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REPORT
of the
UNITED STATES PARTICIPATION
in the
INTERNATIONAL INDIAN OCEAN EXPEDITION

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National Science Foundation

July 20, 1962

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ORGANIZATION AND HISTORY

The International Indian Ocean Expedition (IIOE) was conceived at the first meeting of the Special Committee of Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU) in September 1958. United States participation was initially planned by the Committee on Oceanography of the National Academy of Sciences (NASCO). The preliminary plan was presented to the Federal Council of Science and Technology in May 1960, and approval for United States participation was announced by the White House on June 13, 1960. Scientific responsibility for the United States participation was assigned to the National Academy of Sciences - National Research Council, and the National Science Foundation was directed to plan and coordinate Federal support for United States participation in the program.

At the request of the Director of the National Science Foundation, other Federal agencies with potential interest in the IIOE appointed representatives to serve as single points of contact and facilitate communication among the agencies. As a result of meetings of these representatives held during the summer of 1960, it was determined that the preliminary plans were inadequate to carry out the stated aims of the IIOE, particularly in the areas of biological oceanography and of air-sea interaction, and following international meetings held by SCOR at Copenhagen and Helsinki in July 1960, NASCO enlarged its Indian Ocean Expedition Panel, set up five Working Groups (Biology; Geology, Geophysics, and Bathymetry; Meteorology; Physical and Chemical Oceanography; and Expedition Data, respectively), and drew up an enlarged program for U. S. participation.

During the spring of 1962 it was agreed between SCOR and the new International Oceanographic Commission (IOC) that henceforth the Secretary of the IOC would have responsibility for coordination of the IIOE. Simultaneously NASCO, as the United States adhering body to SCOR, has felt it inappropriate for it to continue to coordinate the United States participation in the IIOE, and full responsibility for the United States program thus has been assumed by the National Science Foundation.

FINANCIAL SUPPORT

The original Presidential directive in June, 1960, provided that United States participation in the IIOE would be funded by normal budgetary process. Accordingly, the United States Navy, historically the chief Federal sponsor of basic research in oceanography through its Office of Naval Research, agreed to permit vessels whose operations it finances through research contracts at Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, and Lamont Geological Observatory to undertake cruises to the Indian Ocean. Likewise the data-processing facilities at the Navy Oceanographic Office were put at the disposal of the U. S. participants, and survey vessels in the Indian Ocean were assigned to make oceanographic observations in support of the IIOE.

The National Science Foundation, which supports research through grants made as the result of applications proposing specific research projects, encouraged United States research institutions to submit proposals for research connected with the IIOE, and took steps to augment its available research funds by the inclusion of a special item for the IIOE, commencing with its Fiscal Year 1962 budget.

Other Federal agencies have been less successful in obtaining the additional funding required to permit them to operate themselves in the Indian Ocean or to support research there in fields related to their specific missions, and in some cases the National Science Foundation has transferred funds to enable these agencies to carry out urgent programs related to the IIOE.

The following tabulation, extracted from the 1963 National Oceanographic Program, prepared by the Interagency Committee on Oceanography of the Federal Council of Science and Technology, (with the addition of information from the U. S. Weather Bureau) summarizes planned Federal support of the U. S. participation in the IIOE through Fiscal Year 1963:

THOUSANDS OF DOLLARS

Fiscal Year	<u>1961</u>	<u>1962</u>	<u>1963</u>
USN	760	580	1,300
NSF	-	1,500	4,000
Bur.Com.Fish.	-	-	70
Weather Bureau	-	-	792

SCIENTIFIC PROGRAM BY DISCIPLINES

The United States program for the IIOE, in accordance with the original stated aims of the expedition, is devoted to the scientific examination of four great areas of interest in the Indian Ocean. The first of these concerns itself with the problems of why there is an ocean basin in the first place; what are the forces that have shaped and are continuing to shape the basin; what are the resemblances between this piece of the earth's crust and any other; and how is the basin of the Indian Ocean dissimilar from other ocean basins? The techniques used in attempting to answer these questions are primarily geophysical and geological, and they have been or will be employed on expeditions sent out by Scripps Institution of Oceanography, Lamont Geological Observatory, Stanford University, and Woods Hole Oceanographic Institution.

The second broad area of investigation involves the chemical and physical description of the waters of the Indian Ocean, and the study of their motions. The techniques used involve sampling of the waters in predetermined patterns, with respect both to horizontal distribution and to vertical spacing of the samples; concurrent precise measurements of water temperature; subsequent chemical and isotopic analyses of the water samples; and determination of current flow at

various depths by all possible means. All United States ships participating in the IIOE will be equipped for such water sampling, and the direct measurement of current flow is the particular object of a University of Rhode Island expedition embarked in the Scripps Institution vessel ARGO.

The third major field of interest is the living populations, plant and animal, of the Indian Ocean. All United States ships will be equipped to sample plankton and to observe surface biological phenomena, and some will measure primary productivity. The research vessel ANTON BROUW will have biological oceanography as her primary mission, and the Stanford University vessel TE VEGA will concentrate on biological and physiological studies of island groups and other shallow water areas.

The fourth main area of research is concerned with the interaction between the ocean and the atmosphere. Several of the U. S. research vessels that will work in the Indian Ocean will be equipped to make upper-air meteorological observations, but the United States will have the greater part of its meteorological effort based ashore. Observations from meteorological aircraft of the U. S. Weather Bureau and of Woods Hole Oceanographic Institution, working in connection with the International Meteorological Center that has been established with the assistance of the Government of India and the United Nations Special Fund; from meteorological satellites; and from meteorological buoys (to be planted in the Bay of Bengal and Arabian Sea with the help of the Indian Navy), will be utilized in the program.

SCIENTIFIC PROGRAMS OF INSTITUTIONS

As indicated in the preceding paragraphs, research programs of all United States vessels participating in the IIOE will contribute to at least two of the four fundamental areas of interest; many will contribute to three; and some to all four. For this reason, it is more practical to describe the programs in detail by setting forth the past, present, and planned cruises of each institution.

SCRIPPS INSTITUTION OF OCEANOGRAPHY

The Scripps Institution of Oceanography of the University of California at San Diego plans to undertake three major cruises to the Indian Ocean under the overall direction of Dr. Robert L. Fisher. The first of these, called MONSOON, was carried out by the research vessel ARGO according to the following itinerary:

<u>1960</u>	<u>Schedule</u>	<u>Program</u>
19 October	ARGO left Darwin	Geological-geophysical exploration, under Dr. R. L. Fisher. Emphasis on two-ship seismic refraction work between Darwin and Jakarta.
23 October	Joined by M/V MALITA	
13 November	MALITA detached	
14 November	ARGO arrived Jakarta	
18 November	ARGO left Jakarta	Same program, except for seismic refraction. Emphasis on heat flow, large-volume water-sampling; topography.
7 December	Arrived Mauritius	
10 December	Left Mauritius	

1961

2 January	Arrived Fremantle	Same
6 January	Left Fremantle	
15 January	Arrived Hobart	
17 January	Left Hobart	
22 January	Arrived Wellington	

The following observations were made between Darwin and Wellington:

Underway Observations

Precision depth recordings	17,000 miles
Gravimeter recordings	15,500 miles
Towed proton precession magnetometer recordings	16,000 miles
Insect collection, nets on superstructure	13,800 miles
Bathythermograms	618
Surface water samples (for radio caesium).	29

Station Operations

Seismic refraction stations	16
Gravity cores	48
Piston cores	6
Heat flow measurements by temperature probe	33
Hydrographic casts to bottom	18

Station Operations (Continued)

Special 2-liter water samples	13 stations
Midwater trawl hauls	13
One-meter standard plankton tows	18
17-cm vertical microplankton hauls	49
Bottom samples (biological)	7
Rock dredges	6
Large-volume water samples (C ¹⁴ and trace elements)	18 stations
Bottom photography	18 stations

In addition, some seismic reflection shooting was carried out, occasional air samples were taken, gravity was measured in ports of call; rocks and biological specimens were collected in ports of call; and large organisms were dip-netted at light lures on most night stations.

The second Scripps cruise, called LUSIAD, is also being carried out by the R/V ARGO, according to the following itinerary:

<u>1962</u>	<u>Schedule</u>	<u>Program</u>	
27 June	Leave Singapore	Studies of equatorial circulation during one monsoon season, under Dr. John Knauss. Hydrographic casts and direct current observations with the aid of anchored buoys.	
24 July	Arrive Mombasa		
27 July	Leave Mombasa		
25 August	Arrive Colombo		
28 August	Leave Colombo		
25 September	Arrive Cochin		
1 October	Leave Cochin		
26 October	Arrive Port Louis, Mau.		
28 October	Leave Port Louis		
29 November	Arrive Fremantle		
2 December	Leave Fremantle	In company R/V HORIZON: two-ship seismic refraction work under Drs. George G. Shor, R. W. Raitt, and R. L. Fisher. Bottom-sampling; hydrographic casts; heat-flow measurements. C ¹⁴ collections under Dr. N. W. Rakestraw. Topography, magnetism, gravity, underway measurements; under Dr. R. L. Fisher.	
23 December	Arrive Port Darwin		
27 December	Leave Port Darwin		
<u>1963</u>			
15 January	Arrive Jakarta		
18 January	Leave Jakarta		
14 February	Arrive Visakhapatnam		
17 February	Leave Visakhapatnam		
15 May	Arrive Mombasa	Repeat equatorial circulation during second monsoon, under Dr. Knauss. Geological-geochemical-geophysical observations under Drs. George Bien, John Belshé, and Charles Keeling.	
18 May	Leave Mombasa		
7 June	Arrive Cape Town		

The itinerary of the R/V HORIZON during LUSIAD is scheduled as follows:

<u>1962</u>	<u>Schedule</u>	<u>Program</u>
16 September	Leave Suez Arrive Aden	Conduct underway reflection profiling of Red and Arabian Seas.
17 September	Leave Aden	
27 September	Arrive Cochin	
1 October	Leave Cochin	In company R/V ARGO; two-ship
26 October	Arr. Port Louis, Mau.	seismic refraction work under
28 October	Leave Port Louis	Drs. George G. Shor, R. W. Raitt,
29 November	Arrive Fremantle	and R. L. Fisher. Bottom-sampling,
2 December	Leave Fremantle	hydrographic casts, heat-flow
23 December	Arrive Port Darwin	measurements.

