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Shellback Expedition, 17 May to 27 August 1952

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SHELLBACK EXPEDITION

17 May to 27 August 1952

Warren S. Wooster

Sponsored by  
Office of Naval Research  
and  
Bureau of Ships

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Approved for distribution:



Roger Revelle, Director

CONTENTS

	Page
INTRODUCTION	1
PERSONNEL	2
NARRATIVE	3
SUMMARY OF OBSERVATIONS	4
SHIPBOARD PROCESSING	5
TRAWLS IN THE OXYGEN MINIMUM	6
OXYGEN DISTRIBUTION	7
SUBMARINE FEATURES	7
PANAMA BASIN	7
CURRENT-DRAG MEASUREMENTS	9
GEOMAGNETIC ELECTROKINETOGRAPH OBSERVATIONS	10
SURFACE CIRCULATION	11
MISCELLANY	13

## INTRODUCTION

The 1952 University of California SHELLBACK Expedition was part of an extensive oceanographic study of the eastern equatorial Pacific. In this overall operation, known as, Operation CO-OP, the following agencies participated.

1. University of California, Scripps Institution of Oceanography - carried out SHELLBACK Expedition, furnished some personnel to SHUTTLE Expedition. This work was supported by the Office of Naval Research and the Bureau of Ships.
2. U.S. Navy Electronics Laboratory - carried out SHUTTLE Expedition, furnished some personnel and equipment to SHELLBACK Expedition.
3. Inter-American Tropical Tuna Commission - furnished personnel, equipment, and technical assistance to SHELLBACK Expedition.
4. U.S. Fish and Wildlife Service, Pacific Oceanic Fishery Investigations - carried out SHORTCUT Expedition and other fishing and oceanographic observations during the time of SHELLBACK but in the region to the west.
5. U.S. Weather Bureau - furnished personnel and some equipment for meteorological program on SHELLBACK Expedition. This program was financed by the Office of Naval Research.
6. U.S. Air Force - furnished personnel and equipment for aerial reconnaissance out of Panama. Observations were made by personnel from Scripps Institution.
7. Hydrographic Office of the Peruvian Navy - furnished technical assistance to SHELLBACK Expedition, carried out synoptic bathy-thermograph observations during SHELLBACK's study of the Peru Current.

This report, in addition to presenting the basic statistics of the SHELLBACK Expedition, discusses some highlights of the scientific findings. At this early date it is, of course, impossible for this discussion to be complete or indeed much more than superficial. The author is deeply indebted to members of the scientific party and in particular to Drs. M.B. Schaefer and R.S. Arthur, and to Messrs. J.A. Knauss and G.A. Shumway for their assistance in the preparation of this report. The sections on Current Drag Measurements and GEK Observations are derived from Mr. Knauss's notes on these observations.

## PERSONNEL

The following scientific personnel participated in all or part of the SHELLBACK Expedition (letters A, B, and C indicate legs of the expedition; leg A, San Diego to Acapulco, leg B, Acapulco to Puntarenas, leg C, Puntarenas to San Diego).

Scripps Institution

Allanson, A.	Marine Technician	A
Arthur, R.S.	Assist. Professor of Oceanography	C
Berner, Leo	Research Assistant	ABC
Bush, A.J.	LCDR, U.S. Coast Guard	BC
Cochrane, J.D.	Assist. Research Oce.	BC
Cunningham, L.	Senior Marine Technician	ABC
Ewing, G.	Assist. Research Oce.	AB (1)
Gilkey, R.	Senior Marine Technician	ABC
Goldberg, E.D.	Assist. Marine Chemist	B
Kittredge, J.	Research Assistant	A
Knauss, J.A.	Grad. Research Oce. II	BC
Koide, M.	Senior Laboratory Technician	ABC
Lewis, G.J.	Grad. Research Oce. II	C
Love, C.M.	Research Assistant	BC
Mead, R.	Principal Marine Technician	A
Rakestraw, N.W.	Professor of Chemistry	A
Wisner, R.	Senior Laboratory Technician	C
Wooster, W.S.	Assist. Research Oce. and Scientific Leader, SHELLBACK	ABC

U.S. Navy Electronics Laboratory

Dill, R. F.	Marine Geologist	A
Shumway, G.A.	Marine Geologist	BC

Inter-American Tropical Tuna Commission

Juhl, R.	Fishery Biologist	AB
Schaefer, M.B.	Director of Investigations	B

U.S. Weather Bureau

Franklin, H.	Meteorological Aide	A
Gribble, W.	Meteorological Aide	BC
Richter, A.P.	Meteorological Aide	ABC
Valente, R.A.	Meteorological Aide	ABC

Compania Administradora del Guano, Peru

Avila, Enrique	Ornithologist	B (2)
Barreda, Mario	Fishery Biologist	B (3)
Landa, Antonio	Fishery Biologist	B (3)

Office of Fish and Game, Peru

Ancieta, Felipe	Chief, Div. of Fishery Research	B (2)
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- Notes: (1) Observer in AF B-17 out of Panama  
 (2) On board between Talara and Callao, Peru  
 (3) On board between Callao, Peru and Puntarenas, Costa Rica

## NARRATIVE

At 2307 PST on 17 May, R/V HORIZON sailed from San Diego on the first leg of the SHELLBACK Expedition (see Figure 1). Crossing the equatorial current system to 7°S, then heading north again, she arrived in Acapulco, Mexico on 14 June, to conclude Leg A of the expedition.

On Leg B, the ship sailed from Acapulco on 17 June, crossed the equator to 10°S, then sailed east across the Peru Current into the Gulf of Guayaquil, anchoring in the Guayas River on 5 July. From Guayaquil, Ecuador, the ship sailed on 8 July to Talara, Peru, for fuel and rendezvous with the BONDY of the Peruvian Navy. After four short sections across the Peru Current, Callao was reached on 16 July. From Callao the HORIZON sailed on 20 July on a long section across the Peru Current to 15°S. From here she steamed due north on 85°W to Puntarenas, Costa Rica, arriving there on 1 August. This concluded Leg B.

