University of California
Scripps Institution of Oceanography

Preliminary Report on Expedition DOWNWIND

IGY Cruise to the Southeast Pacific

By

THE MEMBERS OF THE EXPEDITION

Edited by

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IGY General Report Series
Number 2

June 26, 1958

PREFACE

This General Report Series of World Data Center A will include miscellaneous reports on the IGY program of the U. S. National Committee for the IGY and occasionally special reports more conveniently made available through this series.

IGY World Data Center A

Washington, D. C.

June 26, 1958

I. FOREWORD

DOWNWIND was the first of three oceanographic expeditions comprising one phase of the University of California's deep-sea participation in the International Geophysical Year. The second cruise, DOLPHIN, is now at sea, studying the Equatorial Undercurrent. The third, as yet un-named, will set out August 1 to study the Equatorial Countercurrent. All three cruises are being carried out primarily on vessels of the University's Scripps Institution of Oceanography. All are supported in large part by funds from IGY agencies. DOWNWIND was also the thirteenth in a series of expeditions to the deep Pacific undertaken by the Scripps Institution since 1950. As such it was generously supported by the Office of Naval Research of the Navy Department.

DOWNWIND ranged from the Central Pacific to the South American coast, and from the equatorial regions to nearly 50° South latitude (Fig. 1). The name was appropriate, because over most of the track, running counter-clockwise in the Southeast Pacific, meteorological conditions made for following winds and currents.

June 26, 1958

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II INTRODUCTION

A.

The principal aims of the SIO IGY DOWNWIND Expedition to the southeast Pacific were three:

1) to determine the characteristics of the deep waters of the southeast Pacific and to study its circulation by several different means, including measurements of temperature, salinity and chemical properties from the surface to the bottom, and especially the collection of large-volume water samples, from depths of more than 3000 meters, for radiocarbon dating of water masses;

2) to determine the areal distribution of carbon dioxide in the atmosphere near the sea surface and in the surface waters, for study of CO_2 exchange at the air-sea boundary;

3) to make geological and geophysical studies of the structure of the Pacific basin between the coast of South America and the Society Islands.

Since the character of the sea-floor deposits is closely interwoven with the movements and the life present in the overlying water, quantitative collections of marine organisms were mandatory. Measurement of carbon dioxide distribution and radioisotope sampling were limited to the first half of the cruise; the other programs were continued throughout the entire 4 ½ months of DOWNWIND.

Geological-geophysical observations included seismic refraction studies of the shape and thickness of the crust, measurements of heat flow upward through the sea floor, precise measurement of depth and bathymetric exploration of ridges, seamounts and trenches, rock dredging

on seamounts in an attempt to collect fossils and on the deep sea floor to determine the abundance of manganese-encrusted nodules, photographs of small-scale bottom relief and coring of the deep ocean muds and oozes for geological and geochemical studies of sediments. Results of these studies will be synthesized to learn something of the history of the basin, and some clues to the formation of such large-scale structures as the Tuamota Archipelago, the East Pacific Rise and the Peru-Chile Trench, structures that must be surface expressions of changes, or instability, deep beneath the oceanic crust.

B.

This DOWNWIND report was begun before the vessels returned to San Diego, and preliminary bathymetric and biological charts and discussions were completed on shipboard. Other sections, notably those on bottom samples, geochemistry and heat flow, required additional work in La Jolla. This then is not a "shipboard report," but rather a "preliminary" or "narrative" report. It is designed to provide an index to the field program of DOWNWIND and to record impressions gained from a first analysis of the data and samples collected. The writers of Chapter V have requested that these notes be considered as highly preliminary and caution that subsequent analysis may modify greatly or even reverse the conclusions stated there.

III NARRATIVE

A.
SAN DIEGO TO PAPEETE, TAHITI (FIGS. 2, 3)

The IGY - University of California DOWNWIND Expedition sailed from San Diego on the afternoon of October 21, 1957. It consisted of two ships: the R/V *Spencer F. Baird*, Alan W. Phinney, Master, and the R/V *Horizon*, Marvin F. Hopkins, Master. Expedition leader for the first half of DOWNWIND was Henry W. Menard, Jr. *Baird* and *Horizon* each carried eleven in the scientific party, *Baird's* scientists mostly geologists and geophysicists, *Horizon's* party chiefly geochemists and hydrographers.

The ships separated, better to explore the Clarion fracture zone extending west of the Islas Revillagigedo. They did not meet until November 3, when a seismic refraction profile was shot near the Equator. During this interval *Horizon* began a profile of deep hydrographic casts, with stations about 250 miles apart, in the vicinity of 130° W. Longitude. On many of the hydrographic casts a small gravity corer was shackled to the lower end of the wire. Large-volume samples for radioisotope analysis were taken at about half of the hydrographic stations. Carbon dioxide content of the surface water and atmosphere was monitored almost continuously.

Baird began a series of gravity cores at about 24° N. and, on October 25, made the first of many dredge hauls for manganese nodules. The first DOWNWIND bottom photograph was taken at this locality. On this part of the track seismic reflection measurements were made frequently in order to determine the thickness of unconsolidated sediment

beneath the sea floor. On November 1 a short seismic refraction station was attempted, with *Baird* as receiving ship and a launch as shooting boat.

On November 3 the first full-scale seismic refraction profile was shot, *Baird* receiving, meanwhile taking a temperature probe measurement, a piston core, a gravity core and a bottom photograph. On shooting days *Horizon* made a hydrographic cast and one or more net tows either just before or just after a shooting run. On November 5 there occurred the first of a series of mishaps involving *Baird's* heavy cable and her dredging winch; these mishaps resulted in much splicing and re-spooling of the cable aboard *Baird*.

The Tuamotu Archipelago, an area which may have a crustal structure neither typically oceanic nor continental, was the site of special geological and geophysical study. This investigation began with straight runs into an area of oceanic depth enclosed within the Tuamotu platform (similar to the "Tongue of the Ocean" in the Bahama region), where a seismic refraction profile was shot November 10. *Baird* then explored a ridge extending southeast of Anaa Atoll while *Horizon* surveyed a guyot that had been crossed during the 1952–3 CAPRICORN Expedition. Seismic station 6, near Fakarava, was placed to study the platform structure. That night *Horizon* sounded a guyot and there dredged reef coral and manganese nodules. The following day the seismic profile was reversed; *Baird*, on station, dredged reef rock. November 13 the ships entered the lagoon of Fakarava Atoll, to be welcomed by the villagers and the local administrator as the first American vessels in many years to visit the atoll. Expedition members bartered for shell necklaces and

several, equipped with Aqua-lungs, dived on coral reefs for the first time. The following afternoon a reversed seismic profile was shot at the northwest end of the lagoon and both ships headed for Papeete, stopping for gravity cores en route.

Spencer F. Baird and *Horizon* docked at Papeete on November 15, nearly five years after their visit on CAPRICORN. Saturday morning Scripps scientists met with officers of the French Navy to discuss DOWNWIND exploration in the Tuamotus and recent French oceanographic investigations in French Oceania. Capitaine de Corvette Guy Nay, in charge of the IGY program in French Oceania, Lieutenant de Vaisseau Al. Bonnafont, in charge of hydrographic observations, and Lieutenant de Vaisseau Touzet du Vigier, Commander of the corvette *Lotus*, have been active in these investigations. Saturday afternoon local officials, French naval personnel and private citizens interested in the IGY program in Polynesia were invited aboard *Baird* for a reception and a tour of

the ship. Arrangements for this reception were made by Dr. June Pattullo and Miss Elizabeth Strong, Scripps oceanographers then in Papeete for the IGY Island Observatories Program. Ships officers and scientific party later were received at the home of Capitaine Nay. The members of the DOWNWIND Expedition are indebted to all these persons, and to Capitaine de Corvette Bayle, Commander of naval forces, for their cordiality and assistance during the visit of *Baird* and *Horizon*.

B.
PAPEETE TO VALPARAISO, CHILE (FIGS. 3, 4, 5, 6)

Baird and *Horizon* departed from Papeete the morning of November 19, leaving Franco Romagnoli, IGY photographer aboard on the first leg of DOWNWIND to shoot a documentary film, to return to the United States. After Tahiti, coring gained in prominance in the expedition scientific program. A seismic station planned for the smooth apron expected south of Tahiti was abandoned because of rough bottom topography. An oceanic-type seismic station was shot November 21. Two days later a guyot on the Austral Ridge was surveyed, and a small boat seismic refraction profile shot on it.

Rapa, the southernmost inhabited Polynesian island, was visited by both ships on November 24. *Horizon* grounded for a time while navigating the tortuous channel into the caldera in the middle of this volcanic island. During the afternoon expedition members met the islanders, visited the old Polynesian fortresses and dived on the reef.

From Rapa the ships headed southeast to investigate the basin south of the Austral Islands and ultimately to reach the region in which the organisms and sediment are controlled by the sub-antarctic water. Weather became progressively worse as the ships proceeded southeast. Although winds seldom exceeded 50 knots, oceanographic operations were extremely difficult on ships as small as *Baird* and *Horizon.* On November 30, seismic station 12 was shot in the deep area west of the East Pacific Rise. Hourly BT records were taken near and in the Sub-Tropical Convergence.

On December 1 foul weather and rough seas contributed to the loss of a gravity corer and 6000 meters of hydrographic wire from *Horizon*. Recordings from *Horizon's* echo-sounder became progressively worse because of a small leak in the transducer, probably incurred at Rapa. On December 2 it became totally inoperative, forcing cancellation of the seismic station planned for December 4. A spare transducer was rigged over the side for sounding on station, and by December 11 the damaged transducer had been replaced. During the interval operations were severely hampered by the lack of underway soundings on *Horizon*.

On December 7 *Baird* reached the farthest south point on the DOWNWIND track, 48°30' S., and reported light snow. Both ships headed northward, the benefits of obtaining information farther south overbalanced by the increasing rate of damage to ships' deck equipment. A seismic refraction station was shot December 10 on the East Pacific Rise, *Horizon* using her shallow-range echo-sounder to register the explosions. Wind and sea hampered the choice of shooting run, forcing the run to be made from the crest of the rise toward the east flank, rather than north-south along the crest. By December 12, when a seismic station was run on the east flank, most of the equipment had been repaired. Two more seismic stations were shot on this leg, one in the basin just east of the East Pacific Rise, the second on a branch ridge trending southeast from the rise. Very rugged topography made the results of the latter run difficult to interpret.

During this period William Riedel suffered a severe intestinal disorder and, after several days treatment, the expedition's physicians recommended he be moved to a hospital. Accordingly, *Baird* began a nearly direct run to Valparaiso, arriving there December 21. *Horizon* made the sampling stations required to complete the southern run.

Horizon stopped one day, December 21, at Juan Fernandez, the island where Alexander Selkirk, Defoe's "Robinson Crusoe", lived from 1704 to 1709. Some of the company visited with the inhabitants; others dived for lobsters, searched for Selkirk's cave or climbed to the highest point on the island, Selkirk's Lookout. *Horizon* reached Valparaiso December 23.

Operations completed during the first half of DOWNWIND included 16 seismic refraction stations, 27 hydrographic casts, 35 net tows, 17 radioisotope water samples, and 13 bottom photographs, along a total of nearly 21,000 miles of track. Dredge hauls were attempted of 15 localities, and cores at 134 localities; of these, successful hauls were made at 14 localities and cores at 105 localities.

C.
VALPARAISO TO CALLAO, PERU (FIGS. 7, 8)

Valparaiso was the halfway point on DOWNWIND, and the stay was long to allow all hands a Christmas holiday ashore and a chance to visit Santiago. The hospitality and many kindnesses of Lt. Cmdr. Roberto Peralta Bell, Departamento de Navigacion e Hidrografia and formerly a Scripps visiting scientist, made our visit especially pleasant. The help of Captain Alberto Andrade Taralba, Chief of the Departamento de Navigacion e Hidrografia de la Armada, and of Captain Walpole and Lt. Crouter of the U. S. Navy is gratefully acknowledged. Our ships were visited by the staff of the Marine Biological Station of the University of Chile, Vina del Mar, and the visit was returned by our scientific parties. Scientists from the station described their plan to drift from South America to Polynesia by raft, duplicating the KON-TIKI voyage.

Major change-overs in the scientific staff took place at Valparaiso, where ten left and ten joined the expedition. Robert L. Fisher replaced H. W. Menard as expedition leader and Russell Raitt replaced George Shor as chief seismologist. Chemists Rakestraw, Busey, Goldberg, Waterman and Williams secured the CO_2 and deep-water sampling programs to return to the United States. Riedel and Shipek also left the expedition. Bingham, *Baird* physician, was replaced by Andrewes. Jones and Norris joined *Baird's* party. Five South American scientists joined DOWNWIND for the Valparaiso-Callao leg: Erwin Schweigger (Peru-Compania Administradora del Guano), Lt. Alberto Casellas (Argentina - Navy) and Mateo Dragicevic (University of Chile) boarded *Baird*. Julio Cossettini (Argentina - Navy) and Romulo Jordan (Peru - Compania Administradora del Guano) joined *Horizon*.

Spencer F. Baird departed Valparaiso the afternoon of December 28 and headed for deep water, where her dredging wire could be paid out and spliced. *Horizon* departed shortly before midnight that date. Both ships zig-

zagged northward across the southern end of the Peru-Chile Trench, their observations limited by bad weather to sounding, BT lowerings and hydrographic casts. They rendezvoused outside the trench off Antofagasta and began a six-day seismic-refraction, heat-flow, sounding and bottom-sampling investigation across the deep, V-shaped portion of the trench. Repeated long-splicing of *Baird's* heavy wire occupied an unexpectedly large part of the scientific time budget, and permitted only one heavy instrument lowering per seismic station. The piston-coring program was the chief casualty, since temperature probe measurements were given priority, except in the deepest part of the trench. This limitation persisted until the close of the trench work off Peru. From then on, with maximum water depths of 2300 fathoms, the untapered ⅜" auxiliary wire was used for probing and piston-coring.

On January 3 *Horizon* made an unscheduled overnight visit to Antofagasta to disembark a crew member flying home on emergency leave, then rejoined *Baird* in the trench.

Heading westward, the ships occupied a seismic station just east of the Nasca Ridge, then separated for more adequate bathymetric coverage of the then-barely-delineated ridge. *Baird's* initial crossing reached a shoal depth of 625 fathoms. Two probe lowerings were made nearby, the first employing the probe used throughout the first half of DOWNWIND and the second the spare spear, to check reproducibility of the measurements. *Baird* then dredged rock and coralline debris from a 475–500 fathom flat-topped (?) peak. Meanwhile *Horizon* explored the northeast end of the ridge, and established that the trench shoals to an axial depth of only 2550 fathoms near Nasca, and apparently is constricted by the ridge.

On January 12 the ships met southwest of Callao for a three-day trench study similar to that off Antofagasta. Here the trench was shoal enough to permit lowering of the probe at the trench axis. On the second seismic run, at the trench station, *Horizon* struck an unidentified submerged object. SCUBA divers went overside and reported that the EDO echo-sounder tranducer was gone and the lower end of the shaft scarred. *??Horizon* was limited to use of her shallow-water anchoring sounder for the final profile; this station was occupied at the shelf-edge within sight of the guano islands of Hormigas de Afuera. All three of these stations in the Peru Current were notable for the strong development of the deep-scattering layers; as many as four strata, and many discrete echoes, were observed on occasion.

Baird reached Callao in the forenoon of January 15 and *Horizon* that afternoon. The five South American scientists left the expedition; Robert H. Parker, Scripps biologist, and J. N. Nanda, physicist of the

Indian Navy joined for the run to San Diego. Expedition members were guests that evening at a reception in the Club Nacional, given by the Consejo de Investigaciones Hidrobiologicas of Peru. Peruvian scientists, members of the Navy, and the U. S. Embassy staff were welcomed aboard *Baird* in a formal visit the following day. DOWNWIND scientists visited San Marcos University, the seismological observatory at Huancayo, and made field trips to the beaches and dunes of Ancon and Pasamayo. The kindnesses of Ing. Jorge A. Broggi, chairman of the Peruvian I. G. Y. Committee, and his staff are especially acknowledged. Warren S. Wooster, S. I. O. staff member then on leave with the Consejo, acted as DOWNWIND representative, and made arrangements for obtaining a replacement from the Consejo of *Horizon's* lost EDO head.

D.
CALLAO TO SAN DIEGO, CALIFORNIA (FIGS. 8, 9, 10, 2)

At noon on January 18 *Spencer F. Baird* left Callao, to work unaccompanied in the trench and on the northeast portion of the Nasca Ridge. As on the run into Callao, hourly BT's were taken while operating in the Peru Current. *Baird* obtained a profile of gravity cores down the east flank of the trench and in the trench bottom, and successful probe lowerings were made in the bottom and east of the trench near the base of the slope. *Baird* Dredge 9 was taken at about 1100 fathoms on the Nasca Ridge, obtaining globigerina ooze and a single angular fragment of porphyritic igneous rock. Meanwhile installation of *Horizon's* transducer was completed and she departed from Callao at noon 21 January to meet *Baird* January 23 for a seismic run along the crest of the ridge.

On January 24 a seismic station was shot in the 2300-fathom plain just northwest of the Nasca Ridge, completing a three-station profile across the central part of the ridge. The ships crossed several seamounts and three or more guyots, then dropped into a 2000–2200 fathom saddle that may mark the end of the Nasca Ridge. They entered a mountainous region that may be part of an east-west zone of seamounts and ridges, possibly extending from San Ambrosio through the Merriam Ridge to Easter Island and beyond. Time and fuel limitations prevented bathymetric exploration of the intersection of the trends, but *Horizon* dredged manganese nodules and fossil corals from a 500-fathom-deep peak. Thus, it is possible that the ridge drawn east to 92° extends to the mountains near 85° W. (Fig. 9). In order to keep seismic runs in fairly flat terrain, both ships stayed south of the east-west ridge, except for one *Horizon* zig-zag near 92° W. and a *Baird* crossing, at a low angle to the trend, east of Sala y Gomez.

Beginning at seismic station 28, and continuing to northwest of Easter Island, at about 20° S., yield from surface and deep net tows was very small. The scattering layer, poorly-developed, remained at about 200 fathoms. The lack of productivity of these waters is possibly reflected in the bottom sediments, where stiff red clays and very dark foraminiferal clays were obtained from moderate depths in which calcareous oozes would be expected to occur.