Besides serving as consort to the R/V ARGO between Cochin and Port Darwin, the HORIZON will carry out hydrographic studies between Suez and Cochin and from Port Darwin she will return to San Diego via the Pacific. Figure 1 shows the tract of MONSOON and Figure 2 that of LUSIAD.

The third planned Scripps cruise will be carried out by the R/V SPENCER F. BAIRD between February and May 1964 under W. R. Riedel. Emphasis will be on detailed stratigraphic, geochemical, and heat flow development in the central and eastern Indian Ocean where earlier cruises have indicated areas of especial interest. Continuous underway magnetometer recordings will also be made.

LAMONT GEOLOGICAL OBSERVATORY

Three cruises of the R/V VEMA have been planned as part of the IIOE.

VEMA 16 Itinerary Figures 3 and 4

27 December	59	Left Cape Town
22 January	60	Arrive Mauritius
25 January	60	Left Mauritius
22 February	60	Arrive Fremantle
26 February	60	Left Fremantle
14 March	60	Arrive Adelaide
16 March	60	Left Adelaide
31 March	60	Arrive Wellington

Under the direction of C. Fray, as Chief Scientist, VEMA made the passage from Cape Town to Mauritius and from Mauritius to Fremantle. More than 8300 miles of topographic track was recorded with a precision depth recorder in the southern Indian Ocean. The existence of a

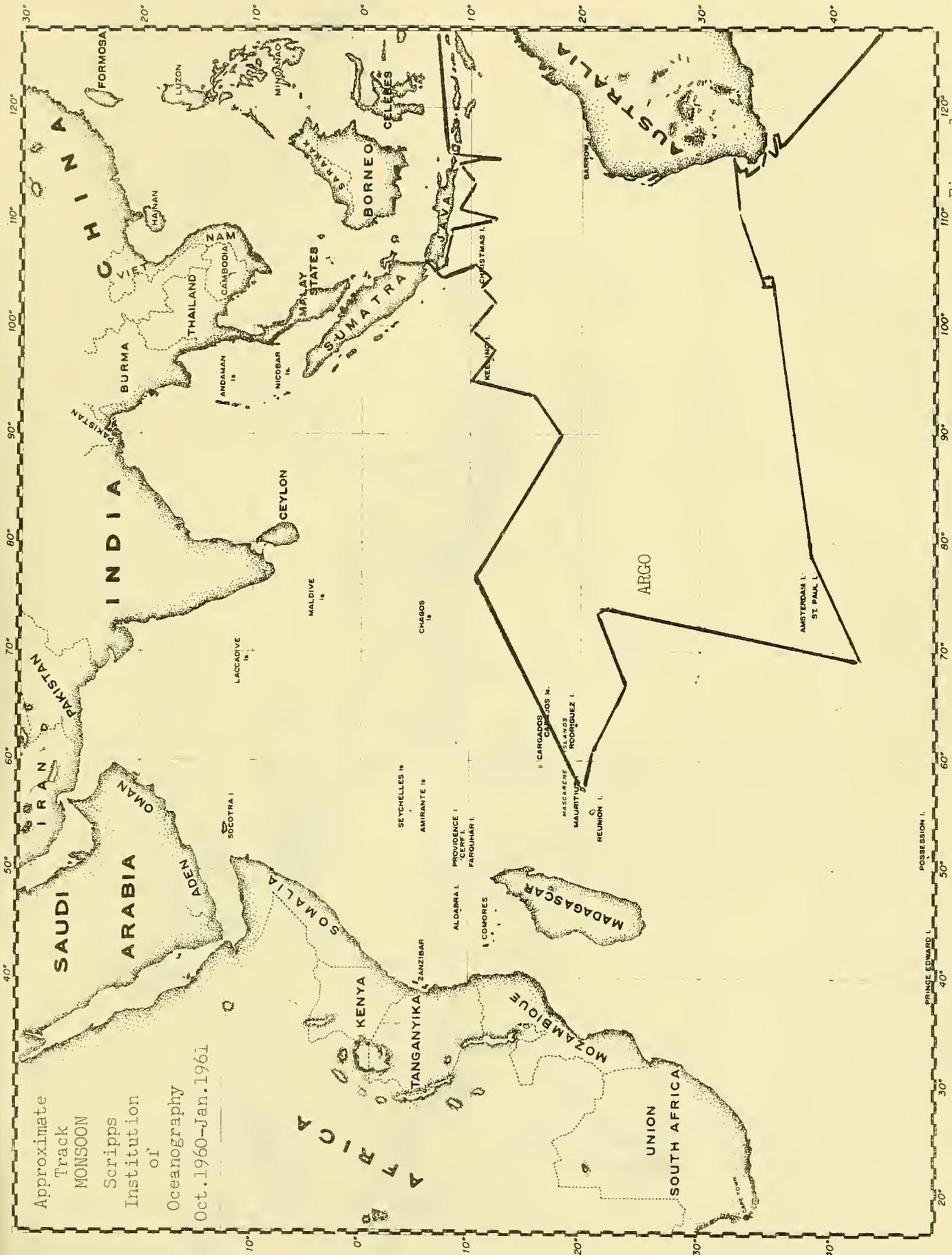


Figure 1.

mid-ocean ridge and associated rift valley was verified by six crossings of this topographic feature. A towed magnetometer produced a continuous plot of the total intensity of the earth's magnetic field along the ship's track. Forty-seven piston cores of the bottom sediment were obtained. Multiple photographs of the bottom were taken at 23 stations. Thirty hydrographic stations were occupied and consisted of serial observations of temperature, salinity, and oxygen. Sixteen large volume water samples, representative of all of the water masses, were collected for C-14 age determination. Biological collections included 11 bottom trawls and 80 plankton samples. Additional observations included measurements of the heat flow through the ocean floor, and propagation of sound through the SOFAR channel.

Under the direction of John E. Nafe, as Chief Scientist, VEMA made passages from Fremantle to Adelaide and from Adelaide to Wellington. During the early part of this program seismic refraction measurements were undertaken in cooperation with HMAS DIAMANTINA. During the remainder of the passage the program of observations under way and at stations was closely similar to that of the Cape Town to Fremantle traverse.

VEMA 18 Itinerary

Figure 5

3 June	62	Leave Cape Town
20 June	62	Arrive Mauritius
22 June	62	Leave Mauritius
12 July	62	Arrive Fremantle
14 July	62	Leave Fremantle
1 August	62	Arrive Wellington

Manik Talwani, as Chief Scientist, directed the work of VEMA from Cape Town to Mauritius. Marcus Langseth was in charge from Mauritius to Wellington. The underway program included continuous magnetic, topographic, gravity, and seismic reflection measurements. At the Stations cores and Camera Stations were the most common combinations, with more emphasis than usual being placed on plankton sampling. In the area south of Australia a number of bottom trawl stations have been occupied. The passage from Bass to Wellington will begin about July 25th. Particular emphasis is placed on comparison of total sediment thickness with that found in the Atlantic Ocean.

VEMA 19 (1963)

VEMA 19 (1963) is being planned to enter the Indian Ocean via either Suez or Cape Town, proceeding to Kerguelen and thence to Fremantle. The new R/V CONRAD, to be operated by Lamont Geological Observatory, will also spend three months in the Indian Ocean in 1963.

During all VEMA cruises, the following program is being carried out under the supervision of the investigators named. Dr. Maurice Ewing is the principal investigator on all VEMA cruises.