On the last leg of the expedition, the ship sailed from Puntarenas on 3 August, to the west across the supposed position of Guardian Bank, then south towards the Galapagos Islands. During the work in this region, stops were made at Wreck Bay on San Cristobal Island and Academy Bay on Santa Cruz Island. From Culpepper Island, the northernmost of the group, the ship returned to the equator, crossing it for the seventh and eighth time, and steaming westward from 95° to 100° W. Here she turned north towards Cape San Lucas, spent 32 hours on a survey of the north edge of the countercurrent, and arrived in San Diego on 27 August.

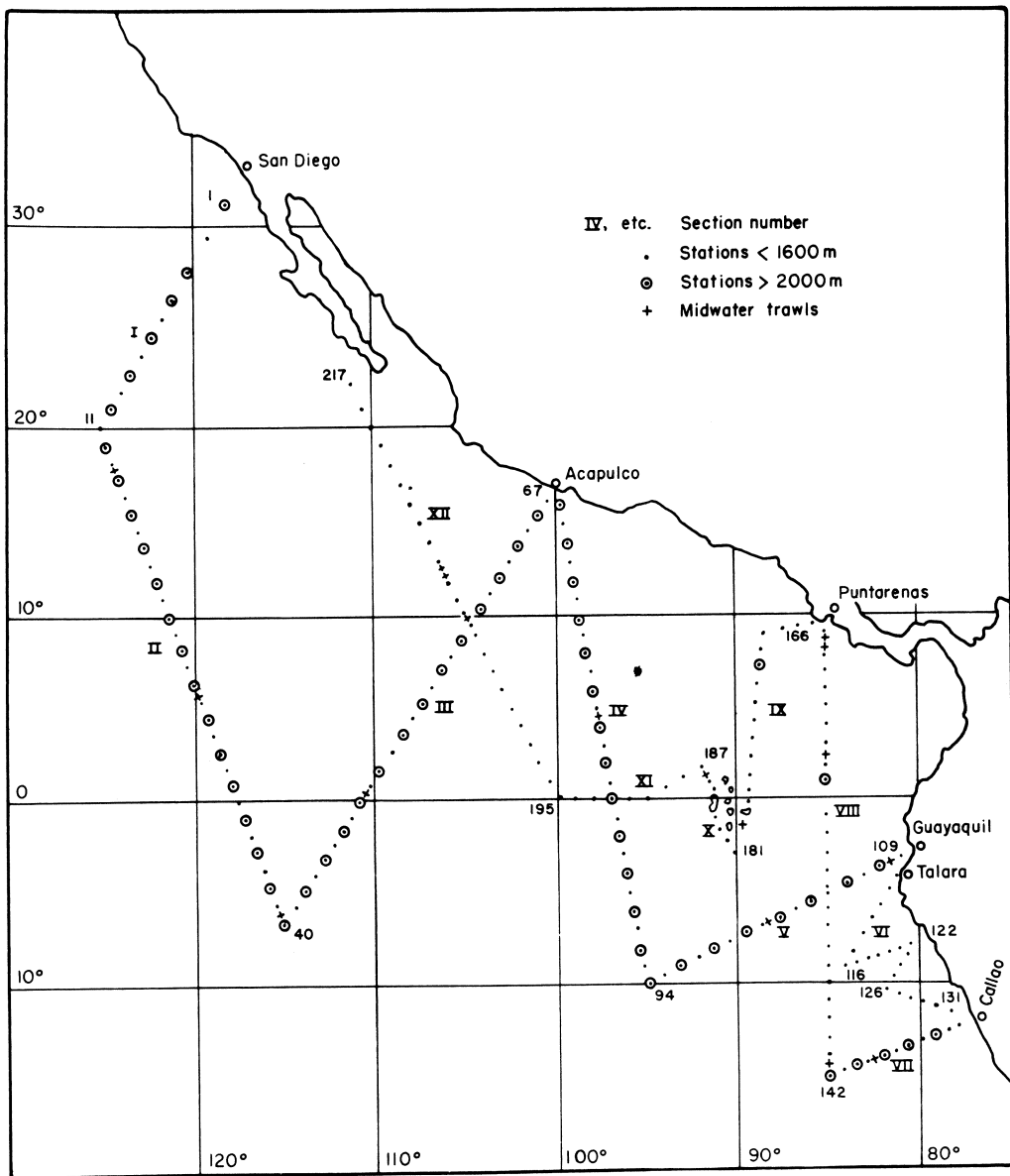


Figure 1. Track chart, Shellback Expedition, 17 May - 27 August 1952.