Reaching Sala y Gomez on January 31, *Spencer F. Baird* made a sight-controlled near-shore survey of the broad peak on which the rocks lie, and a party of three geologists and two crew members attempted to go ashore to collect rocks for petrographic study. Strong southwest winds, and surge all around the island, made a boat landing impossible. The

party swam ashore, landing on the northwest coast, and spent two hours collecting specimens. The return swim was accomplished without incident; two of the party, equipped with face plates, reported numerous curious, but fortunately not belligerent, sharks accompanying the swimmers. The bathymetric survey was secured at dark, and *Baird* headed for seismic station 30, on the rise between Sala y Gomez and Easter Island. Here the highest heat flow of the expedition, to date, was measured. On this station, *Baird* made radio contact with the Chilean ship, "Presidente Pinto", which had just left Easter Island after her yearly supply visit. We learned from Cmdr. Peralta, a *Pinto* passenger, that he and the islanders had installed a long-period wave recorder on the south coast. He requested that our divers check the installation. *Horizon* then ran to Easter Island where, in the dawn hours of February 2, two dredge hauls were made on the shelf north of the Poike Peninsula and off La Perouse Bay. Basalt cobbles, coquina and dead coral were obtained. *Baird* crossed a narrow depression, 350–400 fathoms deeper than the surrounding bottom, and ran along the south coast of Easter Island. Passing between Roca Aguja and

Southwest Cape, *Baird* reached Hanga Roa Bay to find *Horizon* anchored amidst a swarm of skiffs and a brisk trade, Easter Island carving for clothing, rapidly depleting the ships company's already impoverished wardrobes.

Our ships were welcomed by Cmdr. Fernando Dorion-Nicolet, governor of Easter Island and his adjutant, Lt. Manuel Dabelli. Expedition members were received by Father Sebastian Englert, anthropologist and author of "Land of Hotu-Matu a." The governor and his aide provided jeeps and horses, and acted as guides for our exploration of the island. *Baird* seismologists Raitt, Pepin and Jones helped repair the seismograph installed at the Air Force base. We visited Peralta's wave-recorder on

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the southwest coast; the next morning DOWNWIND divers swam out along the hose and reported the installation excellent. Loading 17 persons in two Air Force jeeps, Governor Dorion-Nicolet led a party to Rano Raraku volcano, on the southeast coast, site of the quarries and the best examples of the celebrated monuments, the long-eared moais. In best 36-hour tourist tradition, DOWNWIND personnel, armed with anthropological guide-maps copied from Thor Heyerdahl's "AKU-AKU," covered Easter Island, bargaining for carvings and examining the monuments, memorial piles, caves and pictographs.

Both ships left Easter Island the evening of February 3. *Baird* and two days later *Horizon*, reduced speed to save fuel for the long run to San Diego. Both ships ran at 8 knots, except on shooting runs, 'till mid-February. Heading westward, the ships sounded the 1150–1700 fathom, very irregular top of the East Pacific Rise. Weather worsened during this period, and the combination of high noise level, rough bottom topography and hydrophone difficulties made abandonment of seismic station 31 advisable halfway through the shooting run. Station 32 was occupied on the west flank of the rise, then both ships worked northeast near the crest of the rise, in 1350–1750 fathoms 'till February 12. At Station 33 fragments of very fresh-appearing, basaltic glass and almost crypto-crystalline basalt were found wedged in the piston-corer, and the core nose was badly battered. The accompanying sediment was a very soupy, brown foraminiferal mud. Station 34 was an attempted re-occupation of CAPRICORN station Uncle, near the crest of the rise. Seismic refraction results similar to those observed on CAPRICORN were obtained, but the heat-flow value, was even higher than the highest CAPRICORN value in this region.

North of 20° S., well-defined scattering layers again were observed on the echo-sounder trace and net-tows yielded more plankton. The bottom deposits changed from brown oozes to globigerina oozes northward along the rise. During this period, continuing till the ships reached the Equator, marked bioluminescence, from *Noctiluca*, salps and ctenophores, was present in the surface waters. Single or discrete masses of scatterers, were common at depths of 180–200 fathoms in the equatorial region.

On February 13 *Baird* and *Horizon* began a seismic-heat flow-coring profile northwest across the rise. On this profile, the 1450–1750 fathom rise is bounded on the southeast by a peak of 1050 fathoms, and a rapid drop to 1800 fathoms. The descent to 2000+ fathom depths is sudden on the northwest. At about 6° south, *Horizon* crossed a narrow depression with a maximum depth of 2580 fathoms; thirty miles southwest *Baird* recorded 2360 fathoms. Station 36 was intended as the southwest station of a reversed seismic profile along the crest of the rise, but bad weather forced cancellation of the return run. It was established at station 36 that a crustal structure similar to that at station 34, and a high heat flow, persisted along the top of the rise.

Seismic stations 37 and 38 were located in the equatorial current systems, and strong westward-flowing surface and eastward-flowing undercurrents made gravity coring difficult in spite of calm seas. Both ships cored calcareous oozes in this region: at least one of these cores had manganese nodules at the top. *Horizon* made GEK current measurements every two hours between the Equator and 13° N. on her northerly run. After 39, the final seismic station, the ships separated to better space

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crossings of the Clipperton and Clarion fracture zones. The former zone appeared on these crossings as a single seamount (*Baird*) and several low hills (*Horizon*), the latter as two moderately high seamounts (*Horizon*) and a single peak extending to less than 300 fathoms of the surface (*Baird*).

On this homeward run *Baird's* party, under Andrewes' direction, began work on what is certainly the most immediate result of DOWNWIND, the composition and recording of the "DOWNWIND Calypso", a "true and unbiased account", in twenty-three verses and nine choruses. On February 28, seventeen weeks and 40,000 miles after departing San Diego, *Spencer F. Baird* and *Horizon* reached home.

IV TOOLS AND PROCEDURES

Although modified in details, the instruments and methods used in the following programs on DOWNWIND were essentially those employed on the 1952–3 CAPRICORN cruise and described in the CAPRICORN Shipboard Report (S. I. O. Ref. 53–15):

- Seismic refraction shooting and receiving
- Heat flux measurement
- SCUBA diving
- Dredging and coring
- Surface current measurements with the GEK
- BT and thermograph observations.

Equipment and methods used in the geochemical, biological, hydrographic and photographic programs are described in the appropriate sections of Chapter V.

Both ships were equipped with EDO echo-sounders modified as described in the CAPRICORN report. However, on DOWNWIND the EDO receiver output was recorded on a "precision depth recorder" manufactured by the Times Facsimile

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Corporation, New York. This allowed recording on an expanded scale, in 400 fathom scale increments, on paper 17 inches wide. Thus, soundings could be read to a precision of ± 1 fathom, even at the greatest depths in the trench, except where water noises or excessive ship noise obscured the trace. Greater resolution of the near-surface scattering layers was obtained and single large scatterers could be detected.

V. PRELIMINARY REPORTS

A.
BATHYMETRIC AND GEOLOGICAL OBSERVATIONS

1. Special bathymetric explorations

a. Tuamotu Archipelago

The Tuamotu Archipelago is an elongate group of low coral atolls with a pronounced northwest-southeast trend. Previous expeditions had indicated that these atolls are situated on a series of coalesced ridges. Soundings taken on the Scripps Institution CAPRICORN cruise of 1952–3 had suggested that guyots (subsurface flat-topped seamounts) might be present. the DOWNWIND Expedition made a special survey of portions of the archipelago to explore various features of the structure (Fig. 11).

Some guyots were discovered and surveyed. The first one was found by *Horizon* at about 17° S. latitude, 144° longitude; its minimum uncorrected depth is 690 fathoms. Reef corals were dredged from two other peaks, indicating that they are probably sunken atolls. One of these, a guyot, has a minimum depth of 502 fathoms. The other, less conclusively a guyot, has a minimum depth of 358 fathoms. These guyots were found on the southwest margin of the archipelago, but other unexplored regions of the archipelago may have as many.

The flanks of the atolls are very steep and smooth for the upper 500 fathoms or so. Below this, the bottom deepens more gradually to platform depths and is much rougher. A few of the atolls rise out of deep water especially to the east. A number of small sharp pinnacles rise off the platform and ridges.

The platform is shallowest to the west of Fakarava atoll, where its remarkably smooth surface shoals gradually to 511 fathoms. The shallow portion of the surface may perhaps be correlated with the surveyed guyot a few miles to the southeast that rises to 502 fathoms. East of Fakarava the platform lies at a depth slightly greater than 800 fathoms. To the southeast, the platform breaks up into southeast trending ridges. The tops of these ridges seem to lie at depths of about 1,000 fathoms or more.

These ridges are often sharp features. *Baird* tested the extension of the ridge to the southeast of Anaa atoll. At the atoll, the ridge is about 8,000 feet above the surrounding sea floor and is 24 miles wide. On the last crossing, 135 miles to the southeast, the ridge was still 4,500 feet high and seven miles wide. The northeastern ridge of the group has a much gentler cross-section. The interridge basins usually have very flat or subdued floors. D. C. K.

b. DOWNWIND Investigation of the Peru—Chile Trench

The Peru-Chile Trench, extending from nothern Peru to southern Chile, has been sounded in part by cable ships, naval vessels, on the 1955–1956 Woods Hole cruise and, at the northern end, by the 1952 S. I. O. SHELLBACK expedition. Gravity profiles across the trench have been reported by Maurice Ewing and his co-workers.

The DOWNWIND geophysical investigations were concentrated in two areas, off Callao, Peru, and off Antofagasta in northern Chile, to determine whether differences in trench configuration in these areas were reflected in differences in crustal structure and in rate of heat flow through the sea floor. Off Callao the trench bottom is 3200–3350 deep; off Antofagasta it is more than 4000 fathoms deep. Off Callao the bottom is flat or flattish for widths of 3 to 5 miles; near Antofagasta the trench bottom is V-shaped, irregular or with a flat area only ½ to 1 ½ miles wide. Projecting side slopes, it appears that little or no unconsolidated sediment is present in the trench bottom off Antofagasta, while several hundred meters of fill may exist off Callao. This difference may indicate greater age or more abundant supply of sediment off Peru than off northern Chile. South of 27°–28° S., off central Chile, the trench bottom is considerably shallower and nearly flat-bottomed in cross-section. Perhaps this difference occurs because more rivers reach the sea there than in the Antofagasta region.

Off Chile the trench axial depth is greater than 4000 fathoms for a distance of 200 miles; the trench width at this depth is 2 to 5 miles (Fig. 7). Two small basins deeper than 4000 fathoms lie at 25° S. and at 26°40' S. The trench is continuous at depths greater than 3200 fathoms for 950 miles, with a width at this depth of 6 to 25 miles, usually about 10. The deepest sounding in the trench to date, 4215± 5 fathoms uncorrected, lies near DOWNWIND seismic station 20, and was logged on this cruise. The basin deeper than 4200 fathoms is about 10–12 miles long. Sediment cored from the trench axis at this station was a stiff blue-gray clay. The trench shoals abruptly near 27°30' S. Southward it extends for 350 miles as a series of nearly flat-floored basins of 3000–3400 fathoms depth.

Five seismic refraction stations were shot in the vicinity of the trench off Antofagasta. Mantle velocities were not reached east of the trench axis, at two stations shot at 1600–1800 fathoms on the continental slope. The stations outside the trench show fairly normal oceanic sections, the inner of the pair possibly transitional. At station 20, on the trench axis, the crust is significantly thicker than the normal oceanic thickness of about 6 km. This thickening is not due to the presence of sediment, which here is probably very thin.

Preliminary seismic results from the three-station profile off Peru (Fig. 8) are similar to those off Antofagasta. Mantle velocities were not reached at the shelf edge off Callao; the maximum observed velocity was about 7.5 km/sec. As off Antofagasta at the trench axis the crust is significantly thicker than the usual 6 km oceanic-station thickness. In this part of the trench sediment thickness is little, if any, greater than the normal oceanic values of a few hundred meters. At the outer station the crust is similar to other oceanic localities.

Heat flow values were measured outside, in the bottom (twice) and on the nearshore flank (twice) of the trench. Their pattern is comparable to that previously observed in the Middle America Trench off Guatemala; that is, surprisingly low values were measured in and near the trench. - R. L. F.

c. DOWNWIND Investigation of the Nasca Ridge

The Nasca Ridge (following Schweigger's suggestion) extends as a submarine mountain range from just outside the trench off central Peru, a distance of at least 600, and very likely 1,000, miles to the southwest. Previous to DOWNWIND, it was known from several shoal spot soundings and

two or three echo-sounding crossings. Ten days were spent in exploring the ridge by echo-sounding, seismic refraction lines, heat-flow measurements, rock dredging and gravity and piston coring (Fig. 8).

In structural setting the Nasca Ridge off South America is nearly identical to the Tehuantepec Ridge west of Guatemala. In both cases, a northeast-southwest trending ridge sharply constricts a trench, making it 500–800 fathoms shoaler than its axial depth short distances to either side. The Mexican portion of the Middle America Trench resembles the Peruvian segment of the Peru-Chile Trench in being shoal and generally flat-bottomed. The deepest portions of the Middle America Trench, off Guatemala, are V-shaped in cross-section, and occur near the intersection of the trench and ridge; the same is true off Chile. Seaward both ridges intersect or join a generally east-west zone of irregular submarine topography. The Tehuantepec Ridge extends to the Clipperton fracture zone, which has been traced as a ridge or a zone of deeps and seamounts for more than 2,000 miles west of Central America. The seaward end of the Nasca Ridge reaches what may be the eastern limit of a zone of seamounts and ridges that extends at least 1,000 miles east of Easter Island and that may end near the islands of San Felix and San Ambrosio, only 500 miles from the Chilean coast. The westward extension of this seamount zone may reach the islands just southeast of the Tuamotu group. If such continuity can be established, there is a region of ridges and seamounts which extends from Peru to the islands of Polynesia. In both cases, the northeast-trending Nasca Ridge or Tehuantepec Ridge is more strikingly developed than is the prolongation of the seamount zone east of its intersection with the ridge.

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In the basin southeast of the Nasca Ridge, and well outside the trench off Callao, Peru, are narrow depressions 200–300 fathoms deeper than the general level of the surrounding sea floor. From DOWNWIND and earlier navy soundings, these deeps may be contoured as a series of very narrow, generally north-northwest trending deeps which, if extended, would intersect the Nasca Ridge at an angle of 45°–60°.

The seamount zone east of Easter Island, like the Clipperton fracture zone, is not markedly seismic at present (the cluster of epicenters south and west of Easter Island is probably related to the north-south swell). Neither is the Nasca Ridge reflected on epicenter plots such as those of Gutenberg and Richter. The Tehuantepec Ridge is represented by a number of shallow-focus shocks well outside the trench off Oaxaca, Mexico.

Where best developed, the Nasca Ridge is asymmetrical, with a steeper southeast face dropping to 2,250–2,350 fathoms, and a more gentle slope or sedimentary apron bordering the ridge on the northwest. The ridge, with a general depth of 1,200–1,600 fathoms, is topped by several seamounts with peaks at less than 1,000 fathoms. The three shoalest of these, at 115, 175 and 220 fathoms, are definitely flat-topped; these occur on the southwest portion of the ridge. Others, at 450–800 fathoms, may be guyots. Dredge hauls were made on two guyots of this group, in addition to two deeper hauls. The former hauls include sharks' teeth, manganese nodules, weathered volcanic rock, calcareous sand and corralline debris. Some of these samples are being examined by John Wells and Storrs Cole. Wells has identified specimens of reef corals as *Porites*

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(two species, indeterminable), *Stylophora pistillata* and *Plesiastrea* (sp. cf. P. *versipora*). These specimens are no older than Miocene, and may be Recent. Wells believes they grew within 20 fathoms of the sea surface rather than at their dredged depth of 500 fathoms. Deeper dredge hauls at the northeast end of the ridge yielded starfish and igneous rock. Late Tertiary calcareous ooze was found within manganese nodules dredged from the ridge.

Three seismic refraction profiles were shot near the central portion of the Nasca Ridge. The crustal structure flanking the ridge was generally of the oceanic type. The ridge station, at an average depth of 1,600 fathoms, had one of the thickest crusts yet found, with the mantle perhaps as much as 15 kilometers below the sea floor.

Six measurements of heat-flow were made on or near the Nasca Ridge. None was greater than 2.0 micro-calories/cm^2/sec; the others ranged from 0.3 – 1.5. It appears that the narrow, steep-sided Nasca Ridge, of great relief, has no associated high rate of flow comparable to that found on the much broader, but generally deeper, currently seismic East Pacific Rise. - R. L. F.

d. Sala y Gomez

Sala y Gomez is a low volcanic islet 225 miles ENE of Easter Island and about 1900 miles west of northern Chile. It lies on the northern edge of a zone of seamounts which extends at least 1000 miles east of Easter Island. This zone of irregular topography, and its possible extension both east and west, is discussed elsewhere.

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Although Sala y Gomez had been visited, and even landed upon, several times since its discovery in 1793, visitors had not collected rock samples systematically, and only one note on the petrology of such rocks is known to the writer. Neither had the area near Sala y Gomez islet been sounded with modern recording echo-sounders. Accordingly, on DOWNWIND a party of two geologists and three seamen landed to collect rocks. Meanwhile the R/V *Spencer F. Baird* engaged in a nearshore, sight-controlled bathymetric survey of the area.

The subaerial exposure of the seamount, Sala y Gomez islet, is 800 yards east-west and about 300 yards north-south (Fig. 12). It is bordered by a submarine platform, whth the shelf-break at a depth of about 70 fathoms. This terrace is 1 ½ to 2 miles wide south, west and northwest of the islet; the bottom then drops steeply to 1600–1800 fathoms. To the southeast the bottom slopes off gently to a depth of 150 fathoms 4 ½ miles from the islet, then through a saddle at 1300–1400 fathoms depth to a peak of 1000-fathom depth. There are one or two pinnacles northeast of the islet, and the shoal area is more extensive there. Its outer limit was not explored. From DOWNWIND data, it appears possible that the terrace around Sala y Gomez has been tilted toward the east. The gentle slope in that direction may result from volcanic flows near the shelf edge, however.

The islet consists of several volcanic flows, the exposed surface of which are strewn with loose, sometimes water-rounded, boulders of lava. The surface irregularity is accentuated by crude jointing along which weathering has progressed and by the blocky or 'aa' type of lava in the latest flow.

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From field observations, and from hand specimen examination, three major rock units are present on the islet.

(1) The lower flow is a red to black olivine-basalt scoria. The red scoria probably results from strong oxidation during eruption, suggesting subaerial emplacement.

(2) Above this flow is a discontinuous sedimentary unit, one inch to three feet in thickness. It consists mainly of echinoid spines, shell fragments and pebbles and grains of volcanic rock. It is a coarse-grained calcareous sandstone or clastic limestone.

(3) The upper unit is a dense, fine-grained olivine basalt, locally scoriaceous. Its upper surface is blocky and jagged; its lower contact locally shows crude pillow structure. In the eastern part of the islet this unit lies directly on

the lower flow. One sample from this upper unit may be andesitic; thin-section work will determine this point.

The age of flows is not known. The minor weathering of the upper flow plus the lack of any soil development makes a Recent or late Pleistocene age likely. - R. L. F., R. M. N.

2. Sediment cores

The following brief description of the sediment cores is based on a preliminary examination of some of the gravity cores, and is concerned only with the regional distribution of sediment types. Most of the cores obtained have not yet been opened, and the few which have been cut have been only superficially investigated. Five piston cores, ranging up to

9 ½ meters in length, taken by *Baird* (nos. 14, 21, 119, 131 and 134) may be expected to yield a record of the sedimentation over a much longer period than the gravity cores, most of which are between 0.5 and 1.5 meters long.