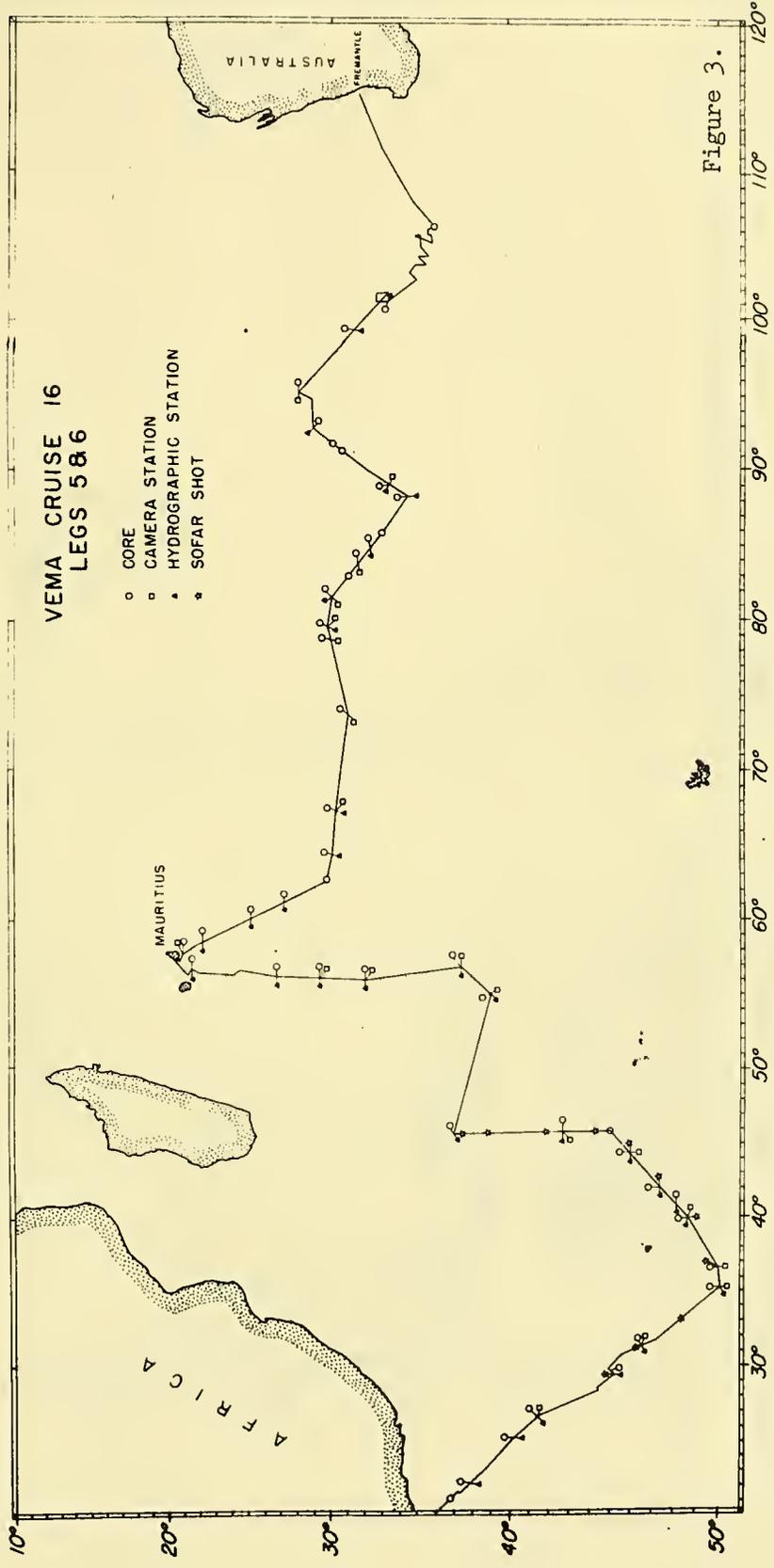
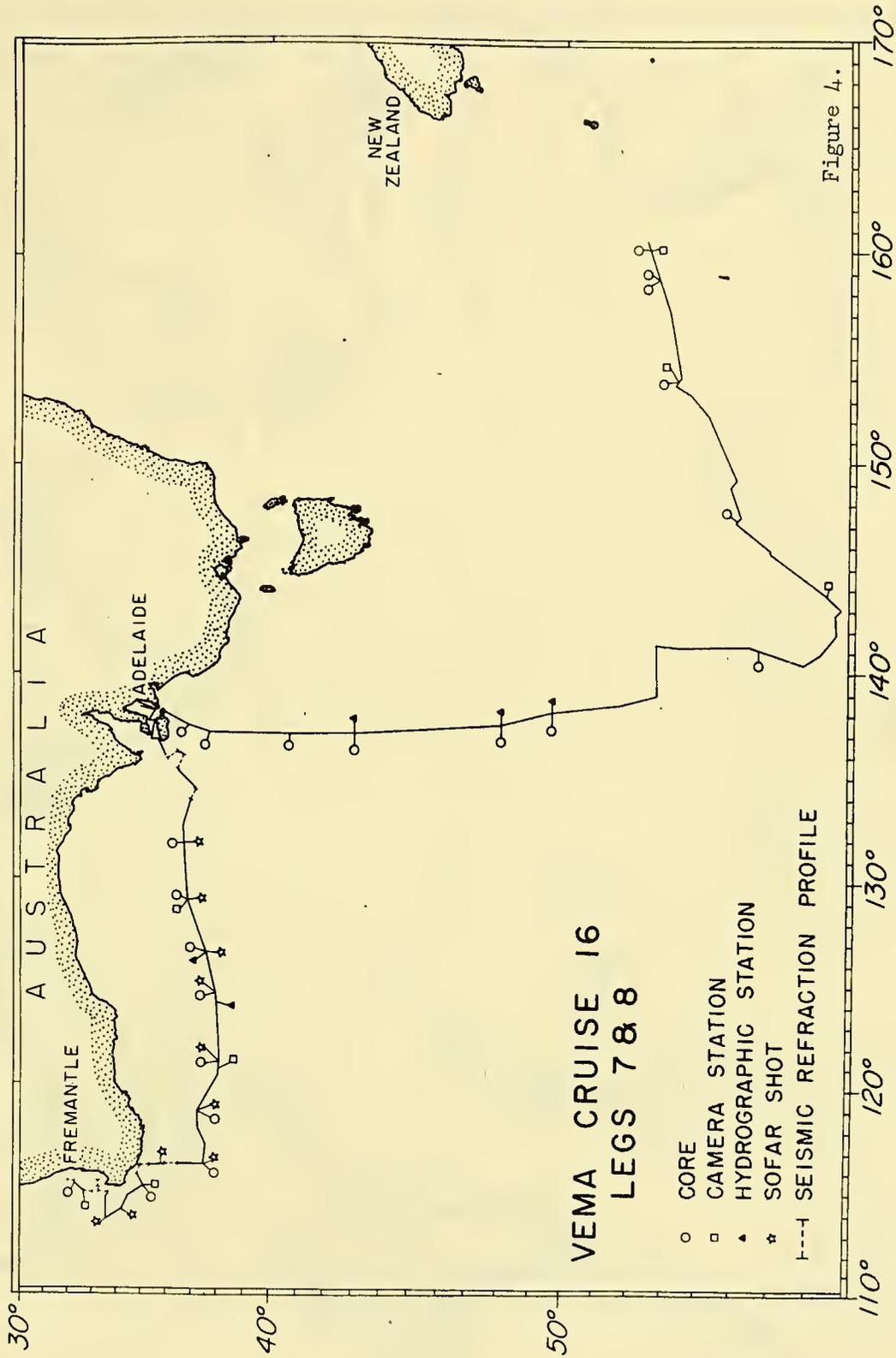


Figure 3.



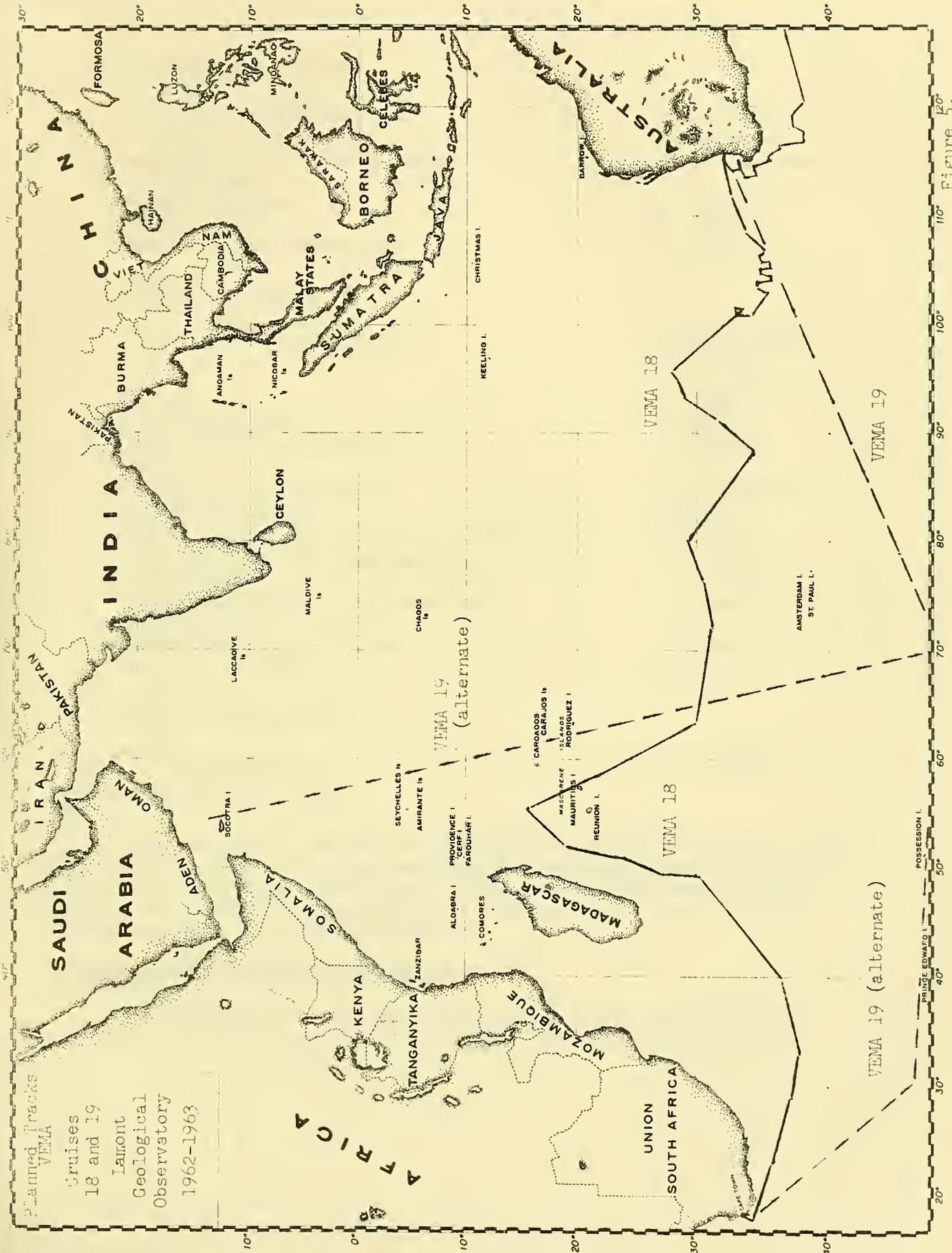


Figure 5.

Underway Observations

Precision depth recordings	Bruce Heezen
Gravimeter recordings	J. L. Worzel
Magnetometer total field intensity recordings	J. R. Heirtzler
Bathythermograms	R. Gerard
Seismic reflection	J. I. Ewing
Surface water temperature	M. Ewing

Station Operations

Seismic refraction profiles	(Charles Drake J. E. Nafe J. I. Ewing)
Gravity cores	C. Fray
Hydrographic casts	R. Gerard
Large-volume samples for C ¹⁴ , H ³ , Sr, Cs	W. Broecker
Microbiological sampling	P. R. Burkholder
Plankton sampling	Alan Bé
Bottom trawling for biological specimens	Alan Bé
Sound velocity and transmission measurements	J. I. Ewing
Bottom temperatures and temperature gradients	M. Langseth
Bottom dredging for rocks	C. Fray
Bottom Photography	M. Ewing

In Port observations

Rock collections	C. L. Drake
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UNIVERSITY OF RHODE ISLAND

Under Dr. John A. Knauss, the Narragansett Marine Laboratory of the University of Rhode Island is carrying out two three-month studies of the equatorial current circulation in the Indian Ocean aboard the R/V ARGO, whose cruise itinerary has been given above. Planned locations of the sections are shown in Figure 6.