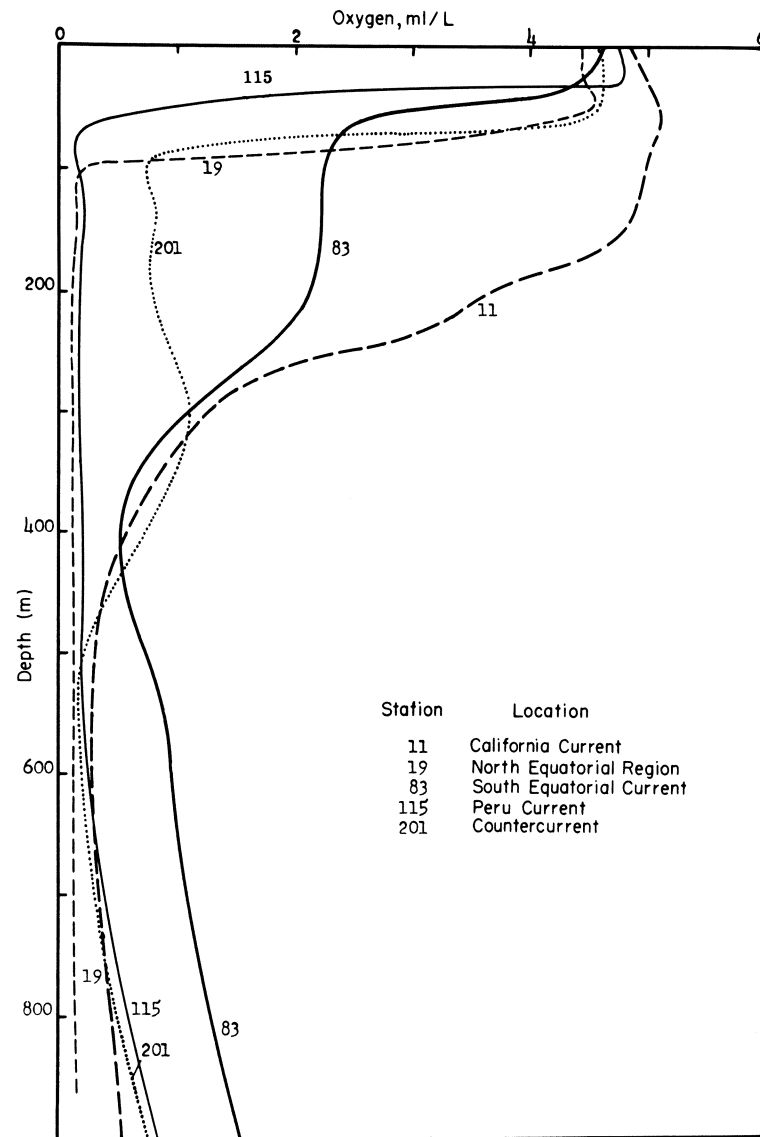


Figure 2. Typical vertical oxygen curves, Shellback Expedition.

During the SHELLBACK Expedition the following distances were steamed:

Leg A	San Diego to Acapulco	4,320 miles
Leg B	Acapulco to Puntarenas	5,780
Leg C	Puntarenas to San Diego	<u>4,480</u>
		14,580 miles

#### SUMMARY OF OBSERVATIONS

1. Two hundred and sixteen oceanographic stations were occupied, 19 to a depth of less than 1000 m, 144 to a depth of 1000 to 1600m, and 53 to a depth of 2000 m or more.
2. Seven hundred and sixty-five bathythermograph observations were made underway, in addition to those taken on oceanographic stations.
3. Five hundred and twenty-one current measurements were made with the geomagnetic electrokinetograph (GEK).
4. During a portion of the cruise a continuous record of surface temperature was kept using the Thermitow.
5. Direct measurements of the vertical distribution of velocity were made on eight stations using a current cross from the drifting ship.
6. Special detailed oceanographic studies were made in the Peru Current, the Gulf of Guayaquil, the Gulf of Nicoya, the Galapagos Islands, and on the north edge of the countercurrent.
7. The following new pieces of equipment were tested:
  - a. Small type GEK electrodes
  - b. Hydraulic GEK winch
  - c. Remote-indicating meter counter, tachometer, and dynamometer for the hydrographic wire
  - d. Current cross, from the drifting ship
  - e. AN/UQU-1B (EDO) recording echosounder
  - f. Meter-net cod end for Isaacs-Kidd midwater trawl
8. One hundred and seventy radiosonde releases were made. Surface weather observations were made at 3-hr intervals throughout the trip.
9. Water samples from all stations were analysed for dissolved oxygen content. In addition, phosphate and silicate analyses were run on samples from 110 stations.



10. Thirty-seven productivity experiments were run, using the radioactive tracer technique of Steeman-Nielsen.
11. On two stations, special casts were made for the collection of oxygen isotope ratio samples.
12. A continuous record of the bottom topography was kept throughout the trip, over 14,580 miles of largely unknown ocean.
13. Two hundred and four quantitative plankton tows were made successfully, with a one-meter net towed obliquely from a depth of 300 m to the surface.
14. One hundred and ninety-seven qualitative microplankton tows were made successfully, with a 17-cm net hauled vertically from 100 m to the surface.
15. Seventeen trawls were made with the Isaacs-Kidd midwater trawl, one at 3350 m , four shallow trawls in the oxygen minimum, and 12 at an average depth of about 1400 m.
16. On suitable stations dipnet collections were made. A continuous record of biological observations was kept.

#### SHIPBOARD PROCESSING

An attempt was made to process as much data as possible on board ship, both because this made the work more interesting and because it was then possible to base decisions on the recent observations. The scientific party navigator prepared smoothed plotting sheets and tabulated lists of required positions. All soundings were plotted on plotting sheets as well as on profiles with 10 times vertical exaggeration.

On station data sheets readings from protected and unprotected thermometers were corrected, thermometric depths calculated, L-Z curves drawn, and the vertical distribution of temperature and oxygen drawn. Then vertical sections of temperature and oxygen were plotted, as were the horizontal distribution of surface temperature and the average temperature to 150 m. All GEK observations were plotted soon after completion.

It is important that on future expeditions salinity determinations be made on board ship so that the processing of data can be carried further. Graphs and charts of salinity and density distribution and T-S correlations are essential in interpreting the observations. With a scientific party as large as carried on SHELLBACK and with oceanographic stations no more frequent, it should be possible to complete routine data processing through dynamic computations.

### TRAWLS IN THE OXYGEN MINIMUM

It has long been of interest to determine what creatures can live in the poorly oxygenated waters of mid-depths. Attempts to collect specimens in the oxygen minimum zone with nonclosing-type nets are often inconclusive because of the uncertainty of depth of capture. The Isaacs-Kidd trawl, although not fitted with a closing device, is a useful tool for this study because of its large cross-section of capture and the relatively high speeds at which it can be towed.