Between San Diego and the Tuamotus, the sediments sampled are for the most part those which would have been expected on the basis of the results of previous expeditions in this general area. *Baird* cores nos. 1–3 and *Horizon* cores nos. 1–4 are red clays, some of them zeolitic, with practically no calcareous and very few siliceous microfossils. *Baird* cores nos. 4–10 and *Horizon* cores nos. 7 and 8, taken between latitudes 14° N. and 6° N., are from the belt of radiolarian ooze in which earlier expeditions have found, in many localities, Quaternary sediment disconformably overlying calcareous or siliceous oozes of Middle and Late Tertiary ages: sediments believed to be pre-Quaternary have been found in at least three of these DOWNWIND cores. *Baird* core no. 16, and probably *Horizon* core no. 12, both taken at about latitude 6° S., are radiolarian clays, and thus the southern limit of the equatorial belt of calcareous ooze apparently lies between latitudes 3° S. and 6° S. on longitude 130° W. - earlier sediment charts indicate calcareous ooze at this locality and southward. Approaching the Tuamotus, the sediments are zeolitic clays, some of them with calcareous microfossils (*Baird* cores nos. 17–19 and *Horizon* core no. 14). Two of the calcareous sediments cored among the Tuamotus are Eocene in age (*Baird* cores nos. 23B and 25).

After leaving Tahiti, zeolitic clays were cored in the trough separating the Society Is. from the Austral Is. (*Baird* cores nos. 30 and 31 and *Horizon* core no. 20). Calcareous sediments, some of them Tertiary

in age, were cored on the ridge extending southwestward from the Austral Is. (*Baird* cores nos. 32–36 and *Horizon* core no. 27). Pteropod ooze, a type of sediment rarely encountered in the Pacific Ocean, was obtained from the top of a seamount in this area (*Baird* core no. 35, from a depth of 1320 m.). In the basin south of the Austral Is. and west of the E. Pacific Rise, the sediments were found to be zeolitic clays (*Baird* cores nos. 37–55, *Horizon* core no. 26): manganese nodules occur at the tops of at least four of these cores, and seven coring attempts brought up manganese nodules without sediment cores. The frequency with which manganese nodules were encountered during coring operations in this basin indicates that the density of nodules in this entire area may be comparable to that indicated in Fig. 18. Approaching the E. Pacific Rise (*Baird* cores nos. 56–59, *Horizon* core no. 34, obtained at depths between 4500 and 4640 m.) the sediments were found to be somewhat calcareous, at least near the tops of the cores, and here also manganese nodules occured at the sediment surface. Continuing southwestward, the sediments cored were calcareous oozes with abundant Radiolaria and diatoms (*Baird* cores nos. 60–70, *Horizon* cores nos. 36 and 37, from depths of 2520–4250 m.): the high proportion of biogenous constituents in the sediments obtained on this part of the DOWNWIND track is probably a result both of the shoaler depths of the E. Pacific Rise and of a higher rate of organic production in the subantarctic water. The cores obtained to the east of the Rise (*Baird* cores nos. 72–79, *Horizon* cores nos. 40–48, from depths of 2700–4240 m.) are also highly calcareous, but differ from those obtained on the Rise in containing much smaller proportions of siliceous microfossils. At greater depths, the sediments cored were

zeolitic clays (*Baird* core no. 84, *Horizon* cores nos. 49 and 50, from depths of 4350–4700 m.). Approaching the South American coast, calcareous clays with varying amounts of biogenous siliceous constituents were obtained (*Baird* core no. 83, *Horizon* cores nos. 54–58).

Near the coast of South America, between latitudes 12° S. and 25° S., sediments cored were generally calcareous or diatomaceous oozes or clays, depending primarily on depth and on distance from terrigenous sediment sources. Many of the cores collected in and near the Trench are diatomaceous oozes and silty clays (e. g. *Baird* cores nos. 87, 102, 108 and 109, and *Horizon* core no. 61), while those obtained further westward are more calcareous (e. g. *Baird* cores nos. 91 and 115, *Horizon* cores nos. 69 and 71), except where the depth is apparently too great for the accumulation of calcium carbonate (*Horizon* core no. 67, from a depth of 4740 m.).

In the area around Easter Island and northward to approximately latitude 10° S., the sediments obtained were highly calcareous, often dark brown, containing few or no siliceous microfossils (*Baird* cores nos. 120–130, 137 and 138, *Horizon* cores nos. 74–86). Indications of the existence of this area of calcareous sediments without siliceous microfossils were found on the southeasternmost part of CAPRICORN Expedition. Approaching the Equator, more normal, lighter colored calcareous oozes containing siliceous microfossils were found in *Baird* cores nos. 134 and 139–149, and *Horizon* cores nos. 88 and 89. The northernmost core on the homeward run was taken to the north of the equatorial carbonate belt, and is capped by a piece of manganese (*Horizon* core no. 92, at 10° N.). - W. R. R., R. M. N.

B.
SHIPBOARD GEOCHEMICAL PROGRAM, LEGS A and B

1.

Milligram quantities of organic matter were extracted from four southern deep-water masses. Results of a preliminary survey indicate that amounts and properties of this matter are similar to those of the organic matter extracted from the more northerly stations in the Pacific.

The ionium/thorium ratios at different depths in the sediments indicate that the rates of accumulation of sediments from the southern areas, that is, below 20° S., are of the order of magnitude of millimeters per thousands of years. Surface values of this ratio are dissimilar to values from the region between the Gulf of Alaska and Hawaii. This has been explained by assuming that these isotopes of thorium come from the bottom waters, and the bottom waters in these two areas are different with respect to the source material for the thorium isotopes.

The quartz contents of sediments from the South Pacific are of the order of a few per cent. In the North Pacific, at comparable latitudes, the values are of the order of 20 per cent. These results tend to confirm our conviction that much of the sedimentary material of the North Pacific is derived from the arid regions, the desert and steppe areas, in that hemisphere and is of eolian origin. In the Southern Hemisphere, lacking in deserts, one would expect quite low values of quartz in the deep-sea sediments, assuming that most of the quartz is transported by the tropospheric winds. - E. D. G.

2.

The continuous recorder for atmospheric carbon dioxide was operated throughout the first half of the expedition, the total record covering the range from 32° N. to 48° S., with very few interruptions. From this record nearly 2,000 independent measurements of atmospheric CO_2 are obtainable. Periodic meteorological observations of course accompany the record. The operations were carried out by N. W. Rakestraw, L. S. Waterman and James Costello.

The daily averages of carbon dioxide were all within range of approximately 310 to 313 parts per million. A slight but distinct variation with respect to latitude could be seen, but no diurnal effect, nor any vertical gradient in concentration within the first 30 feet above the surface of the water. Twelve samples of air were taken in 5-liter flasks at various stations throughout the cruise, for determination of CO_2 by the absolute method as a check against the results obtained by the continuous recorder.

Some hundreds of determinations were also made of the carbon dioxide tension in the surface water, by circulating surface water, together with a closed volume of air through an equilibrating apparatus in which the air and water were brought into equilibrium with each other and the carbon dioxide then determined by circulation through the analyzer. The results were more variable than those from the atmosphere and somewhat less precise. However, it was apparent that throughout much of the area covered, the carbon dioxide tension in the water exceeded that in the atmosphere. A closer study of the record will very likely show horizontal trends, particularly with respect to latitude, and possibly diurnal variations.

It was also possible to measure the carbon dioxide tension in subsurface water in a few instances, by raising the water to the surface by pump and circulating it through the equilibrator. A remarkable observation was made near the Chilean coast, where the carbon dioxide tension in the surface water was found to be extraordinarily high, evidently the result of upwelling of deep water.

All carbon dioxide measurements are subject to final calibration of the apparatus, but it is unlikely that this will change the absolute results very much, and the relative measurements of course not at all.

Seventeen water samples were taken for determination of C-14, ten of them from depths of 3,000 meters or more. These cover a range of latitude from 30° N. to 45° S. Fifty gallons of water were brought up in a special sampler, and after acidification, the carbon dioxide washed out with pure nitrogen gas, absorbed and finally precipitated as $BaCO_3$. From most of these same stations water samples were also taken for radium determination, and four deep samples also for measurement of uranium. - N. W. R.

C.
HYDROGRAPHIC WORK

On expedition DOWNWIND 44 hydrographic stations were occupied. Casts on all but six were sent to within approximately 50 meters of the bottom. Temperature, salinity and oxygen determinations were carried out for every depth sampled, and on legs A and B, PO_4 - P, Si, pH and alkalinity determinations were made. Preliminary results indicate

that the South Pacific waters are intermediate between the waters of the South Atlantic and the North Pacific, i. e., lower values of phosphate and silicate were found in the South Pacific than in the North Pacific.

Weather permitting, bathythermograph (BT) observations were taken every two hours while the ships were underway. A special hourly BT schedule was maintained in and near the South Pacific convergence. Hourly BT's were taken again after leaving Peru, crossing the Peru Current. On this survey, a surface water sample for chlorinity determinations was taken with each BT. A total of 867 BT observations was made on *Horizon* and 822 on *Baird*.

A thermograph record of surface water temperature was maintained throughout the cruise, by both ships.

GEK observations were made on leg A while crossing the north equatorial current and equatorial countercurrent, a similar survey carried out on the return leg.

The Nansen bottle casts were arranged so that there was an observation at 0, 10, 100 and 200 meters, then every 200 meters between the 200 meter depth and the bottom. When time and depth permitted, extra bottles were placed near the surface.

A hydrographic station usually consisted of two bottle casts. One, the bottom cast, was made up of 10 Nansen bottles 200 meters apart, and a short Phleger corer with two ball-breakers located 50 meters below the bottom bottle. The bottom cast was lowered until the "ball-break" was received on the EDO receiving equipment. The second or surface cast was designed to overlap the bottom cast, and to sample the depths between

the sea surface and the top of the bottom cast. In order to predict the wire length at which a ball-break would be obtained, the following formula was used:

$$Wl = .45\,Z_s - (\cos\theta\ .45\,z_s) + Z_s$$

where Wl = wire length to the bottom.

Zs = sonic depth corrected.

θ = wire angle at the surface.

This was generally accurate to within ± 50 meters, when the wire angle was less than 30°, and the error of the meter wheel was known. Limiting wire paid out on this basis, core samples were obtained at eight stations at which

the ball breaker failed to function properly. On three of these stations, the bottom bottle came up muddy, and on two other stations the cast failed to reach bottom although thermometric depth computations indicated that the approach was close. The messengers were allowed 7 ½ to 10 minutes per 1000 meters of wire, to travel down the cast, depending on the wire angle. This is somewhat conservative, since there was no evidence that any casts tripped on the way up.

Water samples for chemical analysis were drawn immediately as the bottles came up. Salinity samples were stored in citrate-type bottles until they reached thermal equilibrium. Salinity (o/oo) was determined by the Knutsen method, running two titrations for every sample, and titrating directly against Copenhagen normal sea water, rather than using a sub-standard.

Oxygen (ml/l) was determined by the Winkler method, and one sample was titrated for every depth observed.

Each Nansen bottle had two protected reversing thermometers, and all but three bottles carried unprotected reversing thermometers. Temperature readings were corrected as soon as possible after the cast. Depth of the

observations were determined by the method described by Reid (1950), except that the "accepted" L-Z curve was allowed to follow the computed points back towards L-Z = zero at great depths where a vertical wire profile was assumed. This was done in recognition of the fact that values of 1/Qpm are computed for p m at 1000 meters, and that pm gradually increases enough to give a negative L-Z (34 meters at 4000 meters, for example) at great depth. A correction for the variations of pm with depth was taken from a table prepared by Hans Klein and applied to the accepted values of L-Z.

A special BT observation to a depth of 850 feet was made just before each shallow hydrographic cast.

Nineteen hydrographic stations were occupied along a line running roughly south from Latitude 30° N. to Latitude 47° S., and between Longitude 125° W. and 145° W. Another line of stations (10) extended from approximately Latitude 47° S., Longitude 128° W. to Valparaiso, Chile. This line included three stations, spaced evenly between Mas Atierra, Juan Fernandez Islands and Valparaiso, to obtain a hydrographic section across the Peru coastal current. Between Valparaiso and Callao, six stations were occupied in the Peru Current and in the Peru oceanic current. These stations included one previously occupied by the R/V W. Scoresby (Scoresby No. 612). The remaining 11 stations were spread out between Callao and Easter Island, then north to Latitude 10° N., roughly along Longitude 115° W. (see Figs. 2–10).

On DOWNWIND the ships were working off the coast of Peru at a time when unusually warm (according to available information) surface water was present. Special observations of salinity and temperature were made in addition to routine observations to help describe the phenomenon.

A plot of horizontal distribution of surface temperature off Peru and Chile (Fig. 13) indicated a tongue of warm water next to the coast, and extending as far south as Antofagasta. In the warm tongue, close to Callao, the temperature salinity relationship below 100 meters was typical of Pacific equatorial waters; this probably is normal for the area. The surface salinity was 35.4 o/oo and the salinity at 100 meters was 35.0 o/oo. This seemed too high for "*el Nino*". It may indicate an influx of East South Pacific central surface water, or possibly coastal water from north of Callao, locally warmed with salinity increased *in situ* by evaporation.

After leaving Callao *Horizon* ran on a course of approximately 200° for the first 360 miles. During this time hourly BT's and surface water samples were taken. figure 14 shows the vertical distribution of temperature along this section, and the surface salinity.

In the course of the cruise, particularly on the southernmost crossing of the East Pacific Rise from Tahiti to Valparaiso and on the line running west to Easter Island, possibly significant variations in bottom temperatures and bottom temperature gradient were observed. For example, at 4000 meters the water temperature between the East Pacific Rise and the South American coast off Valparaiso is about 1° C, while west of the Rise the temperature is close to 1.3° C.

Charts showing the horizontal distribution of surface temperature and temperature at 200 meters have been prepared (Figs. 15, 16). - C. G. W., J. P. C.

D.
SEISMIC SURVEYS

Thirty-nine seismic refraction stations were recorded. Rough shipboard interpretations of most of these stations indicate the scope of the accomplishments, although final conclusions must await more detailed examination of the oscillograms.

Five of the stations - 1, 3, 7, 9 and 11 - were of short range for study of the upper layers only. The remainder were normal long-range stations whose objective was to reach mantle velocity of 8 km/sec. This objective was attained at all of the stations in a normal oceanic environment. There was considerable variation of crustal thickness of these oceanic stations and it is not clear if there is a systematic difference on the average from other oceanic areas on the Pacific basin. Stations of unusual interest include station 5 located in an embayment of deep water surrounded by the Tuamotu Islands, where normal oceanic structure was found despite the presence of shallow-water areas on all sides. Station 15, in a basin just east of the East Pacific Rise had one of the thinnest crusts yet found, with about 2 km of 6 ¾ km/sec "crustal layer", an equal amount of "second layer" basement and negligible unconsolidated sediment. Station 26, on Nasca Ridge at an average depth of 1600 fathoms, had one of the thickest crusts yet found, perhaps as much as 15 km below the sea floor.

The principal exceptions where mantle velocity was not reached in spite of strenuous efforts were stations 18, 19 and 25, located east of the South American Trench, off Antofagasta and Callao, respectively, and

stations 34 and 36 on the axis of the East Pacific Rise. At these stations the highest velocity reached was about 7.5 km/sec. This is not surprising for the continental stations, where the mantle could be expected to be too deep to observe at the maximum ranges attained of about 130 km. It is more mysterious for the East Pacific Rise because it is not characteristic of the Rise everywhere. Furthermore, it cannot be concluded that failure to observe the mantle wave is proof of its great depth. It may merely be a result of poor propagation. At stations 35 and 37, on the east and west edges of the Rise, respectively, the mantle wave appears as a very weak forerunner of a strong crustal wave. This effect may be accentuated on the center of the Rise.

Stations 20 and 25 on the axis of the trench off Antofagasta and Callao, respectively, have crustal thicknesses significantly greater than normal oceanic thickness of 6 km. This is not caused by great sediment thickness which is little, if any, greater than normal oceanic values of a few hundred meters.

At nearly all stations a "second layer" of intermediate velocity of 4–6 km/sec. was found between the unconsolidated sediment and the principal crustal layer. Its velocity averaged about 5 km/sec. and its thickness the order of 1 km, although occasionally it is several kms.

Preliminary analyses of some of the stations were made aboard ship; stations 1, 38 and 39 in the equatorial area, confirmed previous observations that there is a thickening of the sedimentary layer in the equatorial carbonate zone, with thickness about double the oceanic mean. Similar results were observed on the reflection shots. On all other oceanic stations, sediment thicknesses were not over a few hundred meters, indicating that the sediment thickness in the southeast Pacific is no greater than in the central and north Pacific, and possibly less.

Reflection shooting was tried wherever possible, with shots fired on coring stations and on occasional special stops. The equatorial region was again found to be an area where strong sub-bottom returns could be easily obtained. In areas farther south, high reflection coefficients of the water-sediment interface and side echoes from rough topography limited the usefulness of the method. - R. W. R., G. G. S.

E.
HEAT FLOW MEASUREMENTS

The measurement of the thermal gradient, and hence heat flow, through the bottom of the ocean was a relatively successful project on DOWNWIND. This was due to the considerable amount of station time alloted to this activity, to good weather, and to improvements on the instrument from experience gained on previous cruises. About 30 temperature probe lowerings had been planned for the cruise, whereas 42 attempts were made. Of these, at least some information was obtained on 39. On three measurements the probe did not penetrate the bottom, five showed incomplete penetration, and two of the records were faulty as a result of instrument trouble. The remaining 32 measurements were wholly successful for the determination of temperature gradient; however, on two of these a core was not obtained at the probe locality. The lack of knowledge of the thermal conductivity results in some inaccuracy in the estimate of heat flux at these localities. The sum of the measurements represents a considerable increase toward the knowledge of the heat flow through the floor of the Pacific Ocean, since a total of 25 measurements had been made on previous cruises.

A majority of the temperature probe stations on DOWNWIND were placed with the idea of learning more about the distribution of heat flow beneath some of the largest topographic features of the sea floor, namely submarine rises and deep-sea trenches. The two main features studied in this connection were the East Pacific Rise and its extensions, and the Peru-Chile Trench. Three profiles were made across the East Pacific Rise proper, two across the Nasca Ridge (a possible eastward extension of the Rise), and two across the Peru-Chile Trench in the vicinity of Antofagasta, Chile and Callao, Peru. In general the heat flow over the Rise is high, over the Trench is low, verifying some results obtained on the earlier MIDPAC, CAPRICORN and CHUBASCO cruises in similar areas. This pattern is opposite to what would be expected to result from a purely topographic effect on a uniform heat flow through a flat surface, and is probably related in a fundamental way to the subsurface structure or tectonics of these large features. The distribution is not entirely so simple, however, since two heat flow profiles made across the Nasca Ridge, a relatively shallow extension northeast of the main Rise, do not show significant differences over the ridge with respect to values on either side. It may be that the anomalous heat flow values across topographic features are connected with their evolutionary stages, which would suggest heat flow as an indicator of the tectonics or manner of formation of these features.