WOODS HOLE OCEANOGRAPHIC INSTITUTION

The Woods Hole Oceanographic Institution, under the direction of Dr. Paul Fye, is planning the following cruises to the Indian Ocean.

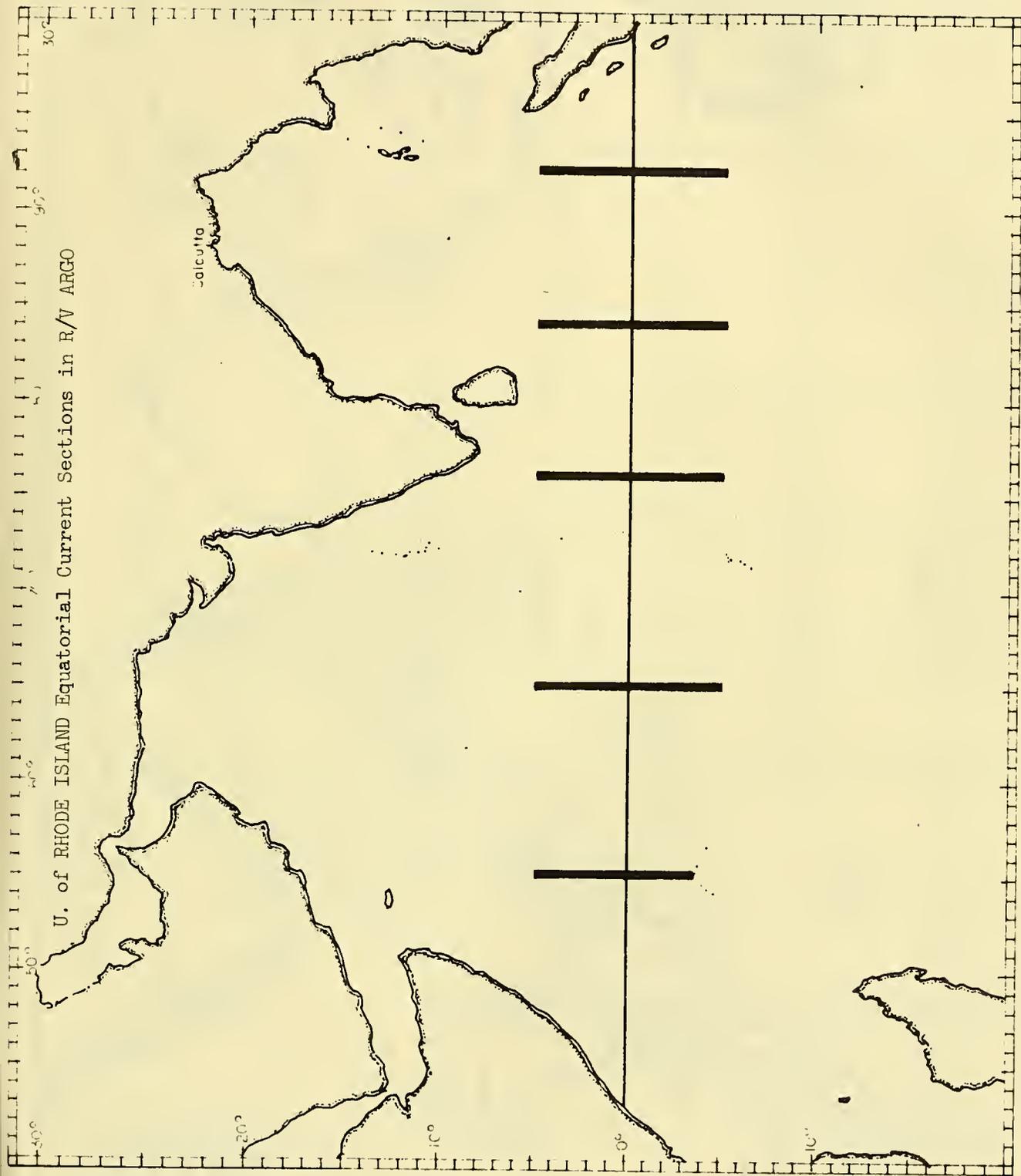
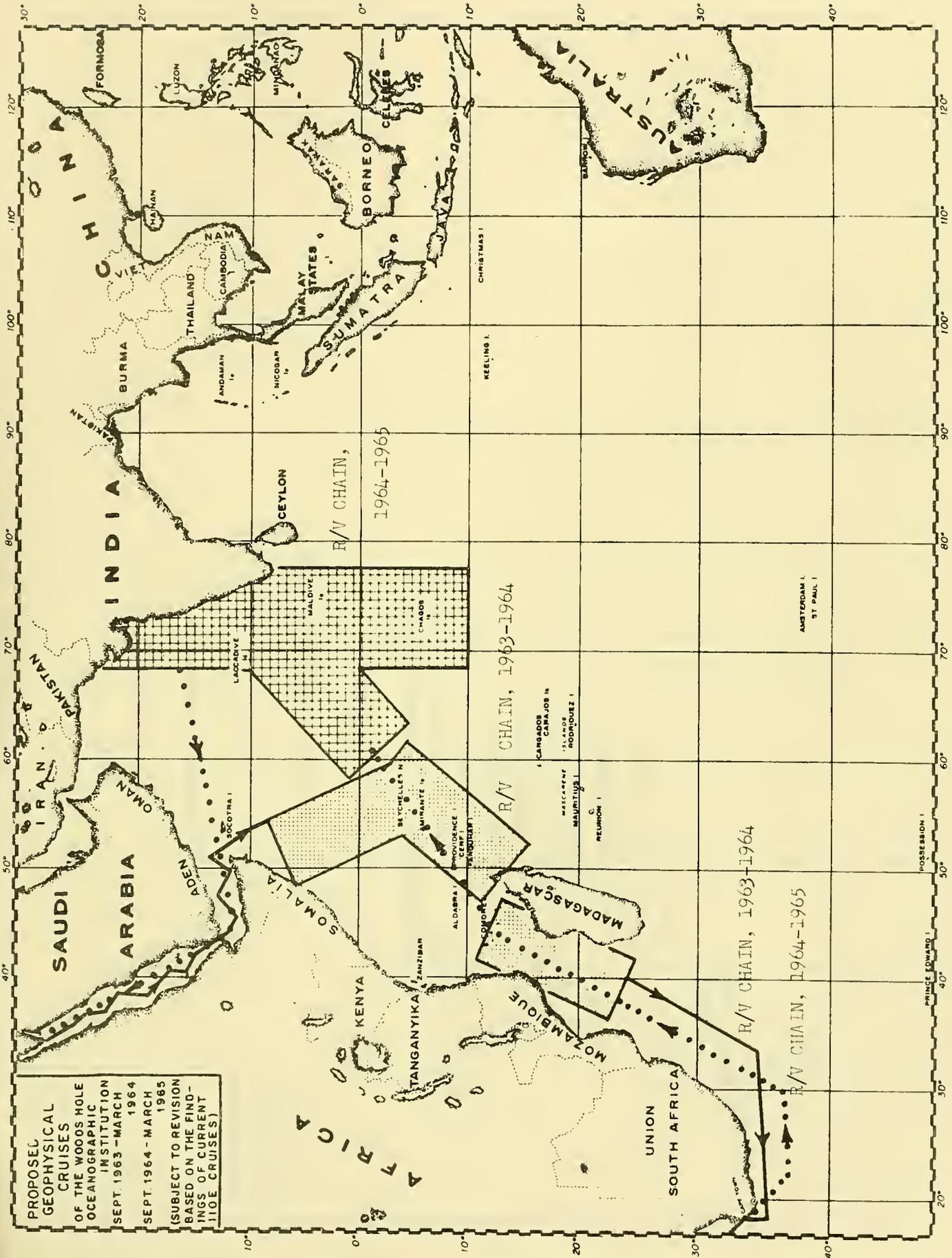


Figure 6.



PROPOSED
GEOPHYSICAL
CRUISES
OF THE WOODS HOLE
OCEANOGRAPHIC
INSTITUTION
SEPT. 1963 - MARCH
1964
SEPT. 1964 - MARCH
1965
(SUBJECT TO REVISION
BASED ON THE FIND-
INGS OF CURRENT
IIOE CRUISES)

R/V CHAIN,
1964-1965

R/V
CHAIN, 1963-1964

R/V CHAIN, 1963-1964

R/V CHAIN, 1964-1965

Figure 7.

1963

June - November ATLANTIS II Physical and chemical studies in Red and Arabian Seas and Agulhas Current (Figure 8)

September

1964 CHAIN Geophysics and submarine geology between Socotra and Cape Agulhas (Figure 7)

March

September

1965 CHAIN Geophysics and submarine geology, Cape Agulhas to Laccadives, Chagos to India, India to Suez (Figure 7)

March

February - July ATLANTIS II Physical and chemical studies in Red and Arabian Sea and Agulhas Currents (Figure 8)

The programs indicated for the CHAIN and ATLANTIS II respectively are the primary ones. The CHAIN cruises will also include physical and chemical oceanography and the ATLANTIS II cruises geophysics and submarine geology.

Key scientists involved in the above programs are: Earl E. Hays, J. B. Hersey, C. O'D. Iselin, and A. R. Miller.