On two stations excellent conditions were found for fishing in low-oxygen waters. At Sta. 165, 125 miles out of Puntarenas, the oxygen content was down to 0.5 ml/L at 225 m and to less than 0.1 ml/L at 400 m. On Sta. 207, about 450 miles southwest of Acapulco, the oxygen content was about 0.1 ml/L between 100 and 600 m. Shortly after departing each of these stations, a trawl was fished for 3 hrs, at 450 m on Sta. 165 (Trawl No. 11) and at 300 m on Sta. 207 (Trawl No. 16). After each of these trawls, the net was sent down again to the same depth and back up, in an attempt to subtract out the material caught en route.

Trawl No. 11, apart from captures en route, contained 1000 or more small, young lantern fish (Myctophidae), perhaps 100 hatchet fish (Sternoptychidae), several Leptocephalus larvae, numerous small squid and other invertebrates. No other trawl on this expedition contained so many small fish. During this trawl the scattering layer was strong at 240-330 m.

Trawl No. 16, although much smaller in volume, was strikingly similar in appearance to No. 11. It contained 200-300 small, young fish of the genus Vinciguerria, a few Leptocephalus larvae, and a moderate quantity of euphausiids, copepods, and other invertebrates. During this trawl the scattering layer was at 350-380 m.

It would certainly be premature to draw any conclusions about the origin and maintenance of the oxygen-minimum zone from these trawls. They do suggest that young lantern fish, hatchet fish, Vinciguerria, and eel larvae can and do live at least part of the time in waters containing only a few percent of the saturation value of oxygen. One wonders what physiological adaptations are required for these fish to exist under such adverse conditions.

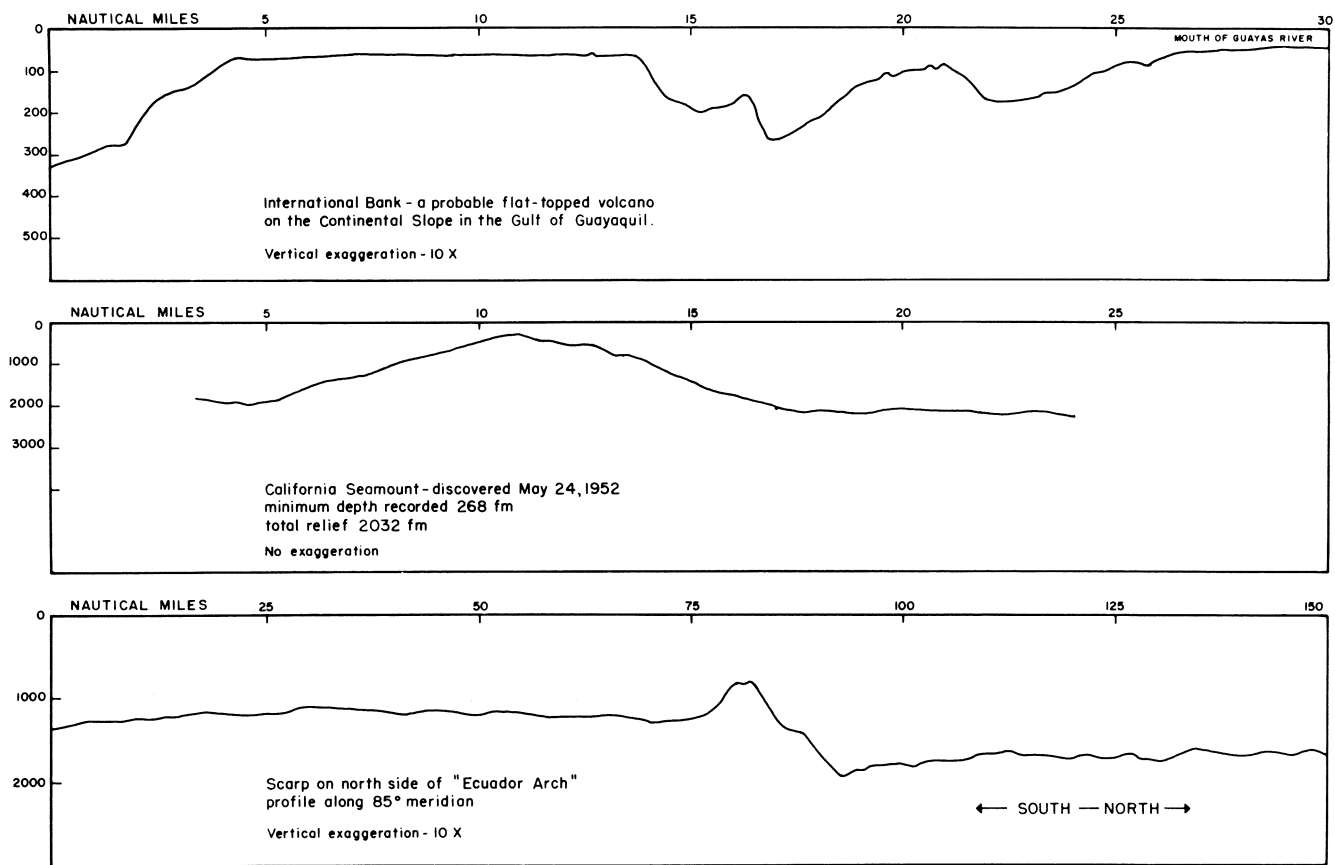


Figure 3. Bottom profiles of International Bank, California Seamount, and scarp on north side of "Ecuador Arch."