Since, on many of the stations, heat flow measurements and seismic refraction stations were made at the same time, correlation between heat flow and crustal structure or seismic velocities may be possible when the data for both programs are analyzed. Such correlations are not yet obvious. For example, on the East Pacific Rise the high temperature gradient may cause a downward decrease of velocity of seismic waves in the mantle, thereby preventing the recording of any refracted waves from

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below the crust. Other correlations with heat flow that come to mind are the thickness of the crust, volcanic layer, or sediment layer, velocity of seismic waves in these layers (and hence differences in composition or temperature?), and age of volcanic action.

There are corrections and calibrations yet to be applied to the heat flow values obtained on DOWNWIND, but the figures are consistent with previously-obtained values and are illustrative of the differences that exist in various locations. The lowest value measured was 0.2 micro-cal/cm^2 sec., in the ocean basin northeast of the Marquesas Islands, and the highest, about 7 micro-cal/cm^2 sec., was measured on the crest of the East Pacific Rise at latitude 12° S. The ratio between the values is about 35 to 1. The Rise value, together with two similar ones nearby, may well be the highest obtained in the oceans to date, depending on calibrations and corrections still to be made. High values obtained on the three crossings of the East Pacific Rise are about 3, 4 and 7 micro-cal/cm^2 sec., at latitudes 45°, 29°, and 12° South, respectively. Thus there appears to be a general increase in heat flow northward along the Rise, at least within the area studied on DOWNWIND; however, the detail is not adequate to establish this relation. In the Peru-Chile Trench, off Antofagasta, there is some indication of lower values toward the center, although not conclusively, since the depth was too great to permit a probe lowering on the axis of the trench. Off Callao, the lesser depth at the trench axis allowed two lowerings to the trench floor; these gave values somewhat greater than 0.2 micro-cal/cm^2/sec. Values of 2.5 and 1.3 micro-cal/cm^2 sec. were obtained on the shoreward and seaward side of the Trench, respectively, in this area, indicating a definite trend toward lower values near the axis. An average of all values obtained on DOWNWIND

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probably would not be very meaningful, since regions of possibly anomalous heat flow were chosen for study. Deviations in values are large for the same reason. Two probes were used in making the temperature gradient measurements, and it should be emphasized that the numerical results presented are preliminary to necessary calibration to be made on the probes.

The high values of heat flow found on the East Pacific Rise extend over large areas, of the order of a hundred or more miles in the narrowest direction; the Rise itself is thousands of miles long. The magnitude of these high

values presents a problem to be resolved. To account for the highest heat flows molecular conduction of radioactively-generated heat assuming either a constant value of radioactivity in a surface layer or an exponential decrease with depth, requires such high temperatures at depth as to cause melting of the rocks, if one uses the values normally assumed for heat conductivity of the rocks. This seems improbable on the basis of seismic refraction profiles recorded in the same area. Either abnormally high heat conductivity is present in these rocks, or there are sources of heat near the surface in addition to radioactivity in the rocks. Slow convective overturn of material in a solid state in the upper mantle is a possible explanation. Such overturn might be accompanied by local volcanic action at the surface, as indicated by the rough topography and rocky surface over large parts of the East Pacific Rise. The convection also may provide forces sufficient for the origin and maintenance of the topography of the Rise itself.—R. V. H.

F.
BOTTOM PHOTOGRAPHY

On DOWNWIND a total of fourteen deep-water camera stations were occupied from the R/V *Spencer F. Baird* (Figs. 1–5). A special U. S. Navy camera, designed and developed at the U. S. Navy Electronics Laboratory

in San Diego, was employed to investigate the distribution of manganese nodules on the sea floor, the effects of benthic biological activity on sediment accumulation, and the influence of deep current or wave action on bottom materials.

figure 17 shows the essential components of the camera which is designated as the NEL Type III Deep Sea Camera. Lowerings were made from the hydrographic winch on *Baird* using a 3/16" diameter wire rope. Six to twelve bottom photographs were attempted for each lowering. Through the use of an electrically-operated shutter and a repeating-type electronic flash unit, successive photos were obtained by bouncing the camera unit on and off the sea floor at intervals of not less than 15 seconds.

Two camera lens units were employed on DOWNWIND. An f2.8 three-cm wide-angle lens was used with 35 mm black-and-white or high-speed color film. An f6.3 80 mm wide-view lens was used with 120 size black-and-white or high-speed color film.

Camera stations were placed for the best use of ship time in sampling different deep environments for which data was desired. Bad weather and sea conditions limited the choice of station positions. Twenty-five deep-sea bottom photographs were obtained.

Photographs showed manganese nodules in areas of siliceous ooze, calcareous clay and calcareous ooze. Calcareous oozes free of nodules and churned by benthic life were photographed. Manganese nodules in red clay areas were photographed, and ripple marks were found in coarse calcareous ooze on a seamount. figure 18 is a photographic print of black manganese nodules resting on a red clay bottom, at a depth of 15,590 feet.

The accompanying table lists the dates, locations, and depths for the fourteen camera stations. Field descriptions of the photographs are given; these are based on sediment samples taken at the time of each lowering and on interpretation of the pictures. A more thorough study of the DOWNWIND bottom photographs is being conducted at the U. S. Navy Electronics Laboratory, and a report of this study will be published.

It is hoped that increased knowledge of deep sea sediments gained through the use of coordinated photographic, bottom-sampling and bathymetric programs will help solve some problems facing the oceanographer working in the eastern and southeastern Pacific. *In situ* viewing of manganese nodules on the ocean floor and a study of the associated bottom sediments appear likely aids in the determination of rate of sediment accumulation in the open oceans. Repeated photographic detection of ripple marks at oceanic depths and in various environments adds information as to the nature of deep current or wave action. — C. J. S.

G.
BIOLOGICAL REPORT

Biological collections were of two general types, plankton tows and dredge hauls. Biological observations of surface pheneomena were also taken on both ships of the expedition, as well as notes on the fauna of Easter Island. The material contained in this report is preliminary, and definite conclusions on the material taken in the plankton tows and dredge hauls await detailed analysis.

Plankton collections were planned so that a general survey of the zooplankton and pelagic fish populations of the eastern South Pacific Ocean might be carried out. Quantitative sampling of the plankton, using a

Table A.

Station Number	Number of Photos	Photo Description	Depth Meters	Location Lat	Location Long.
1	2	Manganese nodules on red clay	4410	21°25' N	126°50.0' W
2	1	Manganese nodules on probably radiolarian clay	4712	10°25' N	130°35' W
3	1	Tan colored calcareous ooze	4440	3°12.5'N	131°31' W
4	1	White-colored siliceous ooze	4510	1°21' S	131°33' W
5	3	White and brown coarse calcareous clay--Manganese nodules on surface	4080	18°31' S	141°23.5' W
6	0	Camera switch in film advance mechanism failed--no photos	2196	16°42' S	149°48' W
7	2	Stereo photo of calcareous siliceous silt--light colored	2311	16°42' S	149°49' W
8	1	Chocolate colored clay sediment with manganese nodules covered by clay caps	4684	21°37' S	147°40' W
9	8	Coarse calcareous Pteropod ooze well-rippled and well-sorted	1320	25°57' S	146°21' W
10	1	Manganese nodules on chocolate colored clay	4754	32°08' S	140°30' W
11	3	Calcareous ooze with large manganese nodules on surface	4560	42°50' S	125°32' W
12	1	Light colored calcareous ooze with red tint. Sediments show churning by benthic life	3180	44°26' S	110°39.5' W
13	1	Red clay with coarse looking foreign particles	4660	42°43.3' S	96°01.0' W
14	0	No bottom photos	3520	41°05.3' S	86°39.0' W
	25 photos total				

Table A.

standard type of net, was attempted. The zoogeography of the central South Pacific, the region of the subtropical convergence and the southern part of the Peru Current were, heretofore, almost unknown. A study of the pelagic ecology of the animals caught in these regions will be carried out in relation to the hydrographical findings.

Types of Collections. Plankton was collected at 67 stations, including the 44 hydrographic stations. Collections were of five kinds:

1) Plankton net of one-meter mouth diameter; mesh opening of 0.65 mm. This is the standard type of net used in the California Cooperative Oceanic Fisheries Investigations. Tows are oblique. Samples for study of bathymetric distributions were collected at most localities using paired nets: 0–200 meters of wire (0–140 meters actual depth), and 0–400 meters of wire (0–280 meters of actual depth), or 0–400 meters of wire and 0–800 meters of wire (0–560 meters of actual depth).

2) Six additional stations were sampled using a plankton of 45 cm. mouth diameter, 0.33 mm. mesh apperture. Hauls were vertical to a depth of 280–300 meters.

3) A microplankton net of No. 20 mesh, 18 cm. mouth diameter, was used at the hydrographic stations. Hauls were vertical from a depth of about 50 meters.

4) A coarse mesh net, the mouth of which was square, 40 inches on a side, was used for collecting macroplankton and small fishes in subsurface layers.

5) Collections were made using hand dipnets and a night-light at 48 localities. Myctophids (lantern fish), flying-fish, and squids were predominant.

Four biological dredge hauls, using a large chain-mesh bag dredge were made: two on Nasca Ridge, and two on the narrow shelf of Easter Island. The one shallow dredge haul, on Nasca Ridge was taken on *Horizon*, while the

deep dredge haul (1101 fathoms) was taken on *Baird*. Both Easter Island dredge hauls were accomplished

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aboard *Horizon*. The fish fauna from these and several of the geological dredge hauls have been turned over to Dr. Carl L. Hubbs. Some of the crustaceans, especially the Galatheids, were given to Mr. William Boyd of Scripps Institution for identification, and the brachiopods have been sent to Dr. Heinz Lowenstam of California Institute of Technology for identification and geochemical studies. The mollusks from the dredge hauls will be identified at Scripps.

Relative fertility of the regions traversed. Figure 19 shows the geographical distribution of zooplankton mass in the DOWNWIND survey area. Settling volumes are based upon collections obtained by means of the one-meter net, usually 0–400 meters of wire.

Amounts of plankton associated with the equatorial current systems were consistently high. On the north-south transect volumes were high between about 20° N. and 10° S., with a maximum near 10° N., - the presumed northern boundary of the Equatorial Countercurrent. An increase was again noted at 45° S. where subantarctic populations contributed to the fauna.

The vaunted fertility of the region of the Peru Current was conspicuous, particularly in the southern, cooler portion. Abnormally high (23°–24°) temperatures in waters off Peru were also associated with abundant plankton composed of species whose zoogeographical affinities were equatorial, (Brinton, 1957)[1] but typical of the region - according to evidence from SHELLBACK Expedition (1952) and from material collected by the old U. S. Fish Commission survey vessel *Albatross*. The Peru Current's giant squid (up to 6 ft.) *Doscidicus gigas*, was consistently encountered from Valparaiso to Callao, and was found again near the equator near 115° W. It was frequently caught by harpoon. The harbor at Antofagasta where relatively cool temperatures (lower than 19°) prevailed, teemed with this squid.

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After leaving Callao, surface waters appeared to be relatively rich in animal life until reaching latitude 28° S. and longitude 94° W. Between longitudes 78° and 80° W., tremendous numbers of *Doscidicus gigas* were observed under the lights at night. The squid seemed to be feeding on lantern fish (Myctophids), and appeared at the surface at the same time the unusually dense deep-scattering layers rose to the surface on the Precision Depth Recorder. The relative abundance of organisms here was indicated by daytime observations of fairly large numbers of oceanic birds, and large numbers of the pelagic gastropod, *Janthina janthina*, and the colonial coelenterates *Velella* and *Physalia* (Portuguese man-of-war). Both *Janthina* and *Velella* were most numerous near the western edge of the Peru Current region, indicating a typical oceanic warm-water community.

The central South Pacific (ca. 20° S.–40° S.) was found to be poor in zooplankton content. Samples taken in the vicinity of Easter Island were among the most meagre nightime collections that have been obtained in the course of extensive coverage of the Pacific by Scripps expeditions. Ubiquitous seabirds, flying fish, and myctophids are almost absent here. In this region the fathogram traces showed only a sparse daytime Deep Scattering Layer and little concentration of organisms at the surface at night. Agassiz (1905)[2] remarked that these same waters were absolutely barren of life, both on the bottom and at the surface. The productive waters extended about 4° more to the west than at the time Agassiz made his observations. This may be related to the warm-water conditions existing on the coast of Peru in January of this year.

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Easter Island Fauna. Although native vegetation is sparse, there were a surprising number of land birds on Easter Island, including a small hawk, a little larger than the Sparrow Hawk, and a Horned Lark. Both of these birds are typical of prairie country, and should be much at home on grassy Easter. The only sea birds were observed on the northwest side of the island, and appeared to be a large black petrel and a cormorant. The only other indigenous land fauna observed were dragonflies, spiders and three species of land snails.

The intertidal fauna and flora, which was sparse, could be divided into three zones. The first zone or splash zone, wet only by the spray and highest waves was inhabited by three genera of snails (*Tectarius*, *Neritina* and *Littorina*), all capable of remaining out of water for long periods. *Neritina* was the most abundant. The second or high-tidal zone was dominated by *Tectarius* and *Neritina*. Here barnacles made their first appearance, and there were small semi-permanent tide-pools inhabited by a species related to the opal-eye fish of the genus *Gyrella*. The lowest or low-tide zone was dominated by barnacles and seaweed. Just below this zone can be found large purple sea urchins and cowrys (*Cypraea caput-draconis*) known only from Easter Island. Father Sebastian Englert, in a conversation, indicated that he had collected over 30 species of mollusks along the shores of Easter Island.

The pale blue water washing this island contributes little to the, nevertheless, abundant well-being of the "Pasquenses". As a consequence, there is little interest in fishing among these islanders, compared with that shown by their Polynesian relations to the west. The people of Easter Island live on the land, whereas Tahitians and Rapans live on the sea. (One can sympathize with the obsession of the "Long Ears" with stone carving and the frustration of the "Short Ears" in this environment. It might be noted, however, that a fairly large school of tuna was observed in the vicinity of Sala y Gomez Island, two hundred miles east of Easter Island.

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On the northward track relatively rich waters were encountered at Station H-39 (15°45' S.) where a portion of the equatorial environment appears to bend southward.

From Easter Island to about latitude 17° S. and longitude 113° W., the waters seemed almost to be devoid of life and exceptionally clear. From this point on north to the equator, the observed number of organisms gradually increased. Up to latitude 11° S. and longitude 109° W., at least six species of birds and large numbers of flying fish were seen. At 11° latitude very strong bioluminescence appeared, beginning at night at about the same time at which the fairly dense deep scattering layers rose to the surface. With the exception of two rainy nights, when no bioluminescence was observed, this display continued until we were well north of the equator. The bioluminescent organisms consisted primarily of fairly large ctenophores and salps (noticed along side in the daytime) and the small flashes of micro-organisms.

From 1°30' S. latitude to the equator, many very large scatters were observed on the Precision Depth Recorder. These occured at fairly regular three-minute intervals, three to eight at a time, and at depths of 180 to 190 fathoms. From mid-afternoon until sunset, the large scatterers followed the normal scattering layer up to the surface. From the shape of the trace, there is a possibility that the large objects may have been large tuna or whales. That same evening, a tremendous school of small (one to two feet) squid appeared at the surface, apparently feeding on Myctophids. This display of animal life was very similar to that observed in the Peru Current. Bathythermograph traces indicated very warm water (27° C.) to a depth of 100 meters, beneath which was a sharp thermocline with

water temperatures of 13° C. below the thermocline. Bioluminescence continued until about 5° north of the equator. None was observed at 9° N.

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A series of stratified tows, using an opening-closing net, was made at the equator at 116°32' W. This was with a view to sampling possible incursion of western Pacific zooplankton species via the Equatorial Undercurrent.

Pelagic Faunal Provinces in the South Pacific. Using plankton species, (euphausiid crustaceans) many of whose zoogeographical affinities are known in the North and Equatorial Pacific, the faunal zones of the South Pacific are indicated in figure 20. Four environments may be described for the survey region:

1) Equatorial, occurring south of the region of the California Current, from 20° N. to 20° S., as determined along the western line of DOWNWIND stations. The equatorial and central assemblages overlap, in the oceanic South Pacific, between ca. 10° S. and 20° S. A zoogeographic boundary was crossed between two plankton stations 35 miles apart, occupied near hydrographic Sta. 41. The more southern of the two stations (9°42' S., 110°11' W.) was dominated by central Pacific euphausiids, and contained some equatorial animals; the northern station (9°13' S., 109°42' W.) contained only equatorial species. The equatorial assemblage extended southward to Station 28 (27°09' S., 72°2' W.) in the Peru Current region. Characteristic equatorial species: *Euphausia tenera*, *E. diomediae*, *E. eximia*, *Nematoscelis gracilis*.

2) Central South Pacific: occurring in dominance from 20° S. near 135° W., and 10° S. near 110° W., to 36°–40° S. This group is adapted to relatively barren waters. Central species encroached in small numbers upon the most westward stations occupied in the region of the Peru Current. Characteristic species: *Euphausia brevis*, *E. gibba*, *E. mutica*, *Nematoscelis atlantica*, *Thysanopoda aequalis*, *S. suhmii*.

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3) Transition Zone: occupying a region of oceanographic transition between central and subantarctic assemblages in the oceanic South Pacific, and between equatorial and subantarctic assemblages in the Peru Current region, and overlapping both. Characteristic species: *Euphausia gibboides*, *Thysanoessa gregaria*, *Nematoscelis megalops*.

4) Subantarctic: Occuring in dominance at only two oceanic stations (21, 22) and at one Peru Current station (26), but present at all stations south of 41° S. Characteristic species: *Euphausia similis*, *E. lucens*, *E. spinifera*.

It was pointed out to us at Juan Fernandez Island that the littoral faunas of this island and of San Felix and San Ambrosio Islands to the north are unique, and differ strongly from that of Easter Island: e. g. the spiny lobster of the former islands, *Jadus lalandei frontalis*, is altogether different from that which occurs at Easter Island. At the same time, the Juan Fernandez-San Felix-San Ambrosio species is not present on the mainland. It is evident that the environment of these latter islands is in the zone of transition, while Easter Island is central, and the coast of Peru and Chile is equatorial and subantarctic; the transition zone species probably never reach to the mainland coast in dominant numbers, but the coastal current contains some endemic species, notably *Euphausia mucronata*, to be discussed below.

Zoogeography of the Region of the Peru Current. In the chapter on the hydrographic work the phenomenon of unusually warm waters encountered by DOWNWIND expedition off Peru and northern Chile in January, 1958 is discussed.

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The surface of the current was 24° C. off Callao and as high as 22° C. near Antogagasta, purportedly causing general alarm in the ranks of Peruvian guano interests. We were advised by Peruvian biologists and oceanographers that the ranges of "tropical" fishes (e. g. flying fishes, opah) and birds (tropic birds and others) were impinging upon coastal waters, a rare occurrence. The odor of hydrogen sulfide could, in fact, be sometimes detected along the waterfront off Callao, although the "Callao Painter" was not evident. Local lore attributes these phenomena to "El Nino," a symptom of southward deflection of the Equatorial Countercurrent or of eastward intrusions of oceanic water.