In addition, the Woods Hole Oceanographic Institution will also have scientific responsibility for the operation of the R/V ANTON BRUUN, which will be devoted primarily to biological work. Under the direction of Dr. John H. Ryther, assisted by Dr. Edward Chin, the following schedule has been established:

1963

February - April 1. Bay of Bengal, Andaman Sea, and Nicobar Islands, A. B. (Figure 9)

May - July 2. Bombay-Colombo-Mauritius-Bombay, A, C. (Figure 10)

August - September 3. Bombay - 40°S - Tamatave, A. C. (Figure 9)

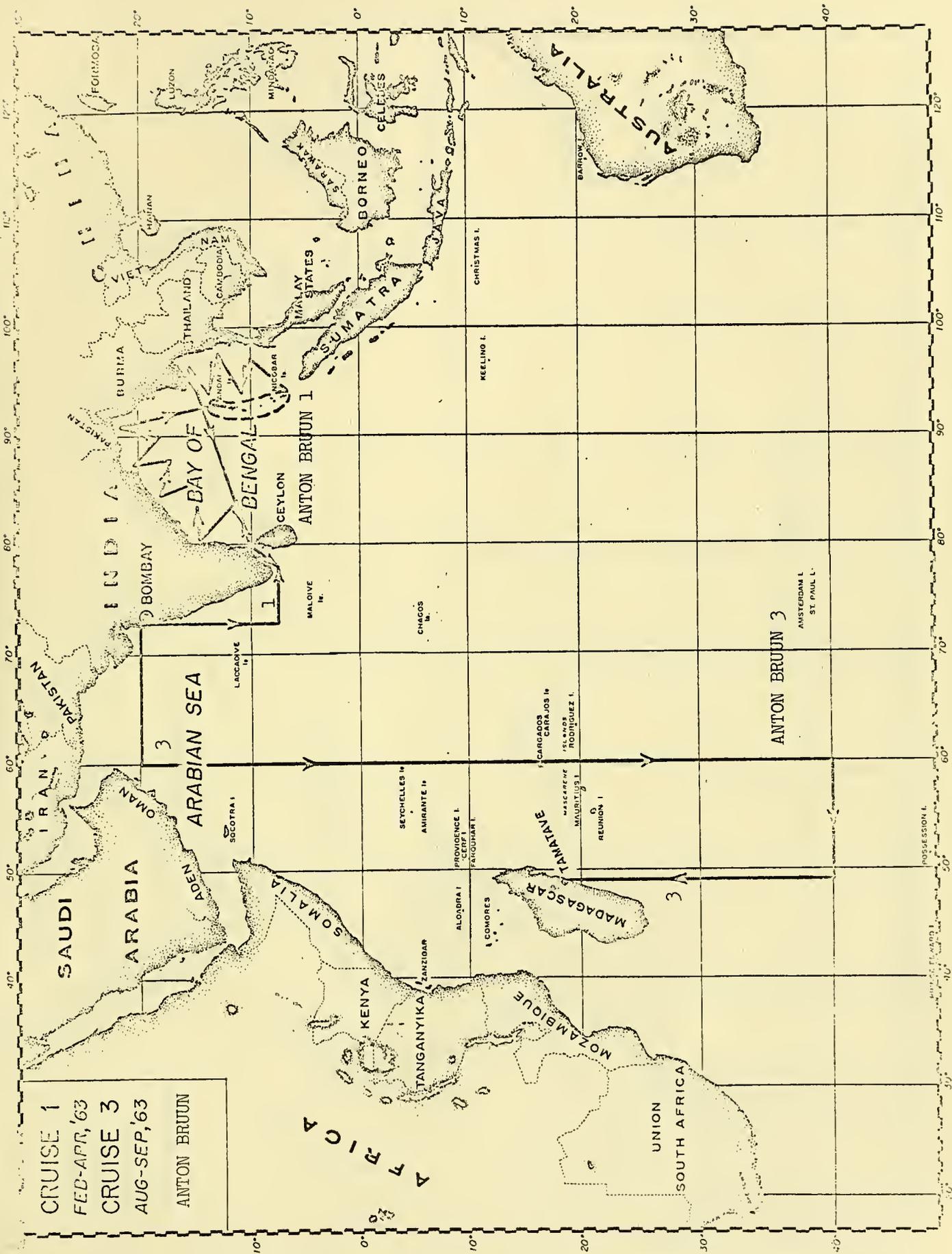
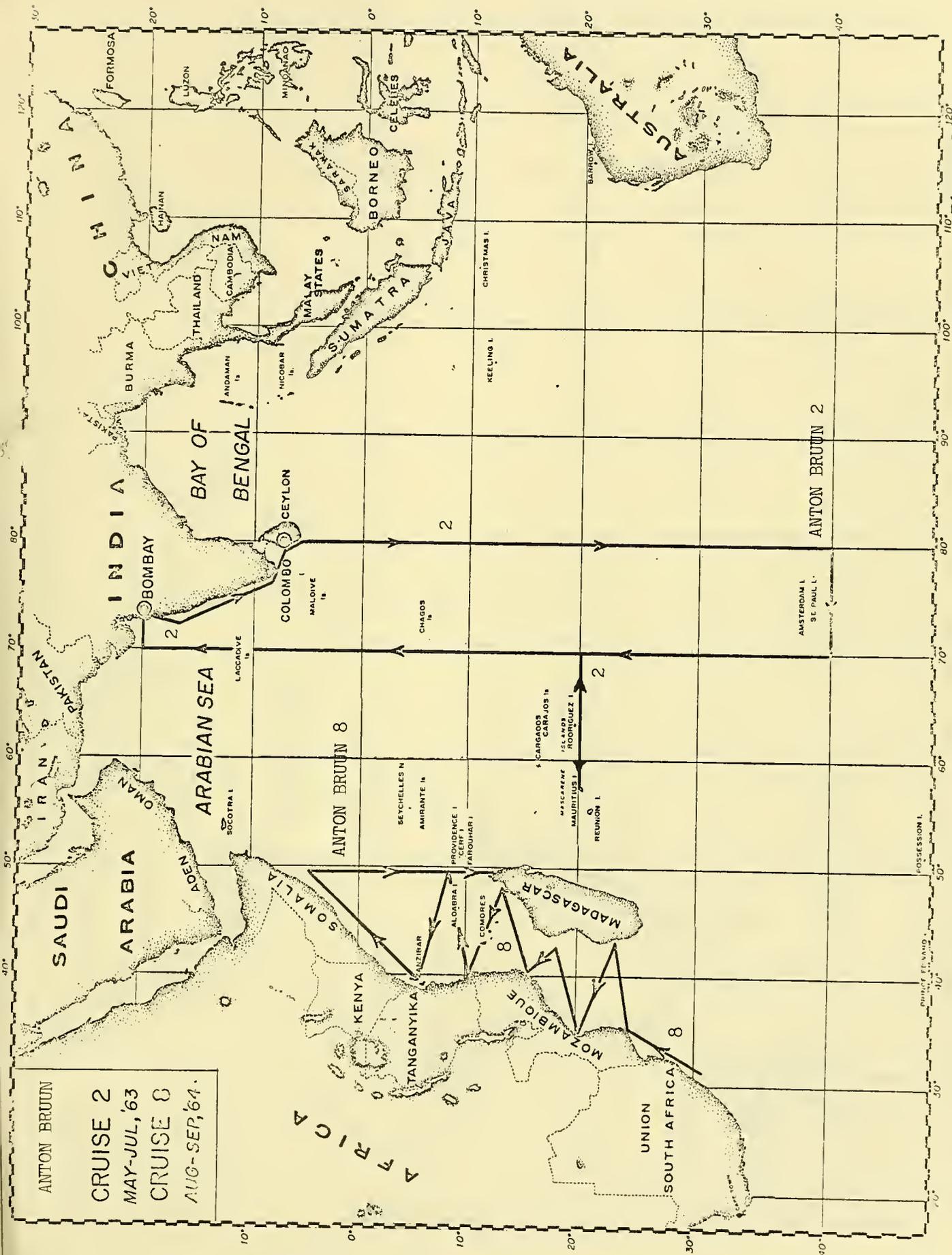


Figure 9.



ANTON BRUUN
 CRUISE 2
 MAY-JUL, '63
 CRUISE 6
 AUG-SEP, '64.