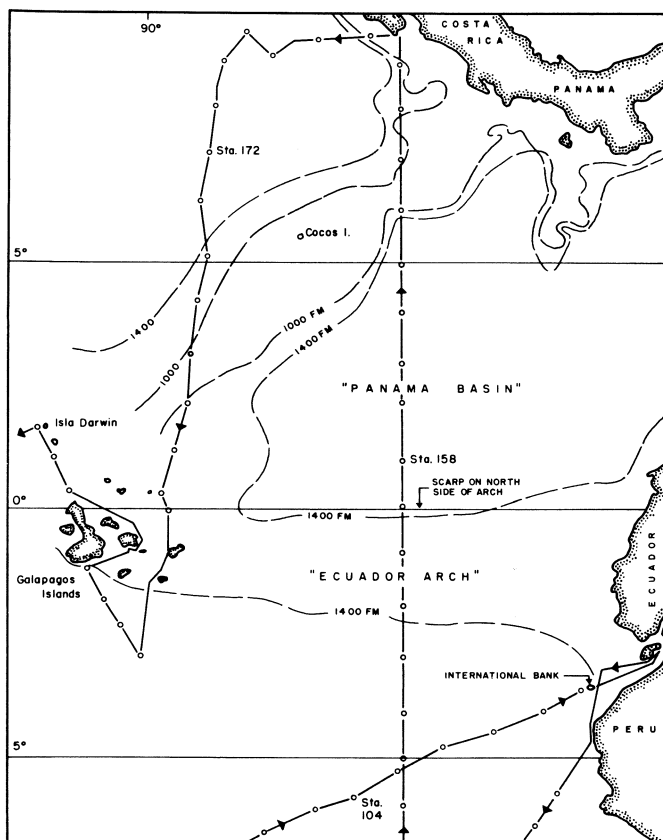


Figure 4. Shellback Expedition track and stations. Contours from H. O. 0526 and H. O. 0823 and from Shellback soundings.

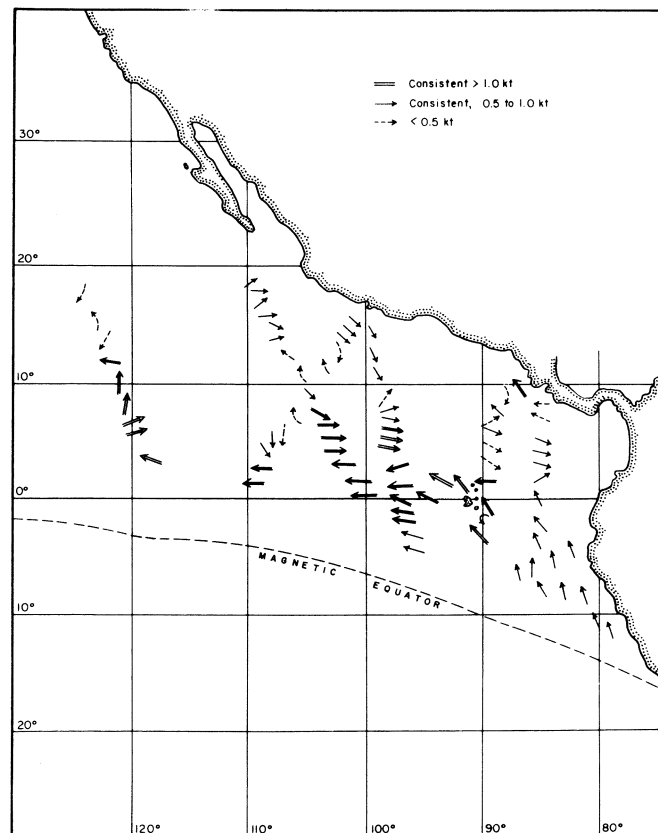


Figure 5. Surface currents from GEK measurements, Shellback Expedition.

from the coast of Central America to the Galapagos at a depth not exceeding 1000 fm. Between these arches and the mainland of Central and South America lies a basin roughly 180,000 square miles in area and reaching depths as great as 2000 fm, although the average depth is probably 1600-1700 fm.

On the north side of the "Ecuador Arch" the expedition crossed a small seamount perched on the edge of a scarp (see Fig. 3). The bottom then fell sharply from 1400 fm into a narrow 1900-fm trench before rising to the general basin level of about 1700 fm. Although it was not possible to explore this scarp, it is felt that the structure and topography of both of these arches will merit detailed study on some future expedition.

Of great interest also is the hydrography of the Panama Basin. Along its southern limits the Peru Current swings towards the west to feed the South Equatorial Current. Into the basin pours the Equatorial Countercurrent, and here the waters which are found to the west in the North Equatorial region are modified and acquire certain of their identifying characteristics.

In order to determine whether these deep arches serve to isolate the deeper waters of the basin, three deep stations were compared -- Sta. 104 to 2750 m, Sta. 158 to 2800 m and Sta. 172 to 2890 m (see Fig. 4 for locations). Comparison of the average concentration of oxygen and silicate, and the average temperature of water between 2400 and 2750 m on these stations shows:

<u>Average Value</u> <u>2400-2750 m</u>	<u>Sta. 104</u> <u>So. of basin</u>	<u>Sta. 158</u> <u>in basin</u>	<u>Sta. 172</u> <u>No. of basin</u>
Temperature, °C	1.89	2.09	1.84
Oxygen, ml/L	2.84	2.39	2.47
Silicate, $\mu$ g at/L	152	162	165

The temperature in the basin below the sill is at least 0.2° higher than it is at the same depth north and south of the basin. The oxygen and silicate concentrations suggest that the deep water in the basin is much more closely related to that north of the basin than south. Thus the deep circulation may be towards the south and east across the "Cocos Arch" and into the basin. Replenishment of deep water in the basin is undoubtedly slow and the slight increase in temperature there due entirely to diffusive processes.

It is hoped that a future expedition can be devoted to an intensive study of this basin, paying careful attention to the oceanographic, biological, and geological aspects of the region.

### CURRENT-DRAG MEASUREMENTS

On eight stations between Sta. 195 and Sta. 205 measurements of the vertical distribution of velocity were made with a current cross. This measurement from a drifting ship is a modification of that proposed by Pritchard and Burt (J. Mar. Res. 10, 180-189, 1951) who made measurements in shallow water from an anchored vessel.