Figure 21a shows the presence of four equatorial euphausiid species in the region of the current. The eastern limit of the ranges of central species (*Euphausia mutica*, *Thysanopoda aequalis*, *Nematoscelis Atlantica*) is also indicated. The plankton off Callao is, clearly, not of central origin, but has obvious warm-water affinities.

In July, 1952 SHELLBACK Expedition encountered cool temperatures (to 16° C.) off Callao. These temperatures increased to 20° C. at a distance of 450 miles from shore. Equatorial species were then, as in January, 1958, dominant in offshore waters to at least 15° S. (the most southern Shellback station), but gave way to "Peru Current species" *Euphausia mucronata* and *Nyctiphanes simplex* (shown, for DOWNWIND Expedition, in figure 21c near to shore.

Evidently, then, equatorial species may be normally maintained in the main body of the current system, south of the limit of their distributional ranges in more oceanic waters, suggesting some continuing transport to the south in at least the offshore part of the Peru Current. Near to shore the cool-water species *E. mucronata* was found at the most northern station occupied.

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It was present in the region of the coastal current at distances of 20 and 80 miles from shore off Peru, where relatively cooler water was present below the thermocline.

Species of the transition zone assemblages (figure 21b) ranged northward to the same latitude, 15° S., at which they were found by SHELLBACK Expedition.

In summary, preliminary zoogeographic evidence relates the warm-water populations near Peru to the characteristic equatorial fauna of the offshore waters of the Peru Current, but also to populations of the same species which are known to live off northern Peru, but not in the eastward extension of the Equatorial Countercurrent. The breadth of the distribution of the Peru Current-upwelling species *E. mucronata* is narrow off northern Peru. The high volume of warm-water plankton in the coastal region and the occurrence of larval chains of these species suggest that the individual species are growing and reproducing locally, supplementing the evidence for the very static picture indicated by the preliminary hydrographic analysis.

Dredge Hauls. Two dredge hauls were taken on or near the Nasca Ridge: a deep one by *Baird* in 1101 fathoms, and a shallow one at 120 to 129 fathoms by *Horizon*. The deep dredge haul was poor in fauna, producing only one pennatulid (sea pen) and two ophiuroids (brittle stars). On the other hand, the shallow dredge haul was extremely productive, containing hundreds of live pelecypods, *Lima*, a few *Pecten*, large gastropods, brachiopods and gorgonians. There were also a few pieces of coral and much calcareous rock. The corals were not those which are necessarily limited to very shallow water.

Two shallow hauls were also made on the slope and shelf of the northwest side of Easter Island. The first dredge haul was taken in from 90 to 70 fathoms, on what appeared to be a break in slope, suggesting a terrace.

This haul consisted of slabs of coquina, composed of shell, rounded pebbles and a carbonate matrix, and a number of pieces of old dead reef coral. The most abundant organisms were a few attaching species of pelecypods (*Barbatia* and *Chama*). Both coquina and reef corals suggest beach or shallow-water deposits, and the depths are in agreement with those of the deepest strand lines on other shelves.

The second dredge haul was taken on the small shelf flat at depths of 22 to 53 fathoms. The dredge came aboard completely filled with lithothamniod-covered, rounded cobbles of volcanic rock and about an equal amount of carbonate material consisting of old corals, worm tubes, shell debris and calcareous algae. This material was similar in many ways to the carbonate material found on Alexa Bank[3] and the calcareous pinnacles on the Gulf of Mexico shelf. Although there were a few living mollusks (primarily attaching forms), most of the mollusks were dead, and consisted of shallow-water species such as oysters and *Astraea*. The most abundant living organisms were sponges, 4 or 5 species of crabs, brittle stars and starfish. There were also considerable amounts of kelp and sea lettuce. In general this dredge haul was considerably richer in life than was to be expected in such clear and barren-looking waters. The corals and shallow-water shells also suggested lowered sea level, although they could have been transported down the rather steep slope from shore. One fact evident from these dredge hauls is that, possibly not too long ago, the waters around Easter Island were warmer than at the present time. Reef corals do not live there now, but if these hauls are any indication they were extremely abundant at one time. - E. B., R. H. P.

VI PERSONNEL

Henry W. Menard, Jr.	Expedition leader, San Diego to Valparaiso
Robert L. Fisher	Expedition leader, Valparaiso to San Diego

Marvin F. Hopkins, Master, R/V *Horizon*

Alan W. Phinney, Master, R/V *Spencer F. Baird*

Scientific Party	
John Andrewes	V to SD
Robert Bingham	SD to V
Edward Brinton	SD to SD
Harold M. Busey (Los Alamos National Laboratory)	SD to V
Alberto Casellas (Argentina-Navy)	V to C
Julio Cossettini (Argentina-Navy)	V to C
James P. Costello, Jr.	SD to SD
Warren Douglass	SD to SD
Mateo Dragicevic (University of Chile)	V to C
Robert L. Fisher	V to SD
Thomas Gobble	SD to SD
Edward D. Goldberg	SD to V
George Hohnhaus	SD to SD
Alan C. Jones	V to SD
Romulo Jordan (Peru-Compania Administradora del Guano)	V to C
Dale C. Krause	SD to SD
Henry W. Menard, Jr.	SD to V
J. N. Nanda (India-Navy)	C to SD
John Newton	SD to SD
Robert H. Parker	C to SD
Robert O. Pepin	SD to SD
Russell W. Raitt	V to SD
Norris W. Rakestraw	SD to V
William R. Riedel	SD to V
Franco Romagnoli (Lowell Institute - WGBH)	SD to T
Erwin Schweigger (Peru-Compania Administradora del Guano)	V to C
Carl G. Shipek (U. S. Navy Electronics Laboratory)	SD to V
George G. Shor, Jr.	SD to V
Maxwell Silverman	SD to SD
Richard von Herzen	SD to SD
Lee Waterman	SD to V
Peter Williams	SD to V
Charles G. Worrall	SD to SD

Spencer F. Baird	*Horizon*
I. Bryer	D. Berger
C. Clampitt	A. Bratz
C. Davis	G. Clark

E. Dennager	J. Croft
R. Donahue	H. Dahlgren
R. Dunkel	A. Doran
C. Hodges	T. Eddy
M. Irano	M. Hopkins
H. Jacinto	G. Koch
J. Knox	T. O'Gorman
R. Long	H. Patstone
P. Malag	R. Pifley
J. Montgomery	P. Quiaoit
R. Nordberg	L. Resland
A. Phinney	C. Rudy
C. Rice	H. Sammuli
E. Scott	J. Schapairo
G. Trease	C. Smilser
V. Vogel	J. Wall
	S. Watson
	C. Zilis

LIST OF ILLUSTRATIONS

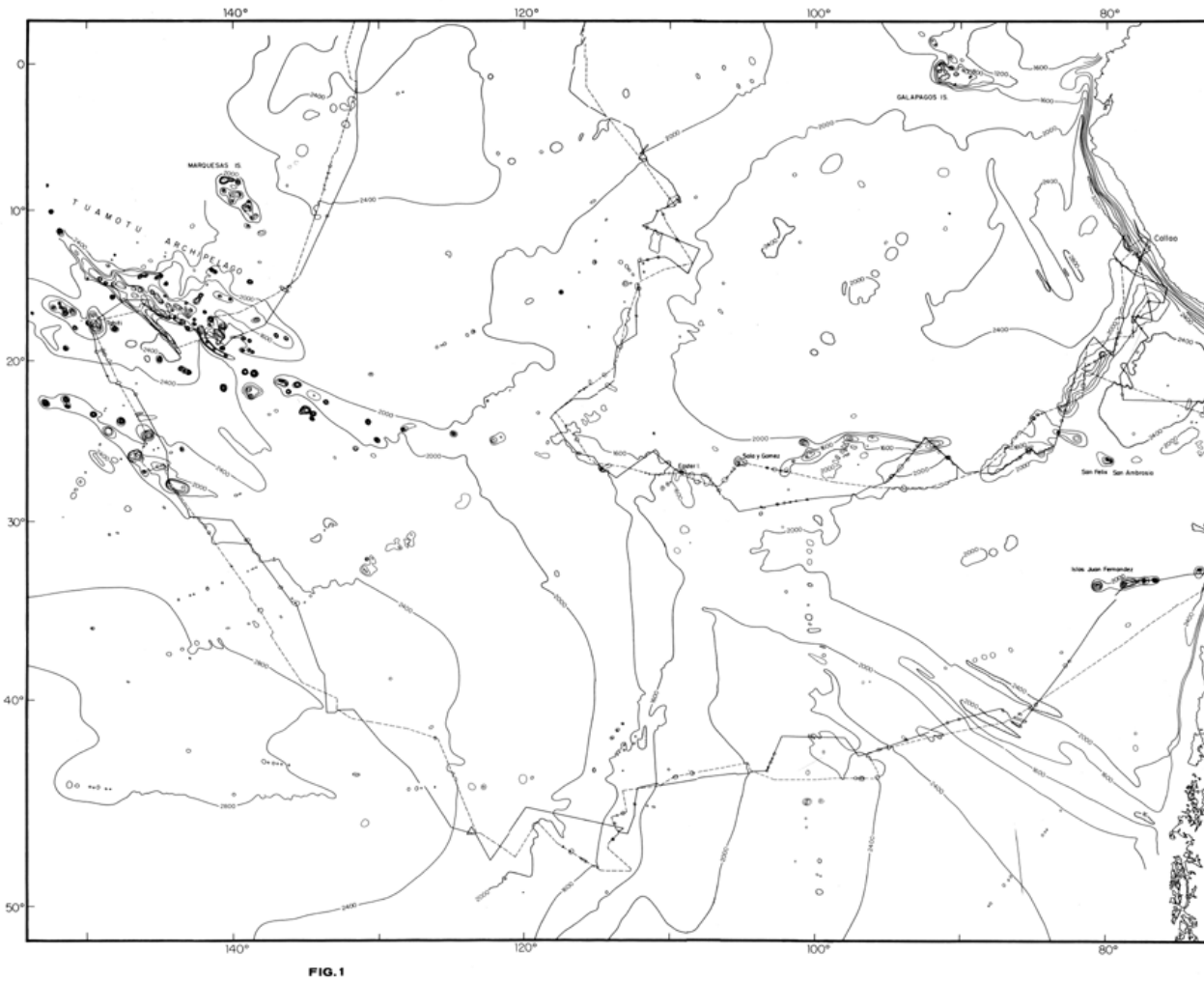

140°
120°
100°
80°
0
10°
20°
30°
40°
50°
MARQUESAS IS.
TUAMOTU ARCHIPELAGO
GALAPAGOS IS.
Callao
Salas y Gomez
San Felix
San Ambrosio
Islas Juan Fernandez
FIG. 1

FIG. 1

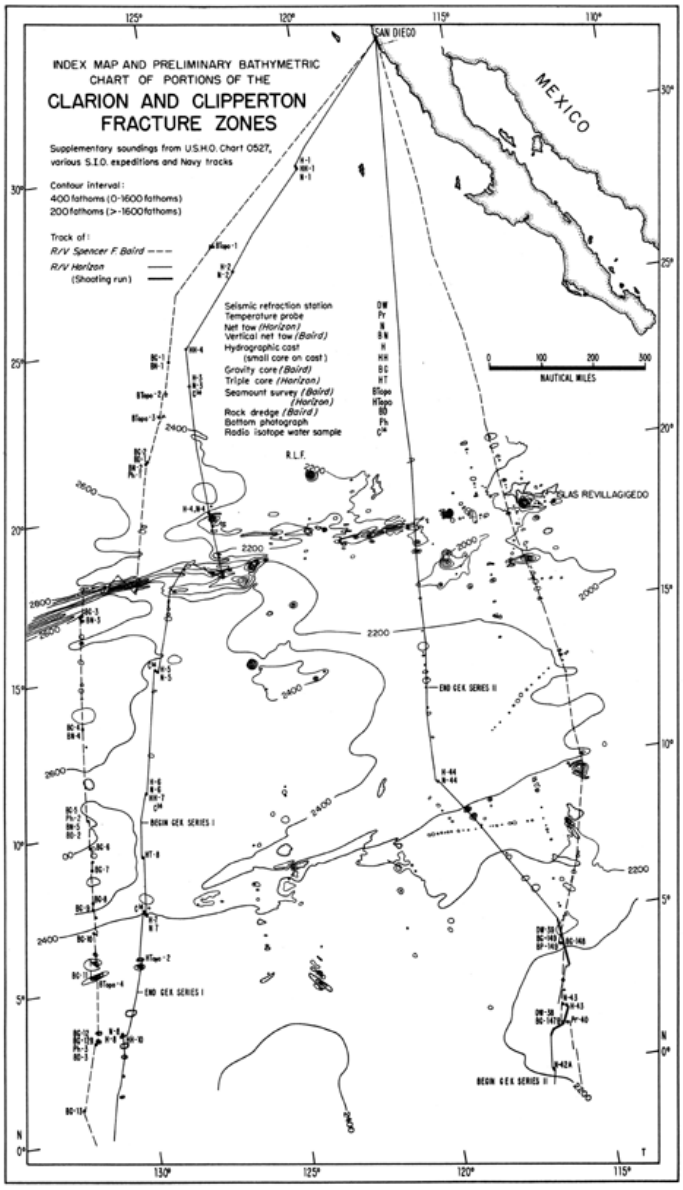

INDEX MAP AND PRELIMINARY BATHYMETRIC CHART OF PORTIONS OF THE
CLARION AND CLIPPERTON FRACTURE ZONES
Supplementary soundings from U.S.H.O. Chart 0527, various S.I.O. expeditions and Navy tracks
Contour interval:
400 fathoms (0-1600 fathoms)
200 fathoms (>-1600 fathoms)
Track of:
R/V Spencer F Baird
R/V Horizon
(Shooting run)
Seismic refraction station
Temperature probe
Net tow (Horizon)
Vertical net tow (Baird)
Hydrographic cast (small core on cast)
Gravity core (Baird)
Triple core (Horizon)
Seamount survey (Baird)
(Horizon)
Rock dredge (Baird)
Bottom photograph
Radio isotope water sample
SAN DIEGO
MEXICO
NAUTICAL MILES
R.I.F.
REVILLAGIGEDO
BEGIN GEX SERIES I
END GEX SERIES I
END GEX SERIES II
BEGIN GEX SERIES II

FIG. 2

FIG. 2

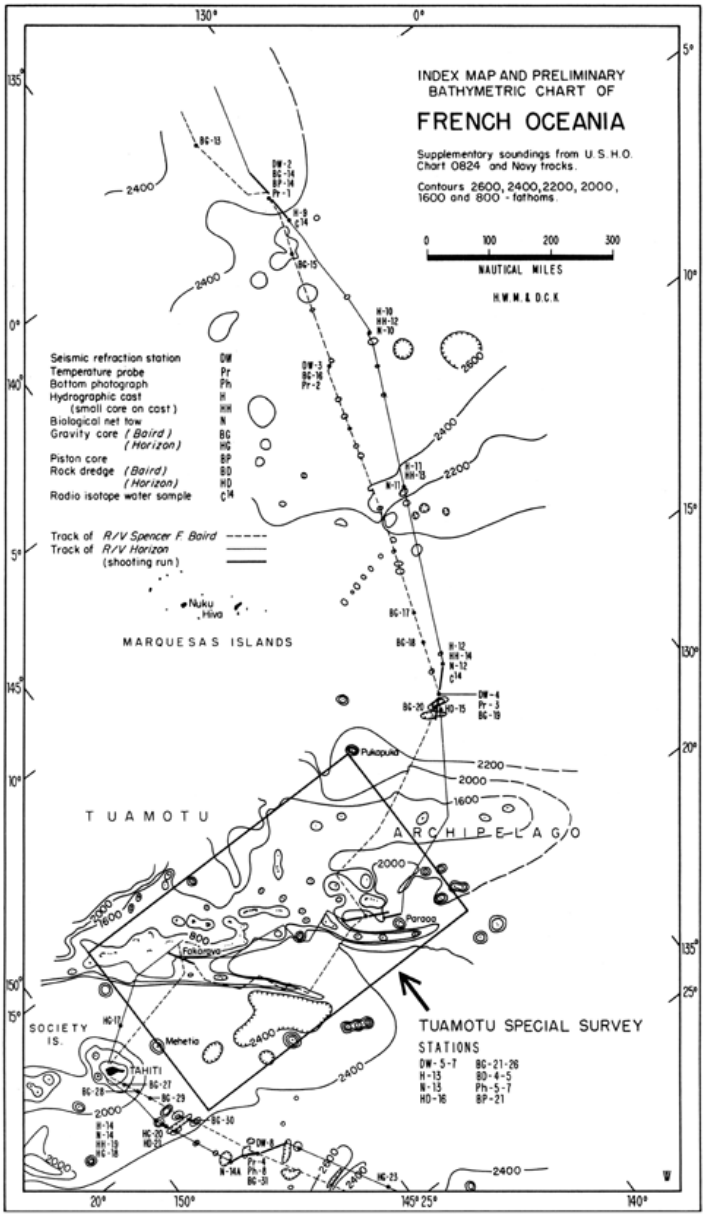

INDEX MAP AND PRELIMINARY
BATHYMETRIC CHART OF
FRENCH OCEANIA
Supplementary soundings from U.S.H.O. Chart 0824 and Navy tracks.
Contours 2600, 2400, 2200, 2000, 1600 and 800 - fathoms.
0 100 200 300
NAUTICAL MILES
H.W.M. & D.C.K.
Seismic refraction station DW
Temperature probe Pr
Bottom photograph Ph
Hydrographic cast H
(small core on cast) HH
Biological net tow N
Gravity core (Baird) BG
(Horizon) HG
Piston core BP
Rock dredge (Baird) BD
(Horizon) HD
Radio isotope water sample C14
Track of R/V Spencer F. Baird
Track of R/V Horizon
(shooting run)
Nuku Hiva
MARQUESAS ISLANDS
Pukapuka
TUAMOTU ARCHIPELAGO
Fakarava
Makatea
Mehetia
SOCIETY IS.
TAHITI
TUAMOTU SPECIAL SURVEY
STATIONS
DW-5-7 BG-21-26
H-13 BD-4-5
N-13 Ph-5-7
HO-16 BP-21
2400
2200
2000
1600
800