Figure 10

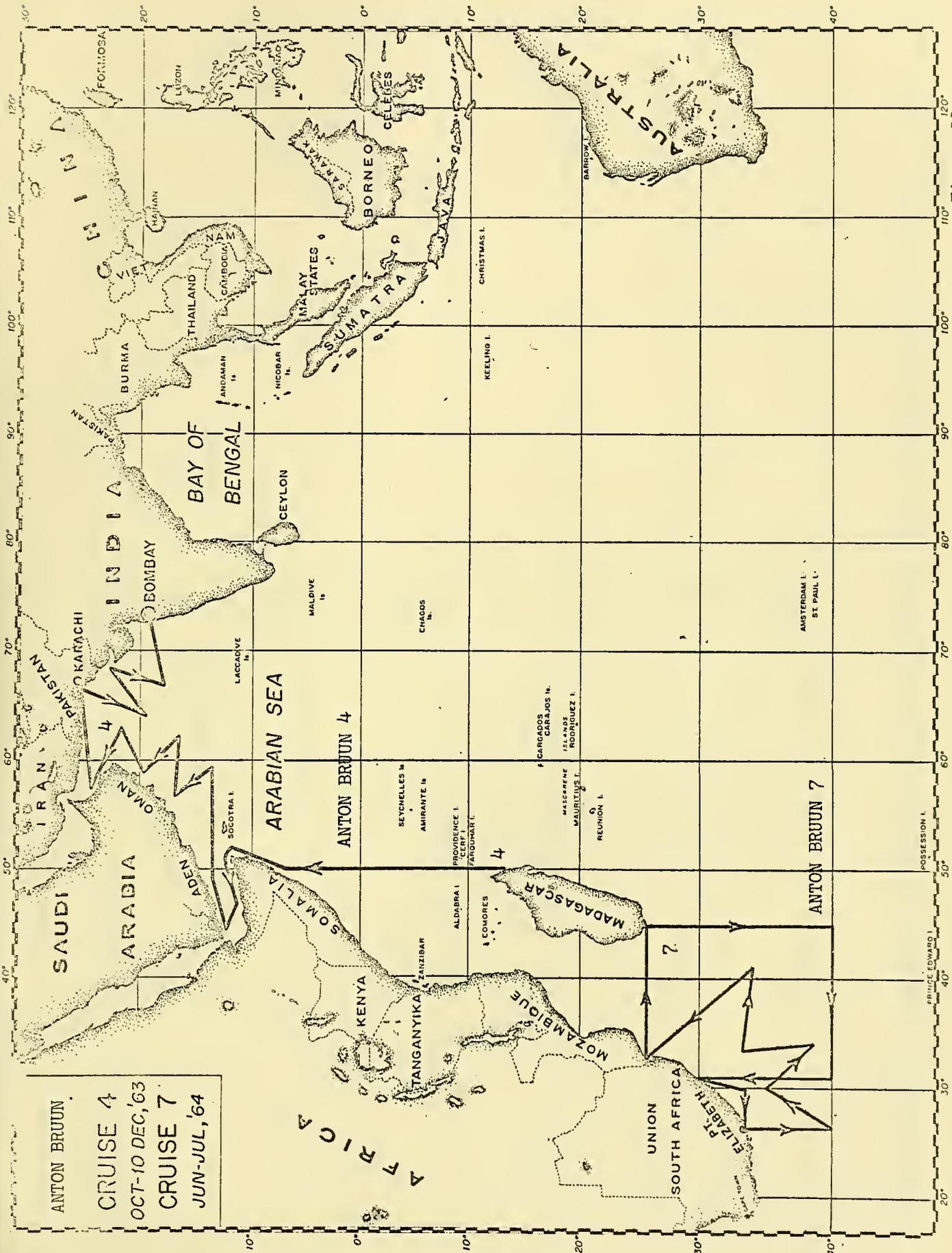


Figure 11

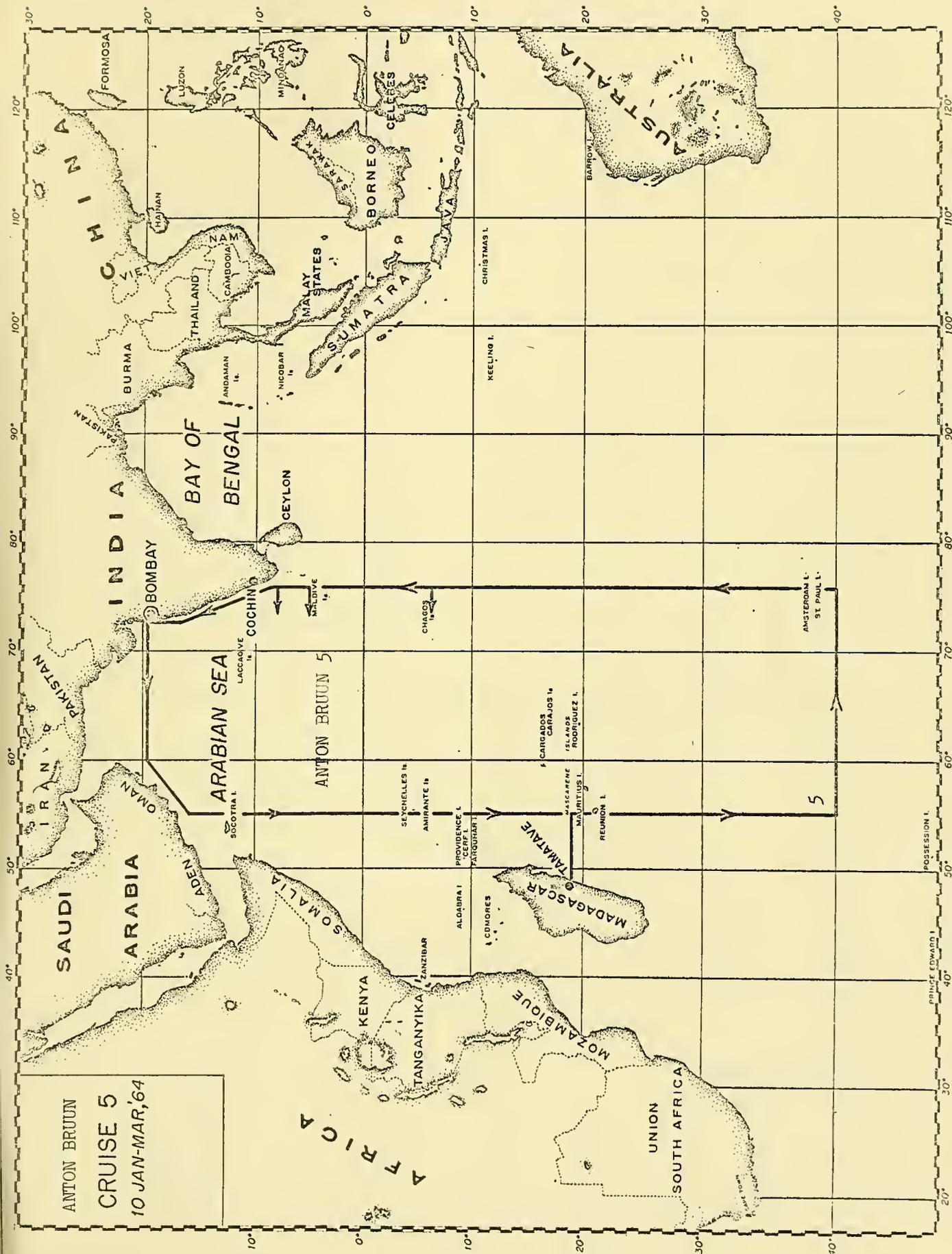
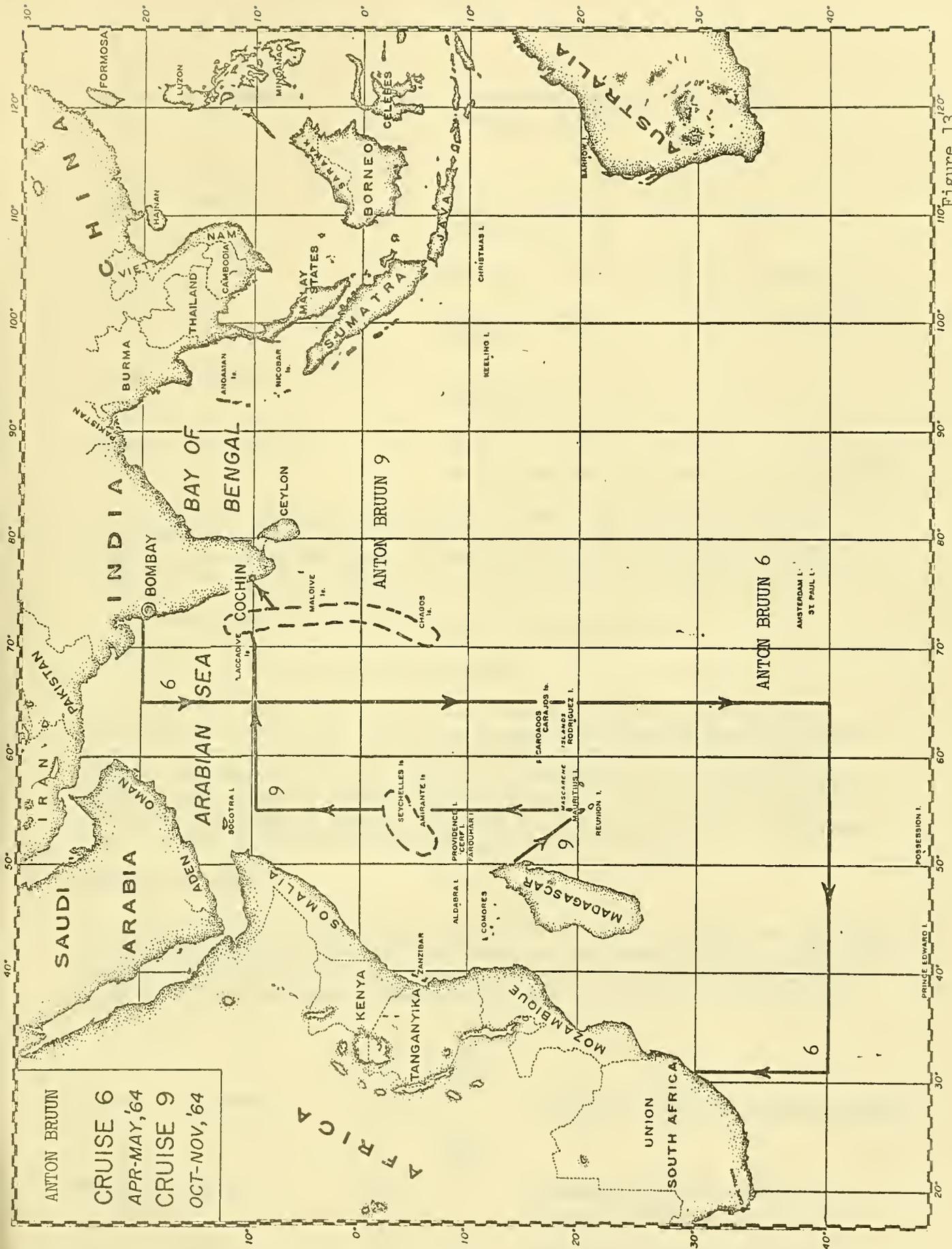


Figure 12



ANTON BRUUN
 CRUISE 6
 APR-MAY, '64
 CRUISE 9
 OCT-NOV, '64

Figure 13

October - December 4. Arabian Sea and Gulf of Aden, A, B.
(Figure 11)

1964

January - March 5. Bombay-Mauritius - 40°S - Bombay, A, C.
(Figure 12)

April - May 6. Bombay - 40°S - Durban, A, C. (Figure 13)

June - July 7. Agulhas Current, A, B. Deep water benthos.
(Figure 11)

August - September 8. Mozambique and Somali Currents, A, B.
(Figure 10)

October - November 9. Nosy Be - Reunion - Bombay, A, B. diving
and collecting from small boats (Figure 13)

A. Complete hydrographic stations to the bottom, light penetration measurement, primary production (C^{14}), phytoplankton pigments, zooplankton sampling from selected depth intervals, mid-water trawl hauls. Station intervals 120 mi on meridional sections, closer on coastal cruises.

