1880 fathoms.

Large volume water sample to 500 metres	dredging winch
" " " " " 1,000 metres	dredging winch
Deep hydrographic cast	hydro. winch
Large volume water sample to 3,000 metres	dredge winch
Bathythermograph	B.T. winch
Shallow hydrocast	hydro. winch
Seismic reflection shot	-
Piston core	dredge winch
Temperature probe	hydro. winch
Large volume water sample to 2,000 metres	dredge winch
Bottom camera	hydro. winch
Plankton tow	hydro. winch

Total Station Time 22 hours.

Although the approximate position of stations was laid down in the cruise plan, the actual position, and, within the same limits, the ships course, was decided on the spot, depending on such factors as the submarine topography, nature of the bottom etc. The watch keeper on the Depth Recorder was, therefore, virtually in charge of the ship.

EXPEDITION MONSOON, LEG IV: MAURITIUS TO FREMANTLE

Route followed

On leaving Port Louis a bathymetric survey of shoal waters off Mauritius was carried out, together with one shallow camera station, for the Dept. of Fisheries, Mauritius, following which base course was resumed. An easterly course was followed to 23°54.5'S; 75°50'E, then southerly to 43°S, north-easterly to St. Paul's Island and easterly to Fremantle via Diamantina Deep.

Submarine topography

Over most of the route followed the topography was diverse and rugged. Three crossings of the mid-Indian Ocean ridge were made. On each crossing it was found that the ridge was relatively low and by no means as prominent a feature as the corresponding mid-Atlantic ridge. It consisted entirely of a series of steep hills or ridges 300 to 400 fathoms high, separated by narrow, steep sided valleys with little evidence of sedimented slopes. The ridge itself was apparent only by a slight increase in the elevation of these hills and valleys above these on either side. The median rift valley (Ewing & Heezen 1960) was also found to be poorly developed and in the succession of prominent peaks and narrow valleys it was difficult to recognise a rift valley at all.

In the eastern sector of the Kerguelen Basin, which was entered on the run south, the bottom topography flattened a little, although remaining hilly, and no indication of a typical abyssal basin plain was apparent. It was not until the southern end of the West Australian Basin was entered, at about 100°E, 37°S, that the bottom topography typical of a well sedimented basin was seen. It seems likely that the rugged topography of this southern part of the Indian Ocean is due, not so much to extreme youthfulness of the Ocean, as to absence of sedimentation in an area which is effectively cut off from supply of sediments from the neighbouring continents.

A brief survey was made over the area in which the Diamantina deep was reported (approximately 105°E, 37°S). This deep, believed to be the deepest part of the Indian Ocean yet sounded, was recorded by H.M.A.S. Diamantina in 1960, but its recognition was based on two deep soundings (4,000 and 4,500 fathoms) in an area in which the average depth was 3,000 fathoms. The soundings were made by audible method on an unmodified Edo Depth Sounder. The Argo survey, on which frequent audio checks were made, revealed a deepest sounding of 3,088 fathoms in this area which was crossed several times. Good star fixes were obtained during the survey and despite poor bottom reflections a good bottom trace was recorded and it must be concluded that the Diamantina deep does not exist. No gravity or magnetic anomalies were recorded.

Bottom sediments

The gravity and piston cores taken in the vicinity of mid-Indian Ocean ridge all consisted of a fairly uniform, tenaceous, pale brown clay believed to be of volcanic origin. The material was only slightly calcareous although the upper few feet contained an increasing quantity of Globigerina tests.

An attempt to obtain a gravity core in position 27°48'S, 73°40.7'E, at a depth of 1900 fathoms, roughly on the centre of the mid-ocean ridge, resulted in the recovery of a few tiny chips of volcanic glass. A second lowering, with the inside of the core barrel coated with grease, brought up several large pieces of volcanic glass containing glassy feldspar phenocrysts and with an outer skin showing small scale ropy structure and many minute gas blisters and pits.

Rock dredging on a sea-mount well to the east of St. Paul's Island was unsuccessful, but a sample of clean foraminiferal sand was brought up in a pipe dredge.

From this brief reconnaissance, detrital sediments and red clays and organic sediments seem to be rare in the central-southern Indian ocean, and the rough bottom topography is due largely to volcanic rocks and clays.

Bottom photography

Photographs taken in shoal waters off Mauritius showed an abundance of marine bottom life on a typical (?) littoral deposit.