FIG. 3

FIG. 3

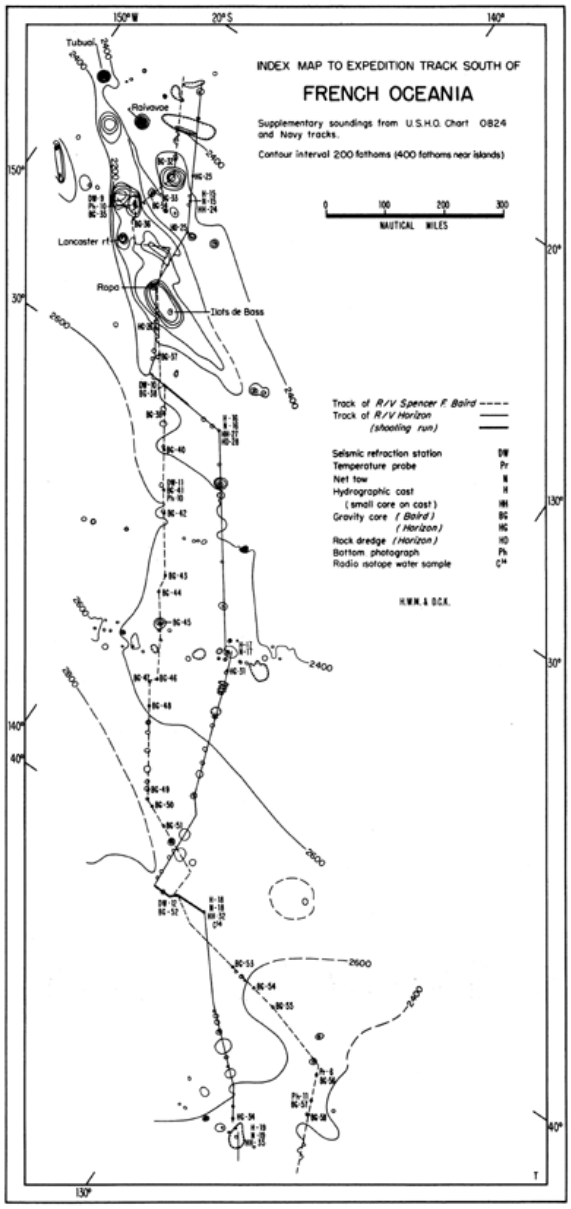
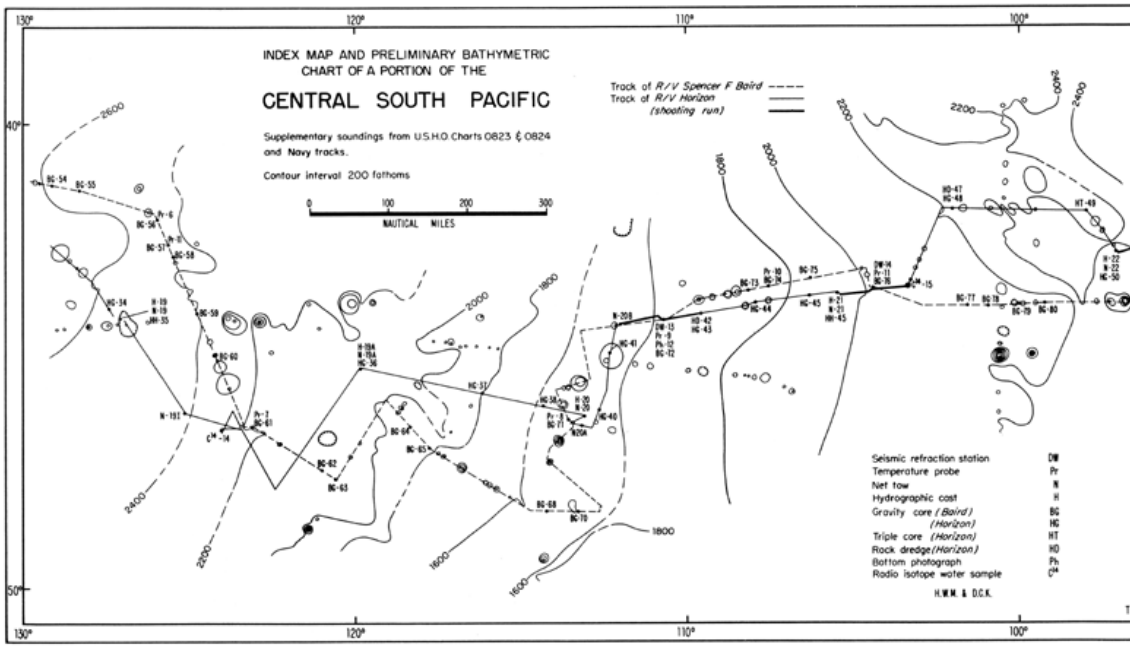

INDEX MAP TO EXPEDITION TRACK SOUTH OF
FRENCH OCEANIA
Supplementary soundings from U.S.H.O. Chart 0824 and Navy tracks.
Contour interval 200 fathoms (400 fathoms near islands)
0 100 200 300
NAUTICAL MILES
Tubuai
Raivavae
Lancaster rf
Ropa
Iles de Bass
Track of R/V Spencer F. Baird
Track of R/V Horizon (shooting run)
Seismic refraction station DW
Temperature probe Pr
Net tow N
Hydrographic cast H
(small core on cast) HH
Gravity core (Baird) BG
(Horizon) HG
Rock dredge (Horizon) HD
Bottom photograph Ph
Radio isotope water sample C14
H.W.N. & O.C.K.
150°W
20°S
140°
150°
30°
140°
40°
130°
20°
30°
40°
2400
2600

FIG. 4

FIG. 4

FIG. 5


INDEX MAP AND PRELIMINARY BATHYMETRIC CHART OF A PORTION OF THE
CENTRAL SOUTH PACIFIC
Supplementary soundings from U.S.H.O. Charts 0823 & 0824 and Navy tracks.
Contour interval 200 fathoms
0 100 200 300
NAUTICAL MILES
Track of R/V Spencer F Baird
Track of R/V Horizon (shooting run)
130°
120°
110°
100°
40°
50°
Seismic refraction station
Temperature probe
Net tow
Hydrographic cast
Gravity core (Baird)
(Horizon)
Triple core (Horizon)
Rock dredge (Horizon)
Bottom photograph
Radio isotope water sample
H.W.N. & D.C.K.

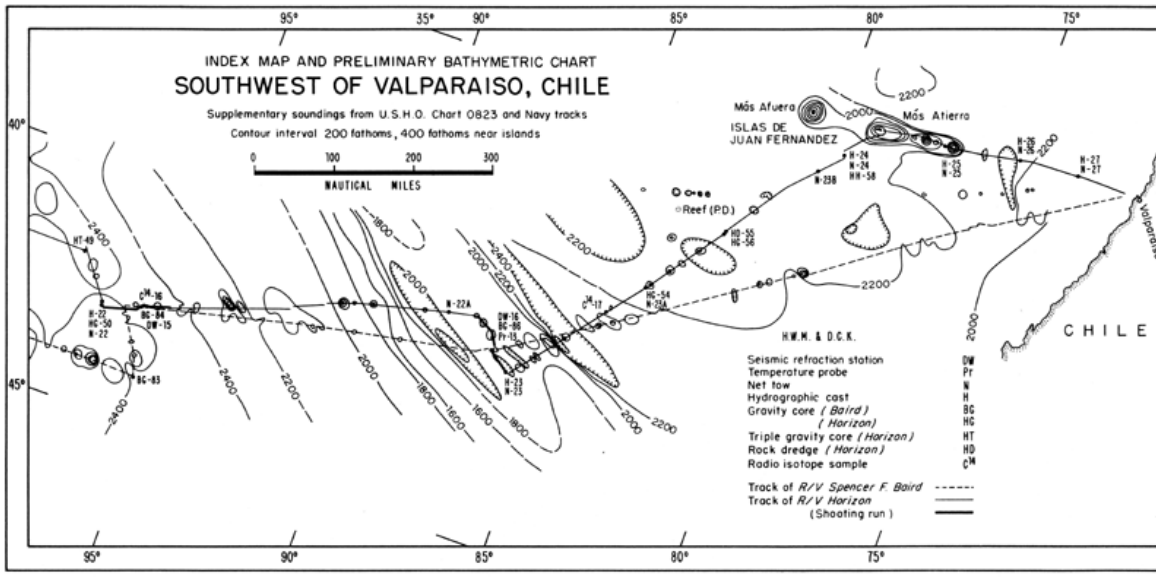


FIG. 6

FIG. 6

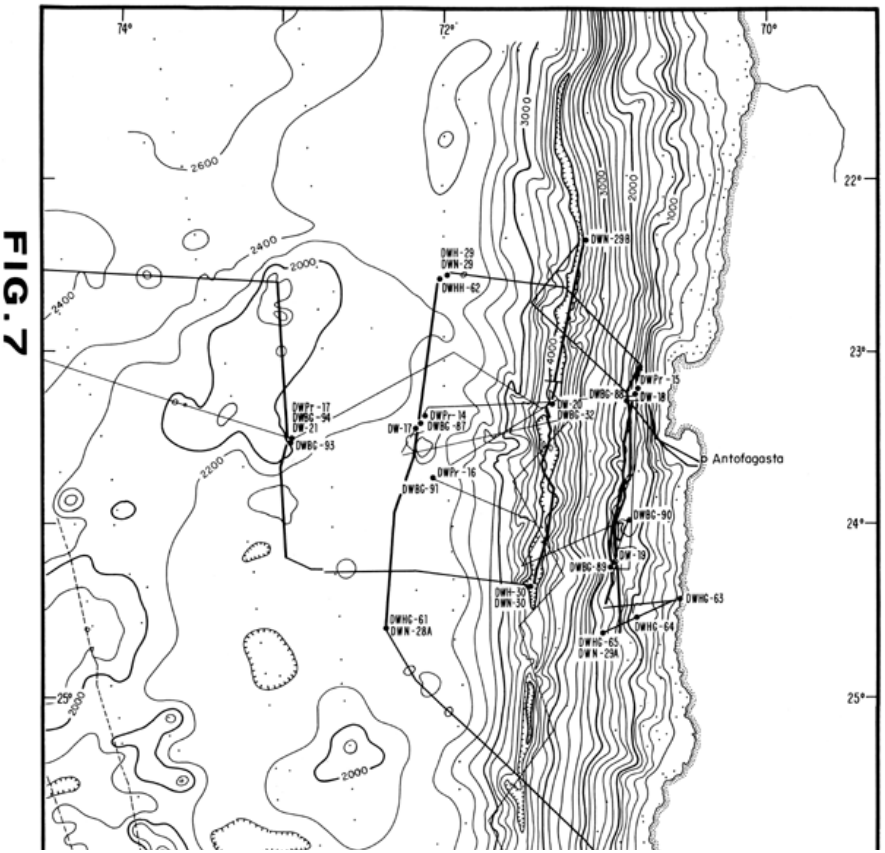


FIG. 7

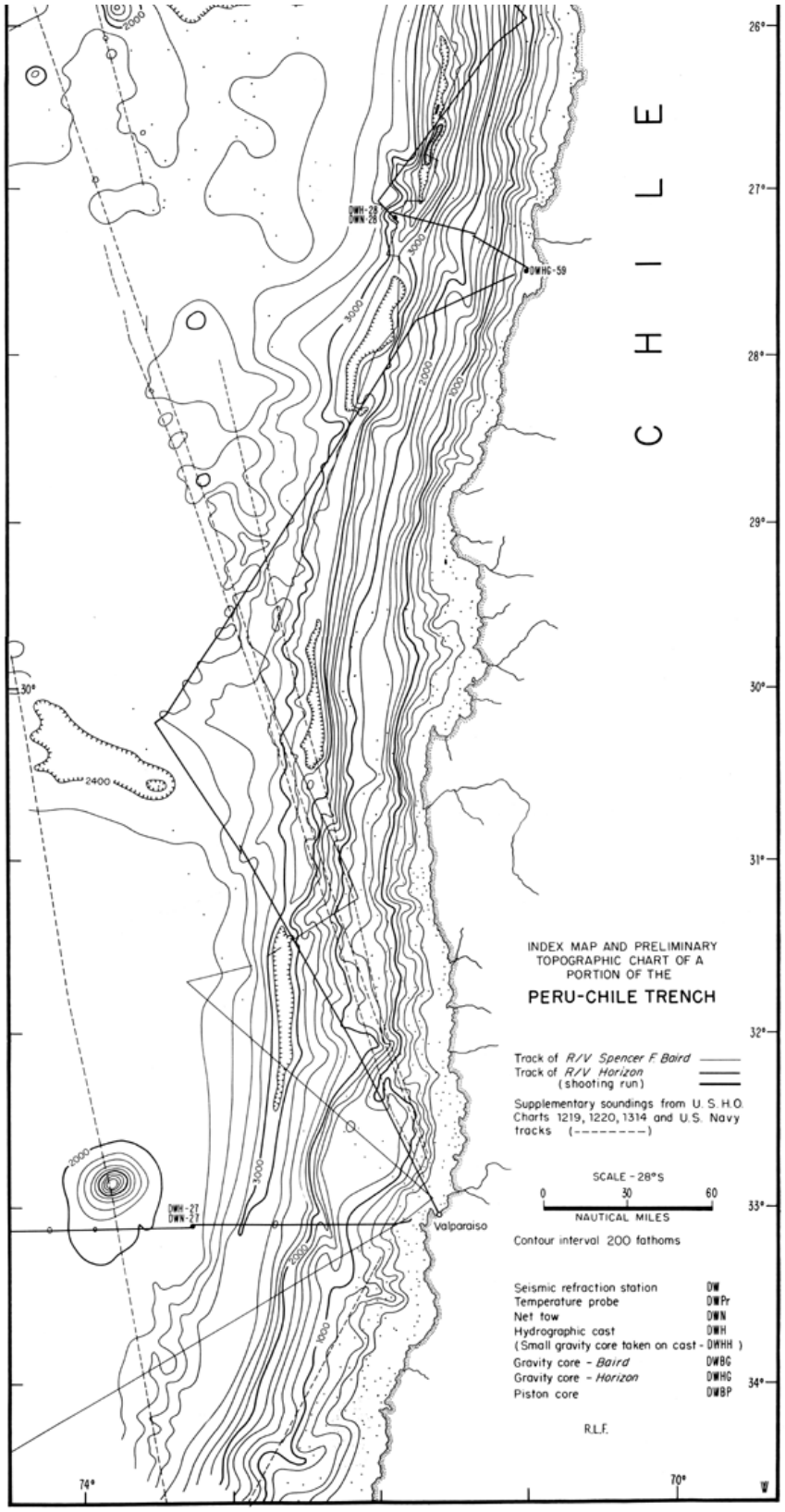

CHILE
26°
27°
28°
29°
30°
31°
32°
33°
34°
74°
70°
W
DWH-28
DWN-28
DWHG-59
DWH-27
DWN-27
Valparaiso
2000
3000
1000
2400
INDEX MAP AND PRELIMINARY
TOPOGRAPHIC CHART OF A
PORTION OF THE
PERU-CHILE TRENCH
Track of R/V Spencer F. Baird
Track of R/V Horizon
(shooting run)
Supplementary soundings from U. S. H.O.
Charts 1219, 1220, 1314 and U.S. Navy
tracks (--------)
SCALE - 28°S
0 30 60
NAUTICAL MILES
Contour interval 200 fathoms
Seismic refraction station DW
Temperature probe DWPr
Net tow DWN
Hydrographic cast DWH
(Small gravity core taken on cast - DWHH)
Gravity core - Baird DWBG
Gravity core - Horizon DWHG
Piston core DWBP
R.L.F.

FIG. 7

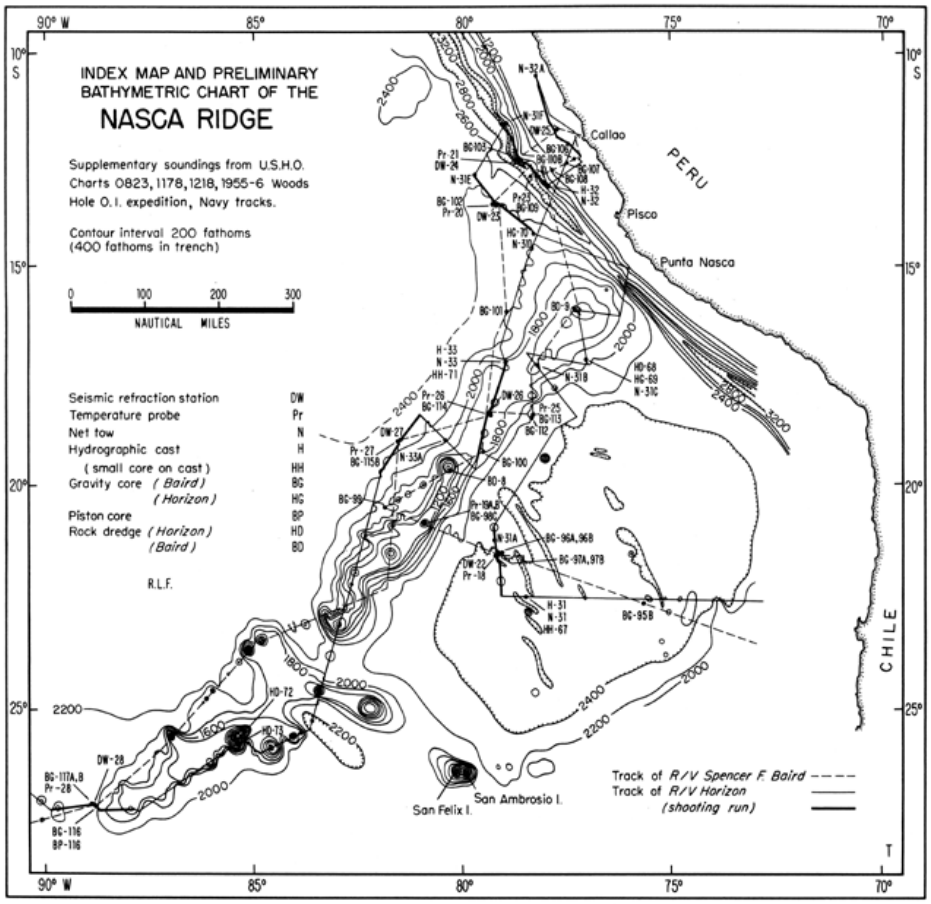
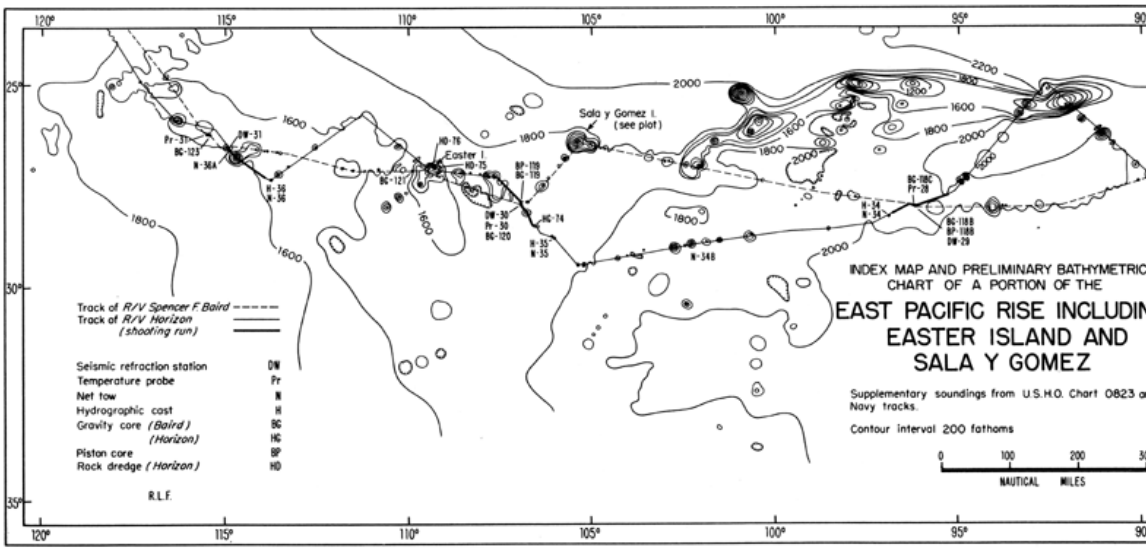