B. Dredging and bottom trawling on continental shelf.

C. Midwater and/or surface collecting.

Under the direction of Professor Andrew F. Bunker, Woods Hole Oceanographic Institution will also operate a four-engined meteorological aircraft over the Indian Ocean during 1962, 1963, and 1964. The plane will be instrumented for the large-scale determination of turbulent transport and the various terms in the heat budget. Four six-week trips are planned. The ATLANTIS II will be equipped with meteorological instruments and will make observations in assistance of the program.

STANFORD UNIVERSITY

The research vessel TE VEGA will undertake three cruises for biological and geological collection and observation in and around island groups and shallow water areas, landing shore parties on atolls for intensive two - to three - month studies. The following schedule has been established (Figure 14):

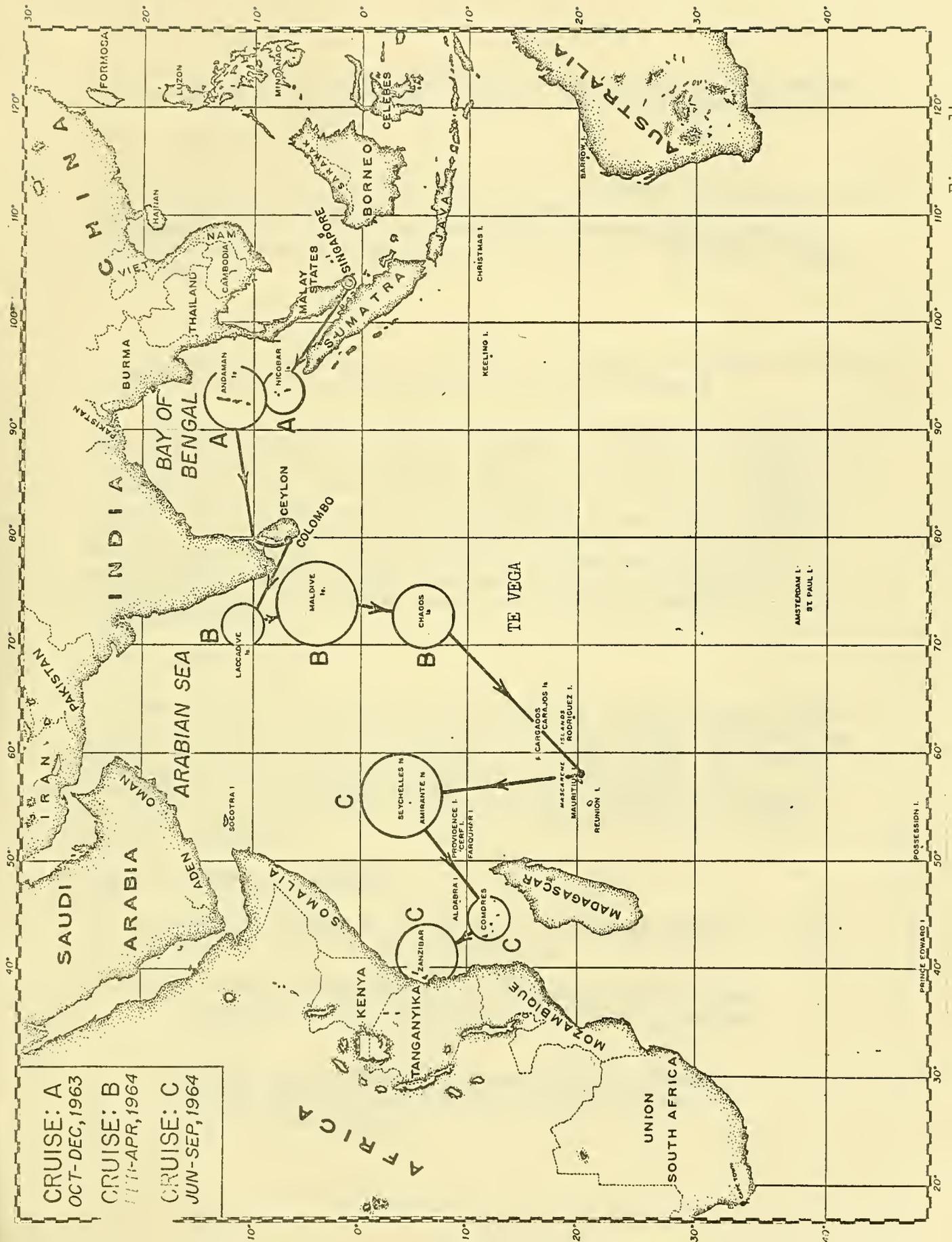
1963

October - December A Singapore-Nicobars-Andamans-Colombo

1964

February - April B Colombo-Laccadives-Maldives,
Chagos, Mauritius

June - September C Mauritius-Seychelles-Comores-
Zanzibar.



CRUISE: A
OCT-DEC, 1963

CRUISE: B
FEB-APR, 1964

CRUISE: C
JUN-SEP, 1964

Figure 14

On Cruise C a party of physiologists will be embarked, and emphasis will be placed on obtaining live Latimeria for physiological study.

U. S. COAST GUARD

During May 1961, the U. S. Coast Guard Icebreaker EAST WIND, returning from a trip to the Antarctic with oceanographic observers from the Hydrographic Office aboard, occupied a line of hydrographic stations from Fremantle west to 78°E, and then north to 4°N. Her track is shown in Figure 15.

U. S. NAVY

Survey vessels of the U. S. Navy have occupied hydrographic stations in the Persian Gulf and Andaman Sea, as shown in Figure 15.

The research vessels CHAIN of Woods Hole Oceanographic Institution, ARGO of Scripps Institution of Oceanography, and CONRAD of Lamont Geological Observatory are owned by the U. S. Navy, and their operations are supported by the Office of Naval Research. The Office of Naval Research also supports part of the operations of the VEMA and HORIZON. The Navy is also providing one R5D aircraft for use in the Woods Hole Oceanographic Institution meteorological program and is supplying a NOMAD weather station. Support has been given to the National Oceanographic Data Center for research on data processing for the NOMAD buoy observations.

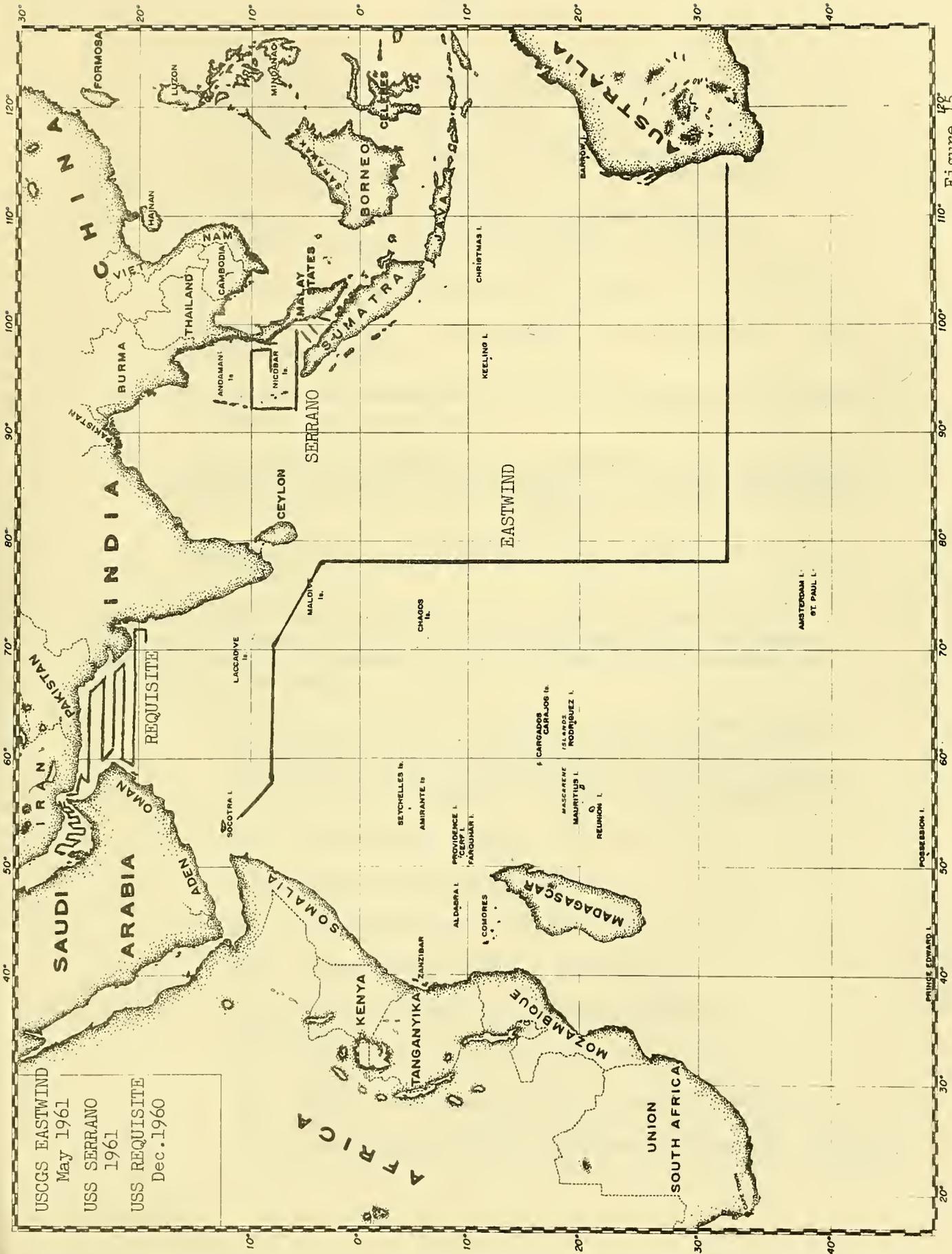
U. S. WEATHER BUREAU

Four planes of the Weather Bureau Research Flight, normally based in Miami, Florida, in hurricane observation, will operate in India from May to July 1963 and again in January and February 1964. The Weather Bureau is also assigning two professional meteorologists to the International Meteorological Center at Bombay. Radiosonde equipment is being loaned by the Weather Bureau for installation on the ANTON BRUUN and ATLANTIS II.