The cross used on SHELLBACK had an effective area of 12 sq ft and carried weights of 100 or 150 lb. In practice it was lowered to various depths between 4 and 200 m, and the vertical and horizontal wire angles measured. In computing current velocity as a function of depth one assumes that the apparent current at 4 m is due entirely to windage, and that the current at 200 m is negligible. The apparent current at 200 m then, minus the windage as estimated at 4 m, is a measure of the current-induced surface drift of the ship.

A further assumption, that the current cross is at an equilibrium position at the time of measurement, was not valid when the cross was suspended from one end of its axis, since with increased angles the system rapidly became unstable, and the cross surfaced. When the cross was suspended from one edge it was much more stable, although still affected by the roll of the ship.

The eight current-drag stations were in the South Equatorial Current and the Equatorial Countercurrent. Rough calculations lead to the following tentative conclusions:

1. Surface currents estimated in this manner are consistent with those measured by the GEK.
2. In the Countercurrent current velocities vary little in the stirred layer, then become too small to be measured below the thermocline.
3. The South Equatorial Current in the upper 80 m swings about 40° in a counterclockwise direction with increasing depth. There is no sharp change in velocity across the thermocline.
4. On Sta. 199, near the boundary between the two currents, there is some evidence that the Countercurrent underlies the South Equatorial Current.

Techniques in handling the cross and in measuring the wire angles were primitive and will bear improvement. But first tests of this device suggest that with refinement it will be a very useful tool in studying the vertical current structure in the upper layers of the ocean.

### GEOMAGNETIC ELECTROKINETOGRAPH OBSERVATIONS

Throughout the expedition geomagnetic electrokinetograph (GEK) observations were made at regular intervals. These observations were compared when possible with the set of the ship as shown by navigational fixes, with horizontal wire angles encountered during net tows and mid-water trawls, and with other indications of the direction and speed of currents. In almost all cases the agreement was excellent. Indeed, later in the cruise when confidence in the instrument had been established, the GEK currents were used navigationally and to guide maneuvering on stations to reduce wire angles.

Most of the success of the GEK program can be attributed to the discovery and application of a hitherto unsuspected correction factor. This factor is required because the two electrodes tow at different depths and thus cut the horizontal component of the earth's magnetic field as well as the vertical component.

In the deep ocean the potential recorded by the GEK is closely approximated by the vector equation:

$$E = \bar{V} \times \bar{H} \cdot \bar{S}$$

where  $\bar{V}$  = the velocity of the electrodes,  $\bar{H}$  = the intensity of the earth's magnetic field, and  $\bar{S}$  = the vector distance between electrodes.

This vector can be reduced to scalar terms:

$$E = v H_z S + v_s H_h D$$

where  $v$  = current velocity,  $v_s$  = ship velocity,  $H_z$  = vertical component of the earth's magnetic field,  $H_h$  = horizontal component of the earth's magnetic field,  $S$  = horizontal distance between electrodes, and  $D$  = electrode droop, or vertical displacement of electrodes.

Thus the GEK apparent current includes a false velocity,  $v_f$ , whose direction in the northern magnetic hemisphere is  $180^\circ$  from magnetic north, and whose magnitude is:

$$v_f = v_s \frac{D H_h}{S H_z}$$

A series of measurements were made on the magnetic equator in order to determine empirically the magnitude of the electrode droop. This was found to be, on the average, 4.7 m at 9 kt and 3.8 m at 11 kt. These values are in good agreement with those calculated theoretically from drag-weight relationships.

As the magnetic equator is approached, and the ratio  $H_h/H_z$  increases, correction for this false velocity becomes increasingly important, as the following values show:

<u>Location</u>	<u><math>V_f</math></u>
Gulf Stream	6 cm/sec
San Diego	12
1000 mi from mag. equator	35
250 mi from mag. equator	175

The results of the GEK measurements are discussed in the next section.

### SURFACE CIRCULATION

It will not be possible to make a satisfactory analysis of the general circulation of the eastern equatorial region until salinity data and computations of density and geostrophic flow are available. However, using the information at hand it is possible to arrive at a general picture of the surface circulation, consistent in some details and highly confusing in others.

This picture is derived from the following sources:

1. GEK measurements (Fig. 5)
2. The horizontal distribution of average temperature between 0 and 150 m (Fig. 6)
3. Vertical sections of temperature and oxygen

The chart of GEK surface currents is an interpretation from over 500 current measurements and represents a much simplified picture of the predominant velocities. The smoothed chart of average temperature between 0 and 150 m was used to estimate geostrophic flow, in the absence of salinity data. This estimate is crude, since it assumes no velocity below 150 m, and constant salinity above 150 m.

#### I. NORTH EQUATORIAL REGION

Nowhere in the area crossed by SHELLBACK did the GEK detect any certain evidence of the North Equatorial Current. For this reason the term "North Equatorial Region" has been used. Isotherms on the average temperature chart suggest a weak westward flow along the 10th parallel. A possible reason for this lack of strong westward drift is suggested by charts of mean resultant surface winds in the tropical Pacific Ocean (Palmer, C. E., "Tropical Meteorology" in Compendium of Meteorology, pp 876-877, 1952). These charts show that the

northeast trades are developed only some hundreds of miles to the west of SHELLBACK's westernmost section. It is possible, of course, that the computed dynamic topographies will show a strong westward current not established by this preliminary analysis.

The waters of the North Equatorial Region can, however, be readily distinguished from the waters of the California Current lying to the north. As Figure 8 shows, the transition from Sta. 12 to Sta. 14 was very pronounced, especially in the oxygen and phosphate distributions. The surface temperature increased from 21.8° to 25.7°C, and low temperature, low oxygen, and high phosphate water was found much closer to the surface. Although common north of the boundary, no Blackfooted Albatross were seen after the ship crossed into North Equatorial water. This type of water was found south of 12°N on Section II, and south of 13°N on Sections III and IV.