INDEX MAP AND PRELIMINARY
BATHYMETRIC CHART OF THE
NASCA RIDGE
Supplementary soundings from U.S.H.O. Charts 0823, 1178, 1218, 1955-6 Woods Hole O.I. expedition, Navy tracks.
Contour interval 200 fathoms (400 fathoms in trench)
0 100 200 300
NAUTICAL MILES
Seismic refraction station DW
Temperature probe Pr
Net tow N
Hydrographic cast H
(small core on cast) HH
Gravity core (Baird) BG
(Horizon) HG
Piston core BP
Rock dredge (Horizon) HD
(Baird) BD
R.L.F.
Callao
PERU
Pisco
Punta Nasca
CHILE
San Felix I.
San Ambrosio I.
Track of R/V Spencer F. Baird
Track of R/V Horizon
(shooting run)
90° W
85°
80°
75°
70°
10° S
15°
20°
25°

FIG.8

FIG. 8

FIG. 9


120°
115°
110°
105°
100°
95°
25°
30°
35°
Sala y Gomez I.
(see plot)
Easter I.
1600
1800
2000
2200
Track of R/V Spencer F. Baird
Track of R/V Horizon
(shooting run)
Seismic refraction station DW
Temperature probe Pr
Net tow N
Hydrographic cast H
Gravity core (Baird) BG
(Horizon) HG
Piston core BP
Rock dredge (Horizon) HD
R.L.F.
INDEX MAP AND PRELIMINARY BATHYMETRIC
CHART OF A PORTION OF THE
EAST PACIFIC RISE INCLUDIN
EASTER ISLAND AND
SALA Y GOMEZ
Supplementary soundings from U.S.H.O. Chart 0823 a
Navy tracks.
Contour interval 200 fathoms
0
100
200
NAUTICAL
MILES

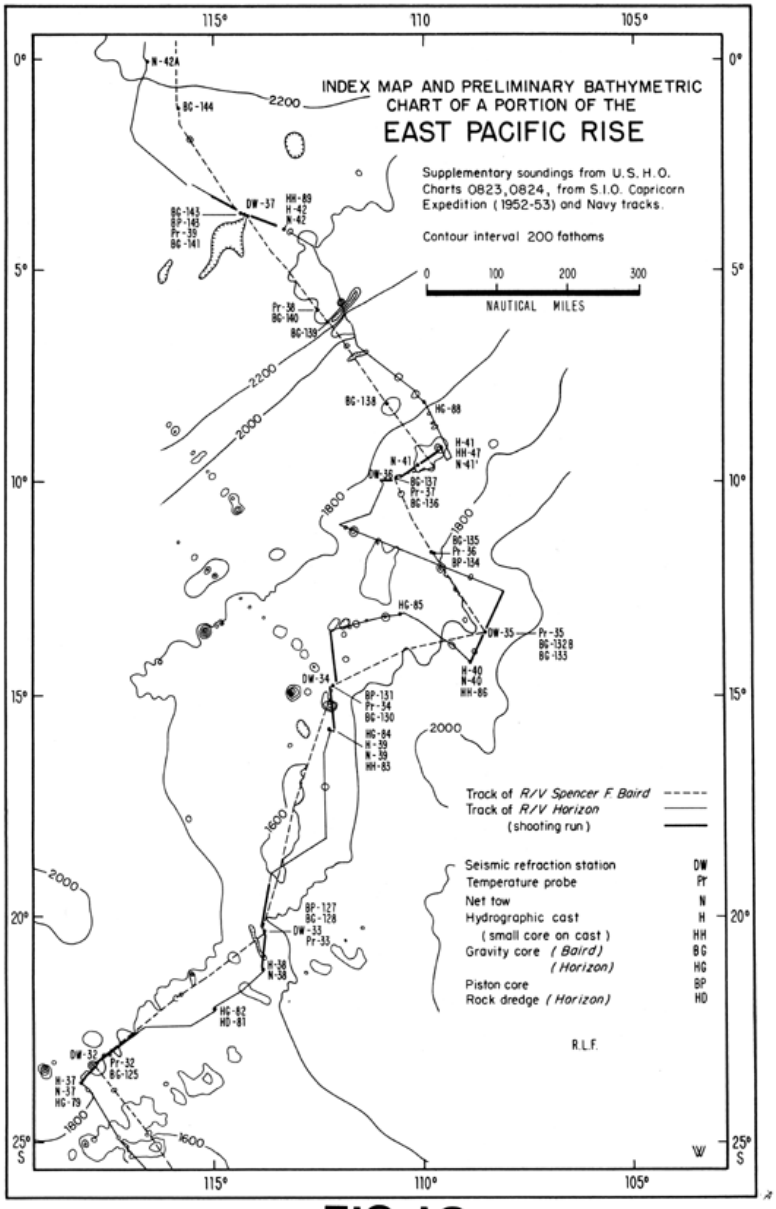
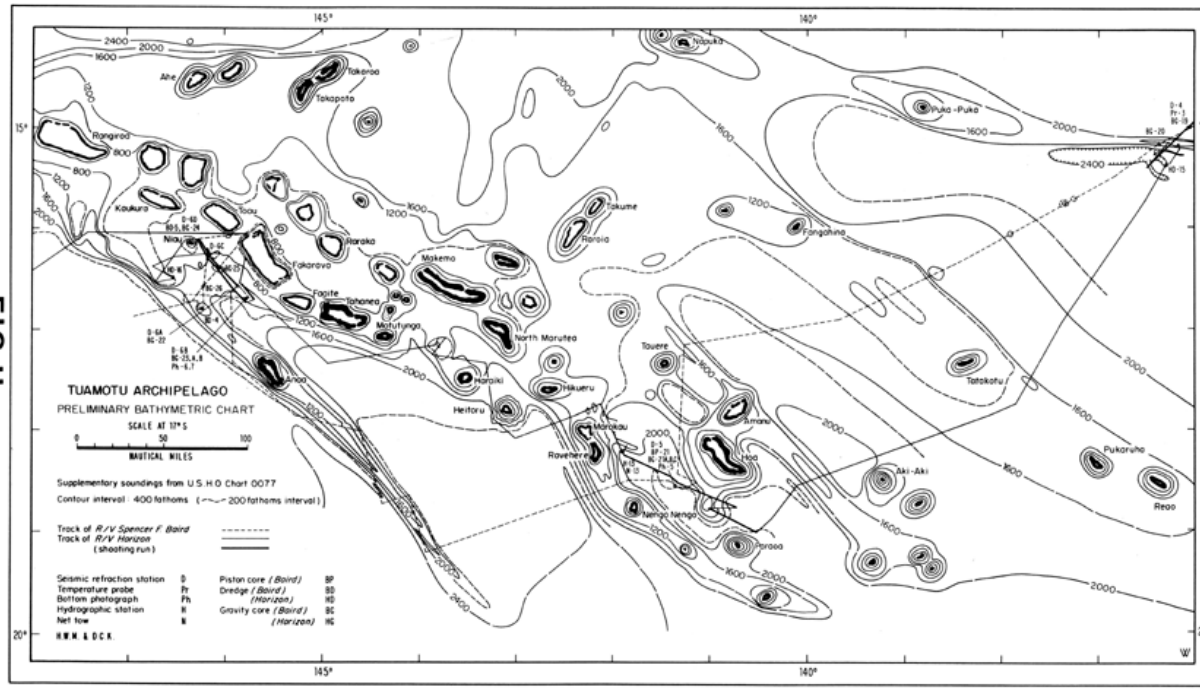

INDEX MAP AND PRELIMINARY BATHYMETRIC CHART OF A PORTION OF THE
EAST PACIFIC RISE
Supplementary soundings from U.S.H.O. Charts 0823, 0824, from S.I.O. Capricorn Expedition (1952-53) and Navy tracks.
Contour interval 200 fathoms
0 100 200 300
NAUTICAL MILES
115°
110
105°
0°
5°
10°
15°
20°
25° S
2200
2000
1800
1600
N-42A
BC-144
DW-37
HH-89
H-42
N-42
BC-143
BP-145
Pr-39
BC-141
Pr-38
BC-140
BC-139
BC-138
HC-88
H-41
HH-47
N-41'
N-41
DW-36
BC-137
Pr-37
BC-136
BC-135
Pr-36
BP-134
HC-85
DW-35
Pr-35
BC-132 B
BC-133
H-40
N-40
HH-86
DW-34
BP-131
Pr-34
BC-130
HC-84
H-39
N-39
HH-85
BP-127
BC-128
DW-33
Pr-33
Pr-32
N-38
HC-82
HD-81
DW-32
Pr-32
BC-125
H-37
N-37
HC-79
Track of R/V Spencer F. Baird
Track of R/V Horizon
(shooting run)
Seismic refraction station DW
Temperature probe Pr
Net tow N
Hydrographic cast H
(small core on cast) HH
Gravity core (Baird) BC
(Horizon) HC
Piston core BP
Rock dredge (Horizon) HD
R.L.F.
W

FIG. 10

FIG. 10

FIG. 11


145°
140°
15°
20°
Takaroa
Takapoto
Rangiroa
Kaukura
Arutua
Fakarava
Makemo
Tahanea
Faaite
Motutunga
North Marutea
Haraiki
Heitoru
Hikueru
Marokau
Ravahere
Touere
Amanu
Takume
Haroia
Fangahina
Tatakotu
Aki-Aki
Pukaruha
Reao
Puka-Puka
Nukutavake
TUAMOTU ARCHIPELAGO
PRELIMINARY BATHYMETRIC CHART
SCALE AT 17° S
0 50 100
NAUTICAL MILES
Supplementary soundings from U.S.H.O. Chart 0077
Contour interval : 400 fathoms (200 fathoms interval)
Track of R/V Spencer F. Baird
Track of R/V Horizon
(shooting run)
Seismic refraction station D
Temperature probe Pr
Bottom photograph Ph
Hydrographic station H
Net tow N
Piston core (Baird) BP
Dredge (Baird) BD
(Horizon) HD
Gravity core (Baird) BG
(Horizon) HG
H.W.M. & D.C.K.

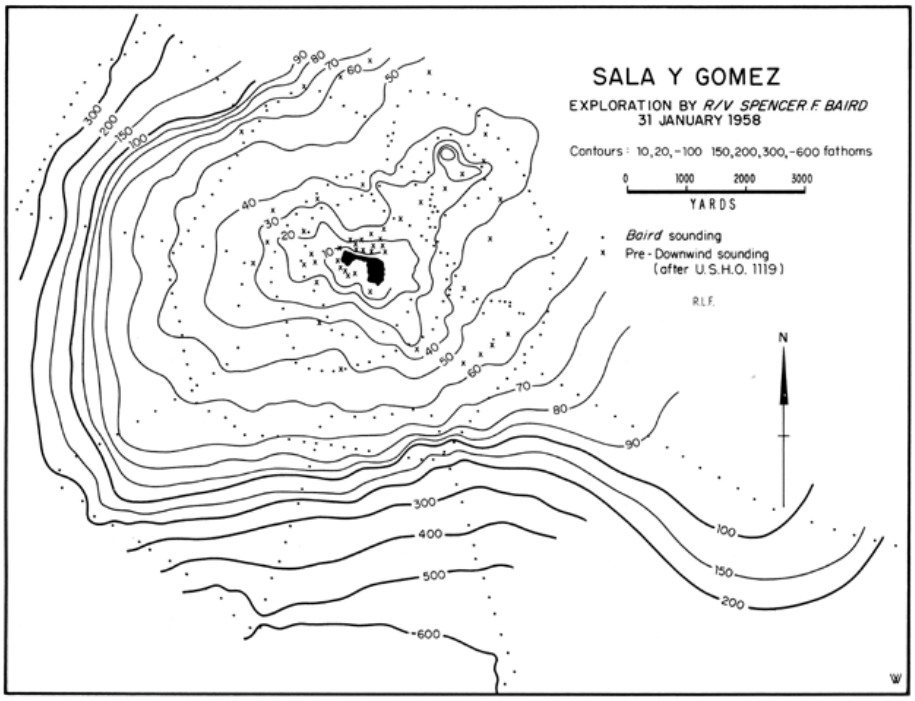

SALA Y GOMEZ
EXPLORATION BY R/V SPENCER F. BAIRD
31 JANUARY 1958
Contours: 10,20,-100 150,200,300,-600 fathoms
0 1000 2000 3000
YARDS
Baird sounding
Pre-Downwind sounding
(after U.S.H.O. 1119)
R.L.F.
N
W

FIG. 12

FIG. 12

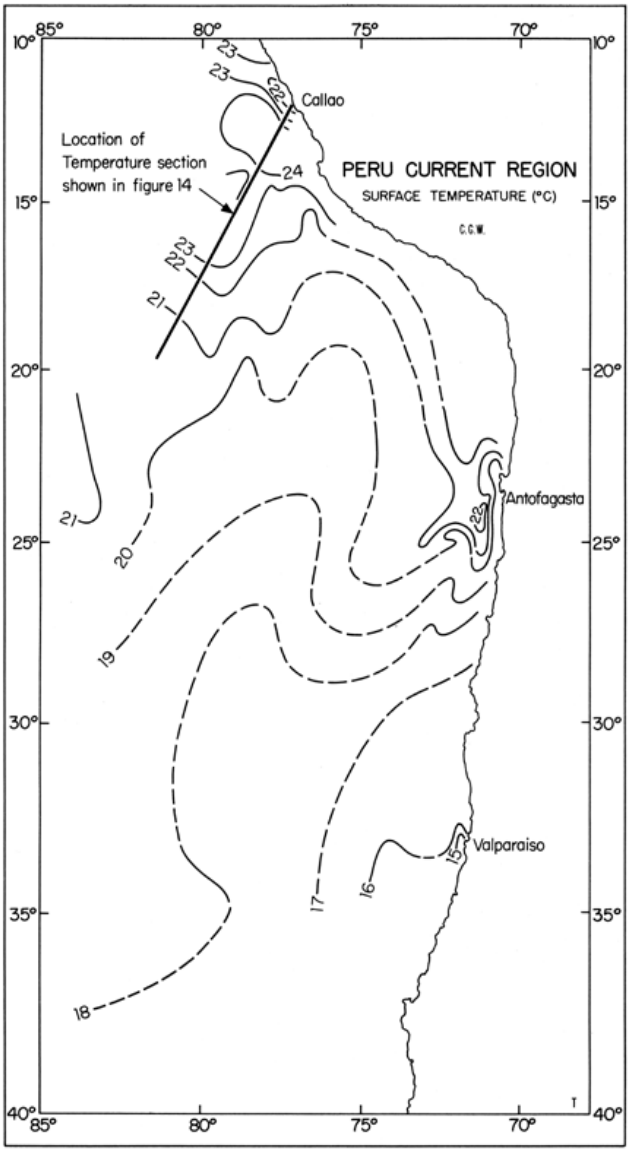

PERU CURRENT REGION
SURFACE TEMPERATURE (°C)
C.C.V.
Location of
Temperature section
shown in figure 14
Callao
Antofagasta
Valparaiso
85°
80°
75°
70°
10°
15°
20°
25°
30°
35°
40°

FIG. 13

FIG. 13

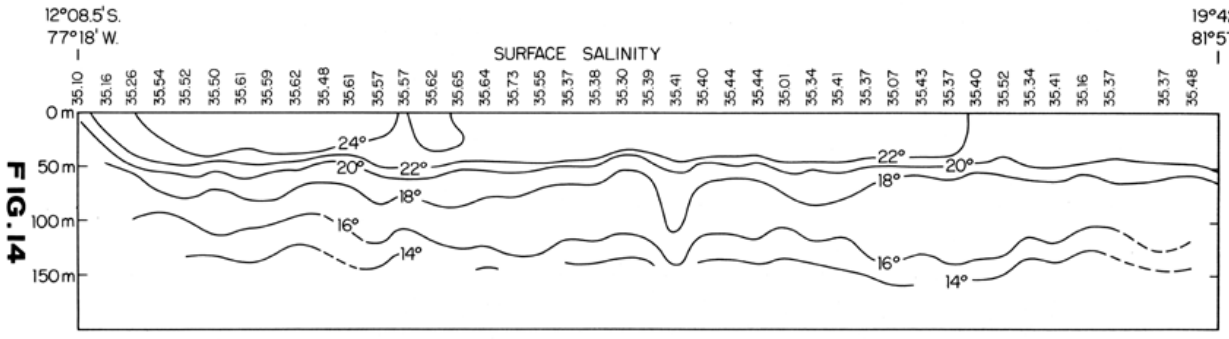


FIG. 14

Downwind Expedition, Temperature profile across the region of the Peru Current, from Bathythermograph observations. Position of the line is shown in Figure 13

FIG. 14

Downwind Expedition, Temperature profile across the region of the Peru Current, from Bathythermograph observations. Position of the line is shown in figure 13

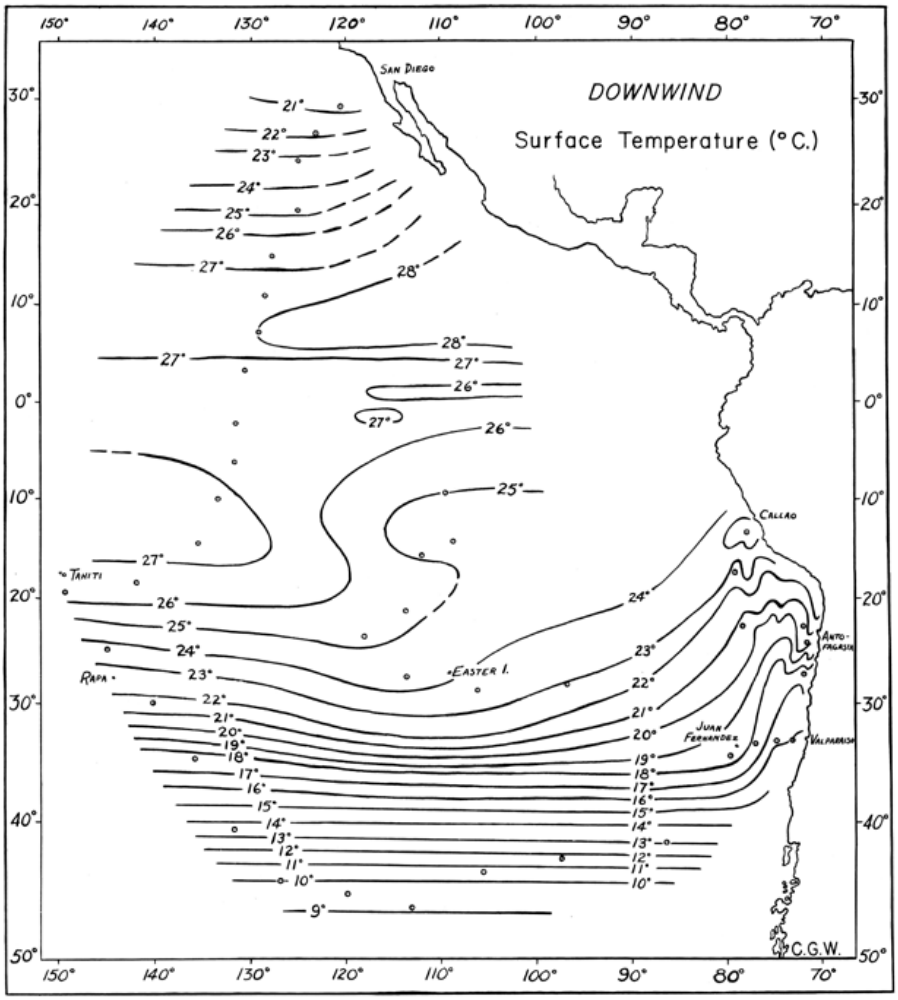

DOWNWIND
Surface Temperature (°C.)
SAN DIEGO
CALLAO
TAHITI
RAPA
EASTER I.
JUAN FERNANDEZ
VALPARAISO
ANTOFAGASTA
C.G.W.
150°
140°
130°
120°
110°
100°
90°
80°
70°
30°
20°
10°
0°
10°
20°
30°
40°
50°