Of several deeper camera stations, one was unsuccessful due to maladjustment of the flash reflector, and one to multiple bottom echoes confusing the Depth Recorder trace so that the camera did not reach bottom. Colour film was used on several stations and could not be processed on board, but a number of good quality black and white photographs were obtained on stations on the mid-ocean ridge. Copies of these should be available shortly.

Heat flow measurements

Heat flow measurements were taken on all stations where there was sufficient thickness of bottom sediment and where a core was available for conductivity measurement. Several anomalously high readings were obtained and several low ones, but, although a full analysis of the readings is not yet available, there did not seem to be any general increase in heat flow on the mid-ocean rise as might have been expected from heat-flow work in the Pacific.

Magnetic and gravity

Again, analysis and reduction of the results has not yet been carried out, but it would seem from preliminary inspections of the results that no spectacular gravity anomalies were recorded. Several well defined magnetic anomalies were apparent but there was not time to determine their trend or true significance. It seems likely that a linear total intensity pattern, similar to that in the east Pacific, may exist in the south-eastern Indian ocean.

Seismic work

Although no seismic refraction work was undertaken on this leg of the cruise, several reflection shots were fired. These were not particularly successful, being affected by extraneous noises and vibrations, and very poor sub-bottom reflections were obtained. Seismic reflection shooting at sea is not, apparently, a very satisfactory method.

Hydrology.

Hydrographic casts to the bottom were made on all main stations and samples were analysed on board for total salinity, carbon dioxide, oxygen and silicates. The most interesting results were found in the vicinity of the sub-antarctic convergence.

Bathythermograph readings were taken every two hours while under-way, and large volume water samples at main stations. It is hoped that C_{14} dating of these samples will provide information on the movement of water masses.

Biology

The biological operations were perhaps the most spectacular and successful of the cruise. Mid-water trawls yielded an excellent haul of deep-sea life including hatchet fish, lantern fish, angler fish, gulpers, eel larvae, stomiatids, deep sea squids, crustaceans, jellyfish etc. Regular plankton tows for productivity measurement, surface plankton, night-lighting etc. were also carried out. Only the otter trawling for deep sea bottom life was unsuccessful.

St. Paul's Island

A landing was made on St. Paul's, a remote volcanic island in the southern Indian Ocean (position $38^{o}43$'S; $77^{o}30$'E). A suite of specimens was collected and a geological sketch map prepared. The island is approximately 3 miles long by 2 miles wide with a central caldera, one mile in diameter, open to the sea on the west side. The rim of the caldera is some 250 metres above sea-level. The basal part of the exposed volcanic cone is comprised of tuffs and agglomerates, including much palagonitic material, with thin lava flows, and was apparently erupted below sea-level. These are overlain by a thick pile of very thin, seaward dipping basalt flows with thin interbeds of scoriae representing effusive, sub-aerial eruption of an extremely fluid lava. On the west and south coasts of the island a series of small cinder cones overlies the basalt flows and appear to represent the last stages of volcanic activity. Several hot springs and patches of warm ground were noted. A detailed bathymetric survey of the adjoining waters was also carried out and heat flow measurements made.

A short publication on the geology of St. Paul's is being prepared.

CONCLUSION

The opportunity to join Expedition Monsoon provided valuable experience in marine geology and geophysics and in the operation of an oceanographic research vessel. The following points are particularly noted.

1. The size of research vessel Argo was appreciated in the rough weather encountered south of 35°S, but it is felt that, in general, a smaller vessel is more suited to intensive oceanographic research. The larger scientific party necessary, or at least desirable, on a large vessel limits the time available for individual investigations.

2. For most marine geological and geophysical investigations the scientific party, under a leader of wide experience, should control the movements of the ship on all occasions, except where the question of the safety of the ship arises.

3. While the depth sounder and other continuous recording instruments can be monitored by a technician or other non-professional personnel, the presence of an experienced marine geologist to interpret results and, if necessary, alter the cruise plan and schedule accordingly, is essential.

4. Adherence to a tight schedule and inflexible cruise plan may reduce the scientific value of the cruise severely.

5. The amount of shipboard work possible on sediment cores etc. is very limited and only essential work should be attempted. Cores should be stored undisturbed and preferably chilled.

6. With the passing of the era of spectacular discoveries in oceanography and the beginning of a period of systematic research and more detailed investigation, the Precision Depth Recorder or Precision Graphic Recorder is an essential piece of equipment, and the Sonar Pinger, used in conjunction with the depth recorder, is an extremely valuable tool.