## II. EQUATORIAL COUNTERCURRENT

On five of the six sections between the equator and 10°N, GEK measurements showed a steady current towards the east, at 6°N in the west and somewhat south of 5°N in the easternmost section. Current cross measurements show the Countercurrent to be concentrated in the stirred layer.

The northern edge of the Countercurrent is apparently characterized by meandering or by large-scale eddies. Evidence for this is as follows:

1. On all crossings of the Countercurrent the velocity shifted to the northeast or southeast as the northern edge was approached.
2. On Section XII east-setting currents were crossed both at 6°N and at 15°N.
3. On Section III the GEK detected no evidence of the Countercurrent between 6° and 10°N, although the average temperatures suggest a weak current. A southeasterly-flowing current was observed at 14°N.
4. A 32-hr GEK survey of the northern edge at 9°N on Section XII found currents towards the southeast on one crossing, and towards the northeast 30 hrs later on the identical track.

It is interesting to note that where Section XII crossed Section II, after more than two months, conditions had changed considerably, the surface temperature averaging about 1°C lower and the average temperature from 0 to 150 m nearly 3°C lower on Section XII near the intersection of the sections. (These differences have been minimized in the smoothed charts of Figures 6 and 7.) Horizontal temperature gradients consistent with the Countercurrent were much smaller on Section III, where no Countercurrent was detected by the GEK, than on Section XII, where a strong Countercurrent was measured.



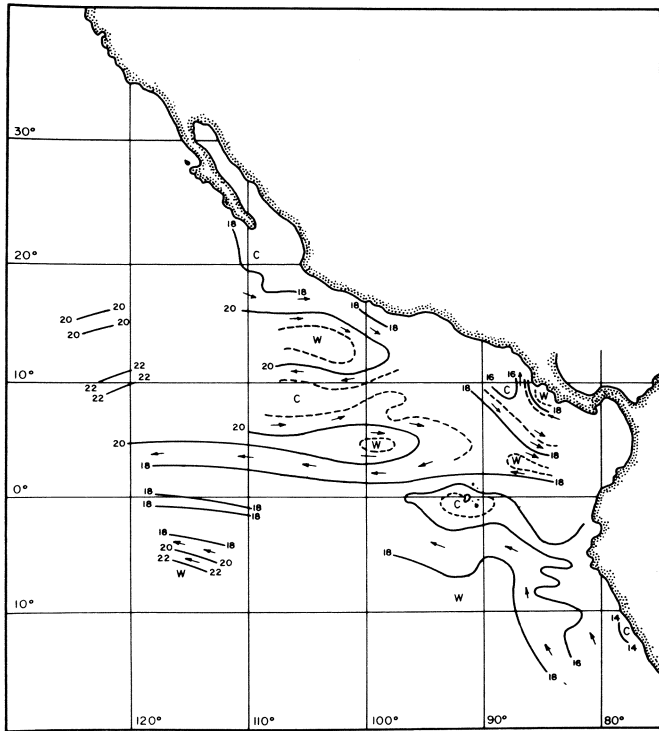


Figure 6. Average temperature between 0 and 150 m, Shellback Expedition. Arrows indicate direction of inferred currents. W, warm, C, cold.

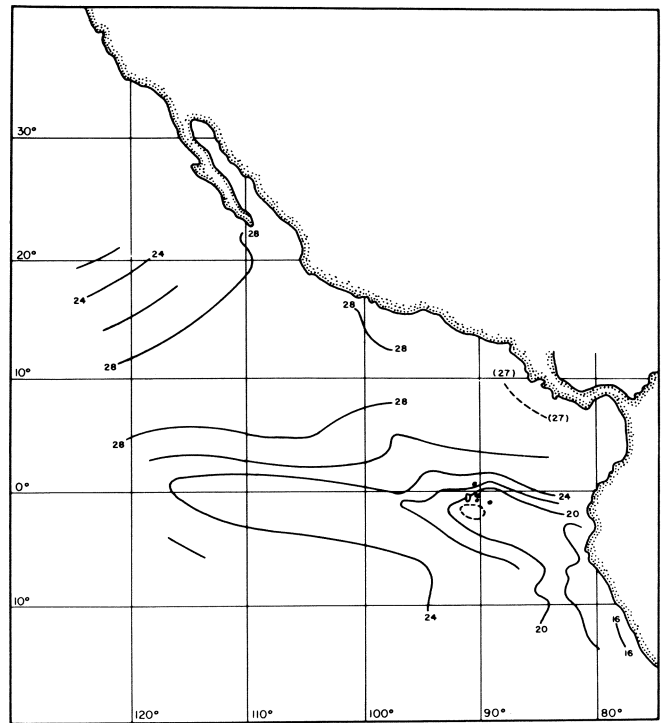


Figure 7. Surface temperature (0°C), Shellback Expedition.