FIG. 15

FIG. 15

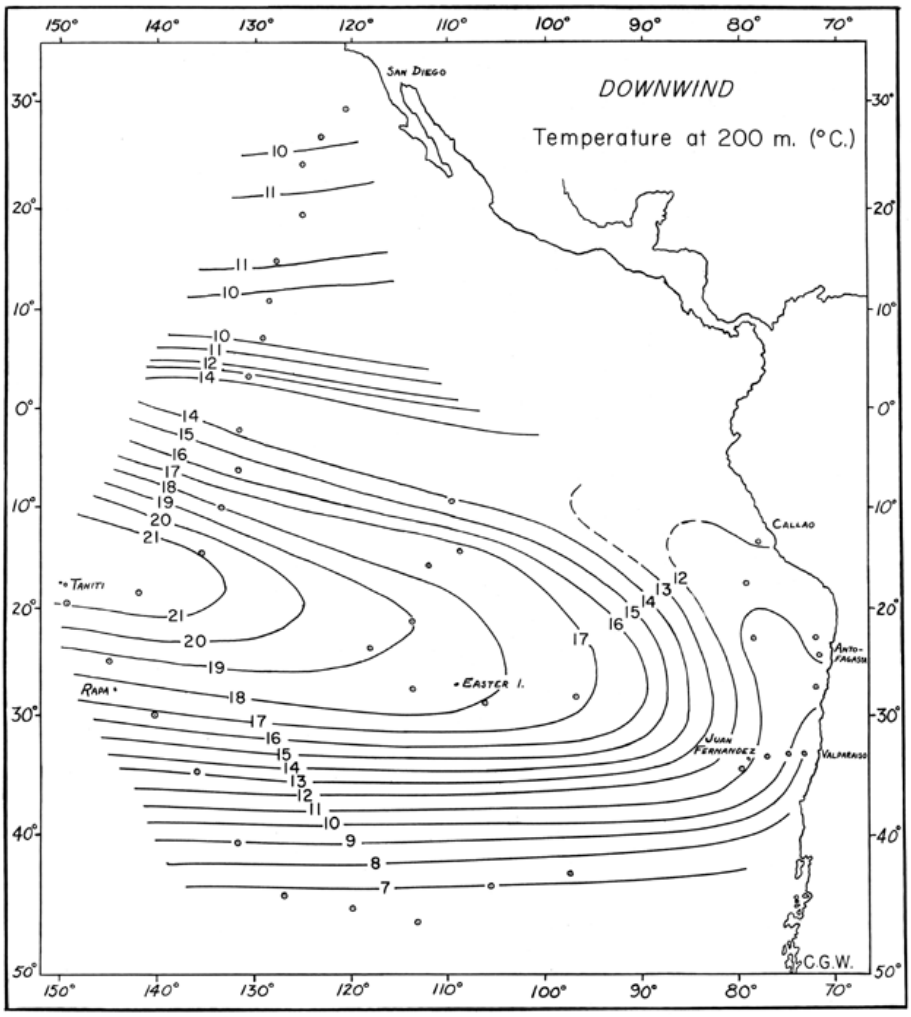

DOWNWIND
Temperature at 200 m. (°C.)
SAN DIEGO
CALLAO
TAHITI
RAPA
EASTER I.
JUAN FERNANDEZ
VALPARAISO
ANTOFAGASTA
C.G.W.
150°
140°
130°
120°
110°
100°
90°
80°
70°
30°
20°
10°
0°
10°
20°
30°
40°
50°

FIG .16

FIG. 16

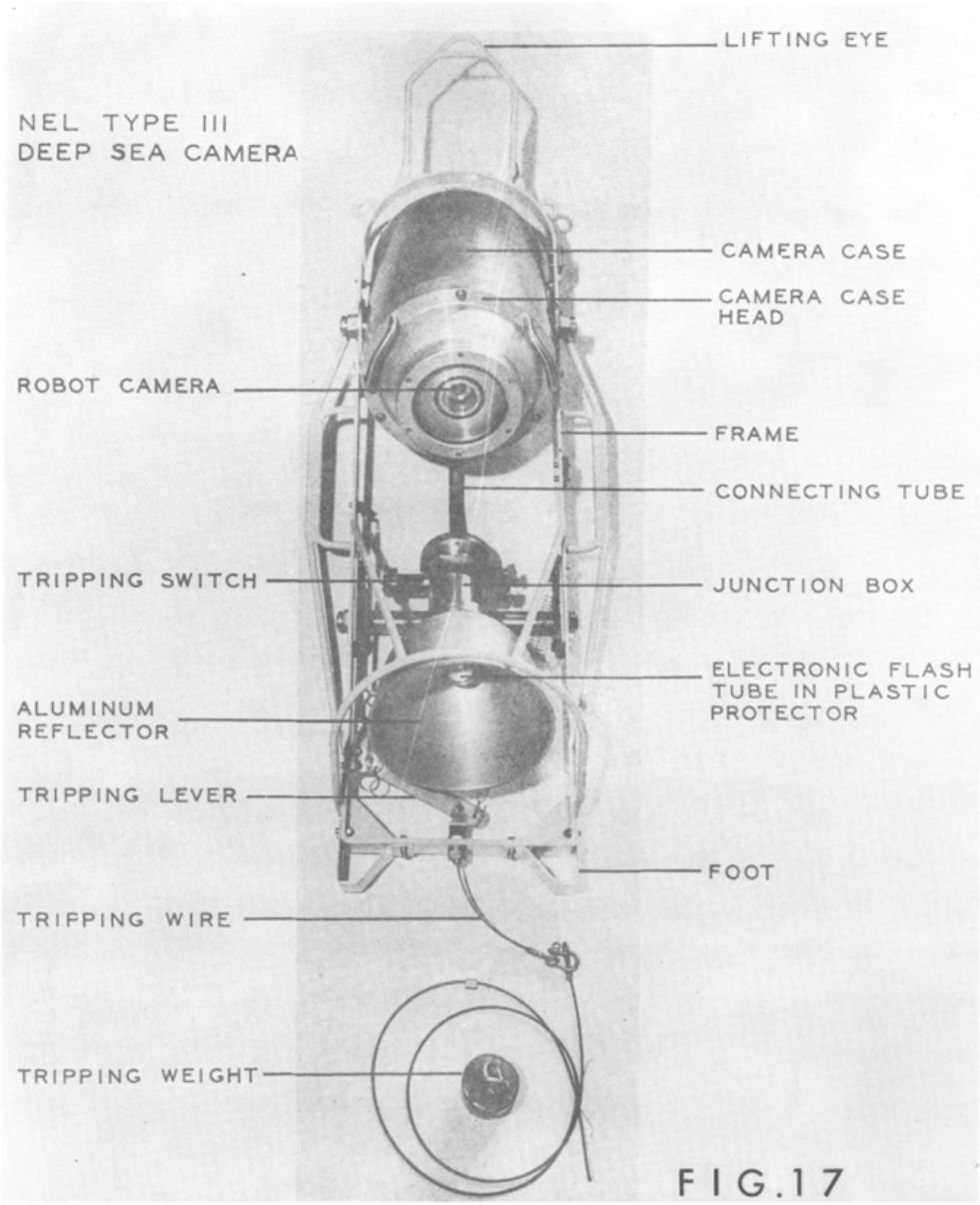
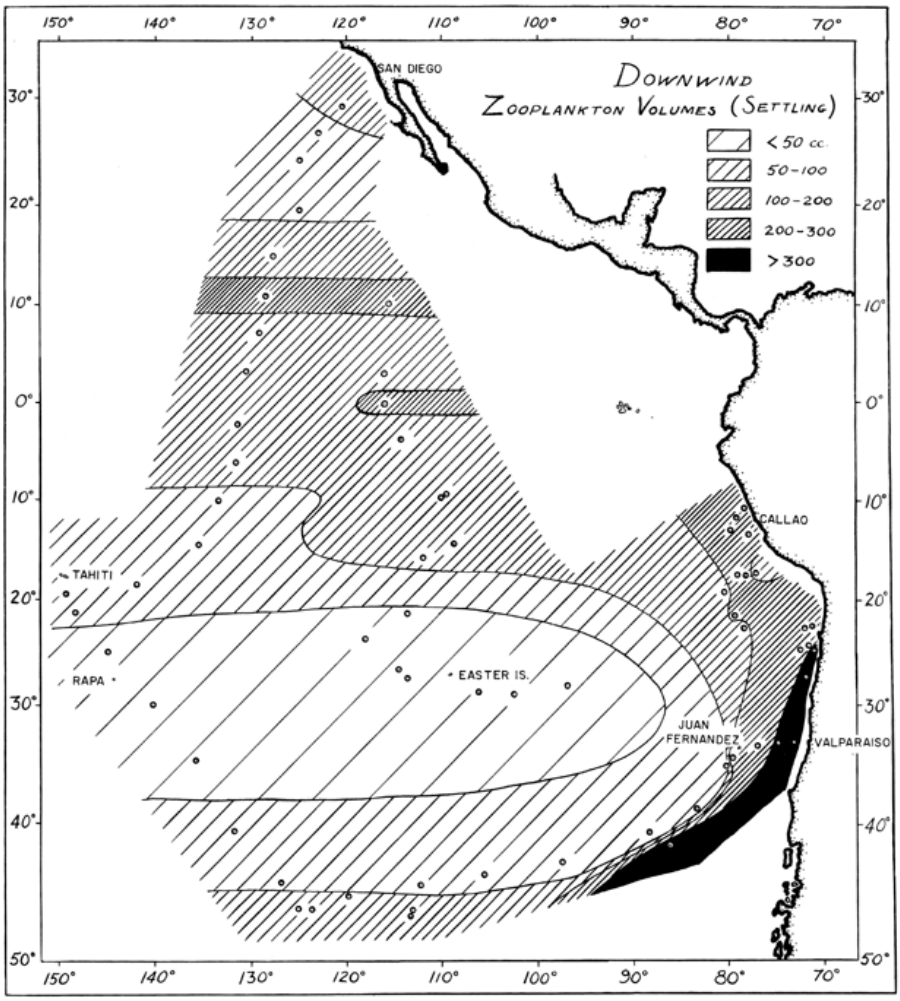

NEL TYPE III
DEEP SEA CAMERA
LIFTING EYE
CAMERA CASE
CAMERA CASE HEAD
ROBOT CAMERA
FRAME
CONNECTING TUBE
TRIPPING SWITCH
JUNCTION BOX
ELECTRONIC FLASH TUBE IN PLASTIC PROTECTOR
ALUMINUM REFLECTOR
TRIPPING LEVER
FOOT
TRIPPING WIRE
TRIPPING WEIGHT
FIG.17

FIG. 17

FIG. 18

FIG. 18

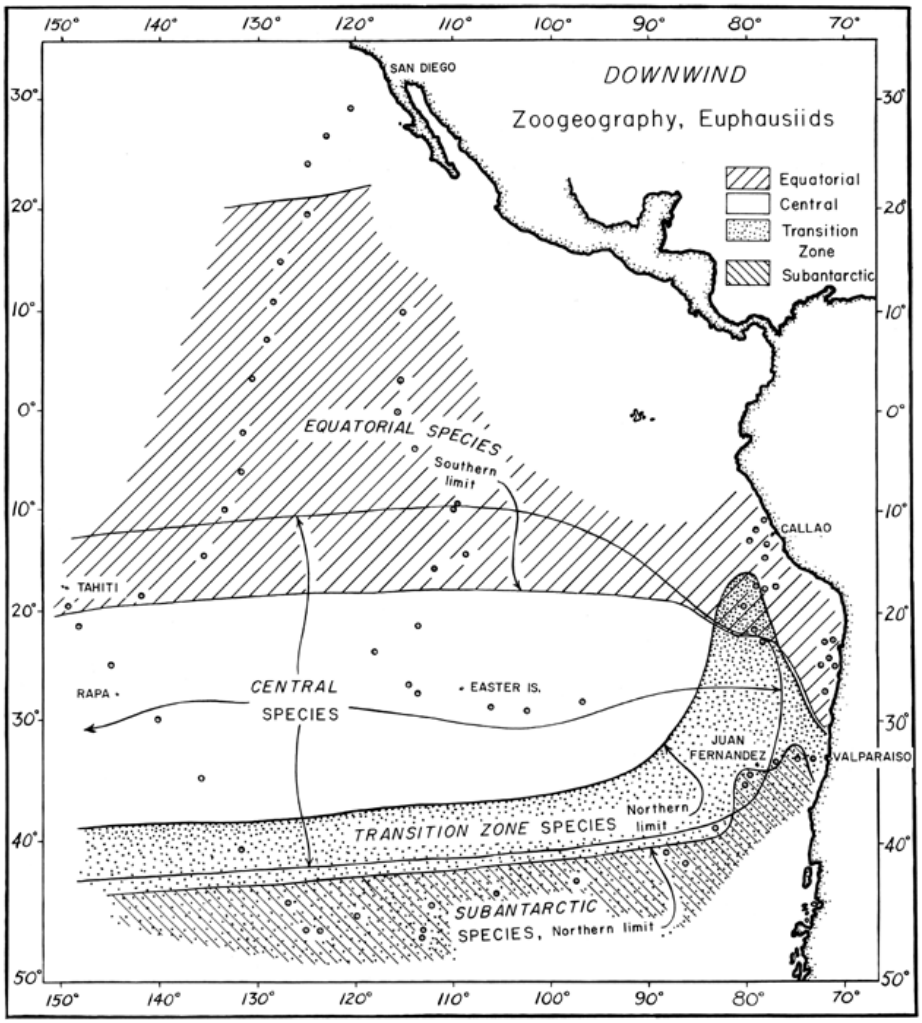


Downwind Expedition. Volume of zooplankton settling in fluid, in standard 0-400 m. tow with one-meter net. Positions of plankton stations are shown.

FIG. 19

FIG. 19

Downwind Expedition. Volume of zooplankton settling in fluid, in standard 0–400 m, tow with one-meter net. Positions of plankton stations are shown.

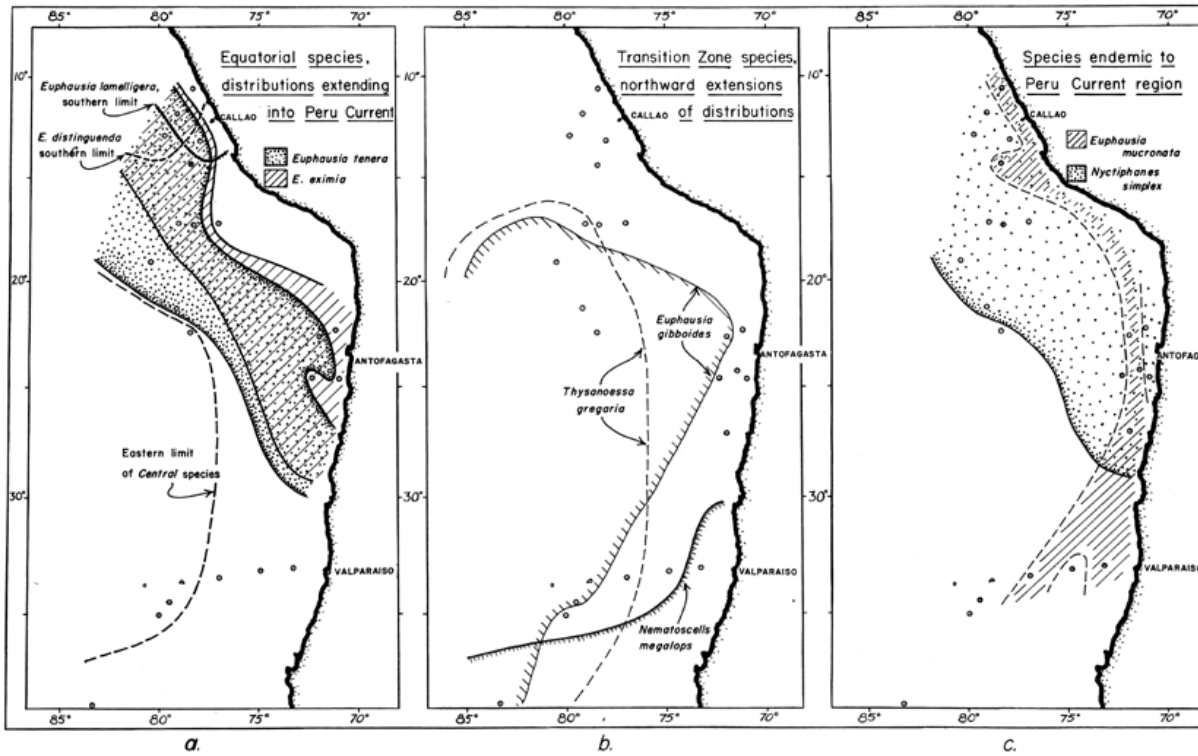


DOWNWIND EXPEDITION. Pelagic Zoogeographic Zones, Indicated by Assemblages of Euphausiid Species.

FIG. 20

FIG. 20

DOWNWIND EXPEDITION. Pelagic Zoogeographic Zones, Indicated by Assemblages of Euphausiid Species.



Downwind Expedition. Distributions of plankton species in the region of the Peru Current, Dec. 1957 - Jan. 1958.

FIG. 21

FIG. 21

Downwind Expedition. Distributions of plankton species in the region of the Peru Current, Dec. 1957 – Jan. 1958.

FOOTNOTES

1. Brinton, E., 1957, Distribution, Faunistics and Evolution of Pacific Euphausiids, Doctoral Dissertation, University of California.

2. Agassiz, Alexander, 1905, Letters to the Hon. George M. Bowers. Bull. Mus. of Comp. Zool., Vol. XLVI, pp. 71–74.

3. CAPRICORN Expedition, Scripps Institution Preliminary Cruise Rept., 1953.