BUREAU OF COMMERCIAL FISHERIES

The research program of the Bureau of Commercial Fisheries in the Indian Ocean has the following objectives:

1. To study the distribution and abundance of adult tunas in relation to the circulation during the two monsoon seasons.
2. To study the relation of the apex predators (tunas, marlins, sharks, etc.) to the food-chain, standing crops and productivity.



USCGC EASTWIND
 May 1961
 USS SERRANO
 1961
 USS REQUISITE
 Dec. 1960

Figure 15.

- a. Organisms eaten (qualitative and quantitative analyses of stomach contents).
 - b. Standing crop of nekton (qualitative and quantitative analyses of mid-water trawl collections).
 - c. Standing crop of zooplankton (qualitative and quantitative analyses of zooplankton collections).
 - d. Phytoplankton productivity (C^{14} uptake).
3. Investigate subpopulations (serology of apex predators: tunas, billfish, and sharks).
 4. Distribution and abundance of larval and juvenile fish (plankton and night-light collections).
 5. Zoogeography of zooplankton and zooplankton forms as biological indicators (distribution and abundance of selected zooplankters such as copepods of the genus Candacia).
 6. Taxonomy, occurrence, and distribution of demersal fishes and invertebrates.

This program will be carried out by personnel of the Bureau's Biological Laboratory, Honolulu, aboard the ANTON BRUUN. On cruises 2 and 5, a party of 8 fishermen and 3 scientists will be embarked to engage in longline fishing as follows:

- a. On each cruise, fish 60 baskets of gear at each station. Occupy 16 stations along each of two meridian; 13 of the stations to be at 5° latitude intervals and remaining 3 stations to be occupied in areas of high abundance.
- b. Data and biological samples to be collected.
 - (1) Catch (by species) and effort.
 - (2) Length and/or weight of each fish.
 - (3) Sex and general state of maturation.
 - (4) Preserve stomachs in 10 percent formalin.
 - (5) Preserve ovaries in 10 percent formalin.
 - (6) Preserve blood samples for serological studies.
 - (7) Preserve selected whole specimens for taxonomic studies.

Bottom trawling to study the distribution and relative abundance of demersal species in relation to the topography and nature of the bottom, will be conducted on Cruises 1 and 4, using a single-warp shrimp trawl. Catches will be assessed quantitatively at sea, given a preliminary sorting, and sent to the U. S. National Museum for final distribution to qualified taxonomists for systematic studies of the fishes and invertebrates collected.

NATIONAL SCIENCE FOUNDATION

Support of the United States program for the IIOE by the National Science Foundation is epitomized by the following tabulation of grants made since 1960:

<u>NSF Grant No.</u>	<u>Institution</u>	<u>Principal Investigator</u>	<u>Title</u>	<u>Amount</u>
G-11800	National Academy of Sciences - National Research Council	R. C. Vetter	Support to the Special Committee on Oceanic Research of the International Council of Scientific Unions.	\$ 47,400
G-16570	National Academy of Sciences - National Research Council	G. D. Meid	Support of Coordinator, Indian Ocean Expedition	56,900
G16570A1	National Academy of Sciences - National Research Council	L. Hoover	Support of Coordinator, Indian Ocean Expedition	44,200
G-17182	Woods Hole Oceanographic Institution	J. H. Ryther	Planning of a program in biology for the Indian Ocean Expedition	24,000
G-19289	University of Hawaii	C. S. Ramage	Support of U. S. Meteorology Program of the Indian Ocean Expedition	97,200
G-20952	Woods Hole Oceanographic Institution	J. H. Ryther	U. S. Program in biology for the International Indian Ocean Expedition	450,000
G-21960	University of Rhode Island	J. A. Knauss	Equatorial Circulation of the Indian Ocean	100,000

<u>NSF Grant Number</u>	<u>Institution</u>	<u>Principal Investigator</u>	<u>Title</u>	<u>Amount</u>
G-22223	Office of Naval Research	J. Hughes	NOMAD weather station for the International Indian Ocean Expedition	\$ 50,000
G-22255	University of California	R.L. Fisher	Participation in the International Indian Ocean Expedition	150,000
G-22260	Columbia Univ.	M. Ewing	Participation in the International Indian Ocean Expedition	150,000
G-22388	University of Mighigan	D.J. Portman	Heat and water vapor exchange for the International Indian Ocean Expedition	231,900
G-22389	Woods Hole Oceanographic Institution	A.F. Bunker	Air-Sea Inter- action for the International Indian Ocean Expedition	97,000
G-22413	University of Hawaii	C.S. Ramage	Atmospheric Cir- culation Project for the Interna- tional Indian Ocean Expedition	146,600
G-23113	Woods Hole Oceanographic Institution	A.F. Bunker	Research Aircraft for meteorological program of the International Indian Ocean Expedition	100,000

U. S. COAST AND GEODETIC SURVEY

The USC&GS Ship PIONEER will sail in mid-February of 1964 from San Francisco to take part in the International Indian Ocean Expedition, returning to San Francisco the following September. In addition to underway observations, en route to and from the Indian Ocean, the PIONEER will concentrate on gravity, magnetic, and hydrographic operations in the Andaman Sea and the eastern Bay of Bengal. Space will be made available aboard the vessel for two meteorologists and one or two biologists. Three north-south profiles of oceanographic stations are planned from 5°N to 5°S across the Equator south of the Bay of Bengal.

These are only tentative plans covering work on specific Coast and Geodetic Survey projects. It is anticipated that they will be modified and added to as the information from other participants becomes available and as other organizations develop cooperative programs with the PIONEER.

These plans are predicated on the assumption that TRANSIT navigation will be available for determining ship positions throughout the expedition.

Leg I - San Francisco to Singapore

Leg II - Singapore Trincomalee (Figure 16)

From Singapore, the track will be northwest through the Malacca Straits into the Andaman Sea. The actual tracklines in the Andaman Sea will depend in part on the results of the work of the ARGO which returns from this area in the early summer of 1963. In general, however, there will be a series of sawtooth crossings of the Andaman Sea carrying out all of the standard underway observations with special attention paid to the bathymetry and the gravity work. Sediment cores and bottom photographs will be taken in the Andaman Sea along these lines. Rock dredgings will be attempted at places where the topography suggests that rock outcrops might be present. Planned tracklines in this area will be modified in the field as dictated by the bottom topography and gravity anomalies encountered. The pattern will include at least two crossings of the Andaman-Nicobar Ridge into depths of at least 3000 meters west of the ridge. These could conceivably be through Ten Degree Channel and Duncan Pass. At the northern end of the Andaman Sea, special lines shall be run to determine if submarine channelling extends seaward of the mouths of the Irrawaddi River.

From the Andaman Sea, the ship will pass into the Bay of Bengal where the underway operations, cores (or dredgings), and bottom photography will continue along a series of East-West lines at approximately two-degree spacing from the coast of Burma out to approximately 88°E. Topographic, gravimetric, or magnetic anomalies found along these lines will be developed more fully. Special

care will be taken along the more northerly of these lines to look for any southerly extension of the Ganges Canyon. This has been surveyed in some detail by the Pakistan Navy as far as the edge of the continental shelf. The GALATHEA's lines showed that it extends south into the Bay of Bengal beyond the shelf, but its extent is not known. It is possible that the valley found by the ALBATROSS east of Ceylon may be the extension of this Ganges Canyon. After a stop at Calcutta, the PIONEER will carry out a detailed survey of the Ganges Submarine Canyon seaward of the continental shelf. The canyon will be traced as far seaward as is possible. Cores will be obtained from the canyon floor where possible and attempts will be made to dredge the canyon walls. Bottom photographs will be obtained where camera lowerings appear feasible. If the canyon terminates well north of the latitude of Ceylon, the east-west lines previously run in the eastern Bay of Bengal shall be continued westward from 88° to the coast of India. If the canyon continues south to or beyond Ceylon, it shall be followed to its termination with cross sections run at frequent intervals.

On the termination of this project, the ship will proceed to Trincomalee, Ceylon.

Leg III - Trincomalee to Djakarta

HO Charts 2523 and 3689 show hard ridges through which has been cut a submarine canyon that heads in Trincomalee and Goddiyar Bays on the northeast coast of Ceylon. The canyon has apparently been cut in quartzite and other hard Pre-Cambrian rocks. The canyon extends seaward to depths of at least 800 fathoms where the soundings terminate. As the ship leaves Trincomalee, this canyon will be traced seaward with a set of profiles, and an attempt will be made to dredge the steep walls. Sediment cores and bottom photographs will be obtained where possible.

Upon the completion of the canyon survey, three north-south sections of oceanographic stations will be occupied from 5°N to 5°S along 84°E , 88°E , and 92°E . Stations will be at 5° , 4° , and 3° , and at $\frac{1}{2}$ -degree intervals to the Equator for a total of 17 stations along each profile. The stations at 5° , 3° and 1°N and S will be deep stations to the bottom, the others will be to 2000 meters. Standard bottle spacing will be used, except that depth of stations and bottle spacing may be modified in the light of other results obtained before the PIONEER sails.

From the southern end of the easternmost line (5°S , 92°E), the track to Djakarta is tentatively planned to accomplish two crossings of the northwestward extension of the trend of the Java Trench. These would be underway observations as described above. The first line would approach the Sumatra coast near Padang and then turn southwest continuing to the latitude of the Sunda Strait, thence due east through the Sunda Strait to Djakarta. The tracklines between the

end of the oceanographic stations and Djakarta are only tentative and will be changed to supplement the work of the ARGO currently operating in this area.

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