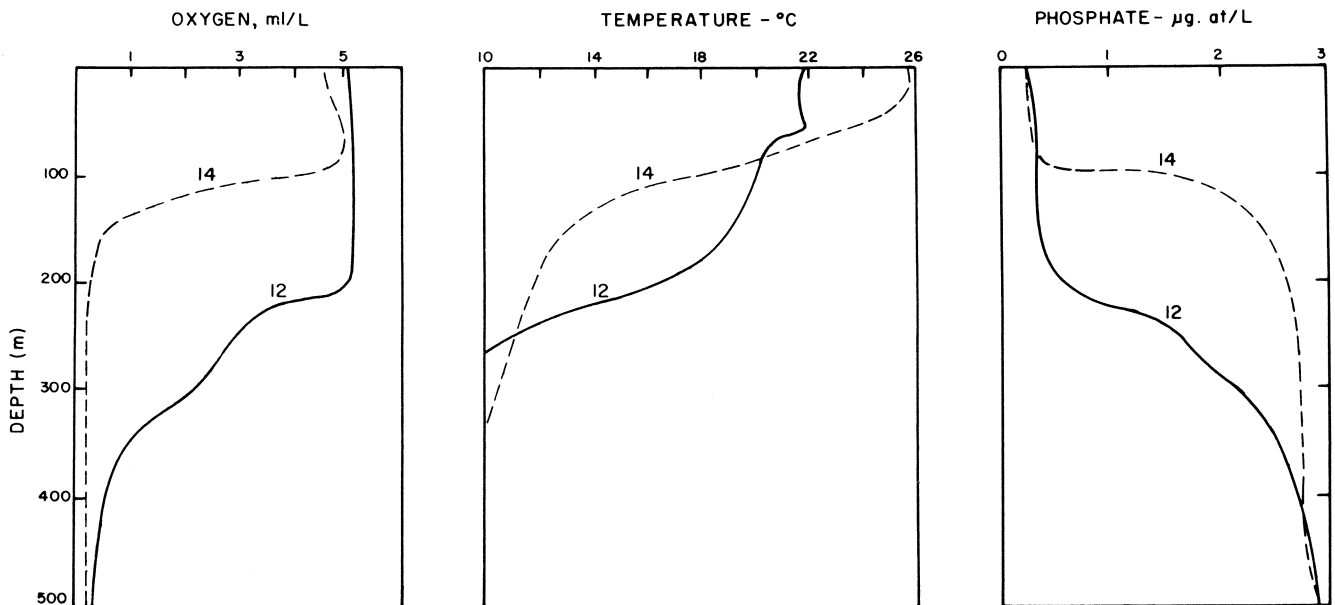


Figure 8. Vertical oxygen, temperature, and phosphate curves in California Current (12) and North Equatorial Current (14), Shellback Expedition.

### III. SOUTH EQUATORIAL CURRENT

During six crossings of the equatorial current system, the South Equatorial Current was measured by the GEK on four sections. The southern end of the westernmost section was too close to the magnetic equator for meaningful measurements to be made. On the easternmost section the current was not yet formed.

The north edge of the current was usually found at about 3°N. The southern edge was probably never crossed. On Section IV strong currents to the west were measured as far south as 5° 45'S. The average temperature chart (Fig. 6) also suggests a steady flow to the west as far south in the current as the ship travelled.

On the north edge of the current, the highest sustained current velocities of the entire cruise were measured, commonly as high as 100 cm/sec. Indeed, the South Equatorial Current appeared to be both strong and steady everywhere observed except in the vicinity of the Galapagos Islands. There the currents often had a pronounced northward component and were varied in speed and direction.

### IV. PERU CURRENT

The Peru Current appeared as a broad, strong current toward the north along the coast of Peru, swinging to the west in the vicinity of the Gulf of Guayaquil, and flowing with an average speed of 35-40 cm/sec. The influence of its cold waters was apparent to the west (see Figs. 6 and 7) although it was not always evident whether the cold surface temperatures observed along the equator were due to the Peru Current or to the equatorial divergence.

Superimposed on this broad, northward flowing current appeared to be a complicated system of tongues and eddies. GEK readings showed considerable variation from one measurement to the next, the current occasionally reversing or disappearing and current speeds differing by as much as a factor of 3.

Additional evidence can be seen in the horizontal temperature distributions of Figures 6 and 7. A more detailed study of the temperature distribution, besides showing centers of upwelled water along the coast off Talara and Callao, showed spots of cold water out in the center of the current.

### MISCELLANY

On 24 August 1952 on Sta. 215, large quantities of pumice were dipnetted. This station lies about 55 miles northeast of San Benedicto Island in the Revillagigedo group. The largest piece of pumice measured about 10 x 9 x 7 cm. In general the pieces were less than a quarter this size, somewhat weathered, and supporting a small population of barnacles and small gastropods.

The next morning on Sta. 216, about 120 miles southwest of Cape San Lucas, more pumice was dipnetted. This time the pieces were much smaller, well rounded, and darker in color. The attached barnacles were larger, the small gastropods more numerous, and some of the pieces were green with attached algae. The rocks were accompanied by numerous twigs supporting much the same fauna.

The following is a partial list of oceanic birds seen and identified during the expedition:

Blackfooted Albatross (*Diomedea nigripes*)  
Galapagos Albatross (*Diomedea irrorata*)  
Cape Pigeon (*Daption capensis*)  
Sooty Shearwater (*Puffinus griseus*)  
Galapagos Shearwater (*Puffinus lherminieri*)  
Wilson's Petrel (*Oceanites oceanicus*)  
Leach's Petrel (*Oceanodroma leucorhoa*)  
Hornby's Petrel (*Oceanodroma hornbyi*)  
Red-billed Tropic Bird (*Phaethon aethereus*)  
Red-tailed Tropic Bird (*Phaethon rubricaudus*)  
Brown Pelican (*Pelecanus occidentalis*)  
Piquero (*Sula variegata*)  
Blue-footed Booby (*Sula nebouxii*)  
Masked Booby (*Sula dactylatra*)  
Brown Booby (*Sula leucogaster*)  
Guanay (*Phalacrocorax bougainvilli*)  
Great Frigate Bird (*Fregata minor*)  
Magnificent Frigate Bird (*Fregata magnificens*)  
Gray-hooded Gull (*Larus cirrocephalus*)

The region around the Galapagos was particularly interesting from an oceanographic point of view. The surface temperature 40 miles south of Isabella Island was 18.6°C; 40 miles north of the island it was 22.9°C. Midwater trawls were taken north and south of the islands to see if the fauna differed. Currents were strong and seemed to vary markedly with depth. Slicks were common in great bands often edged with foam.

Neither Germaine Bank nor Guardian Bank was crossed although attempts were made to locate them.