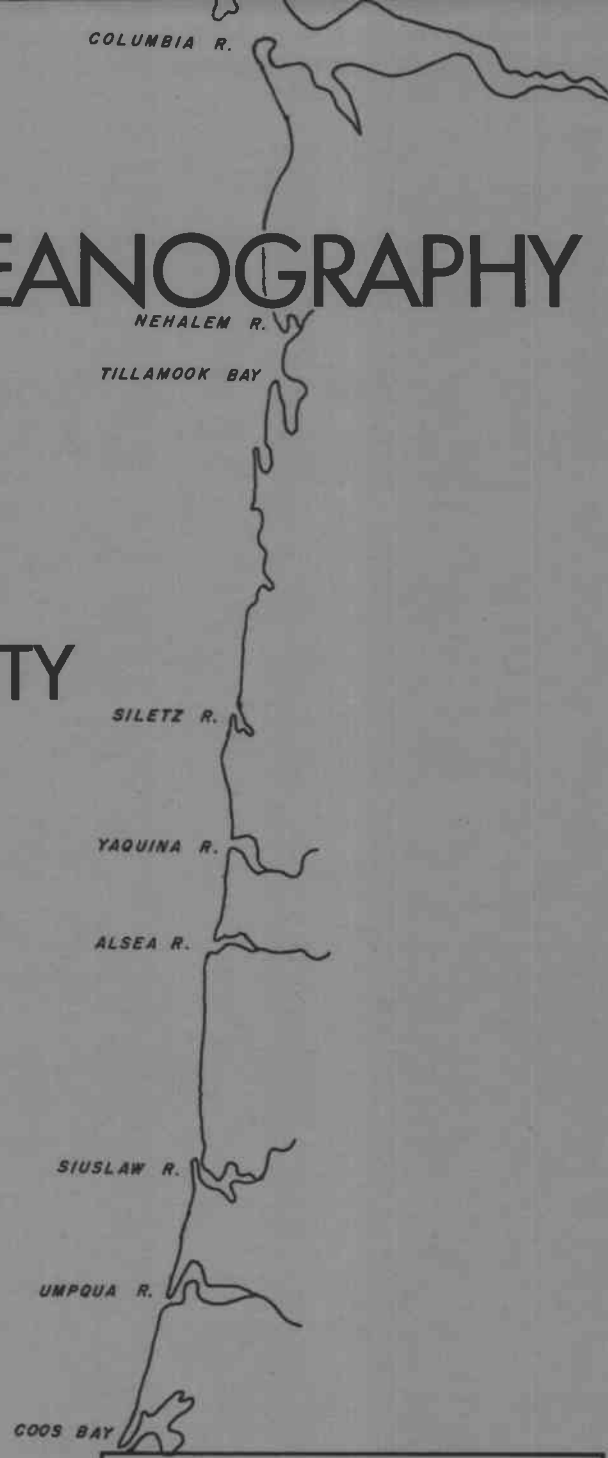
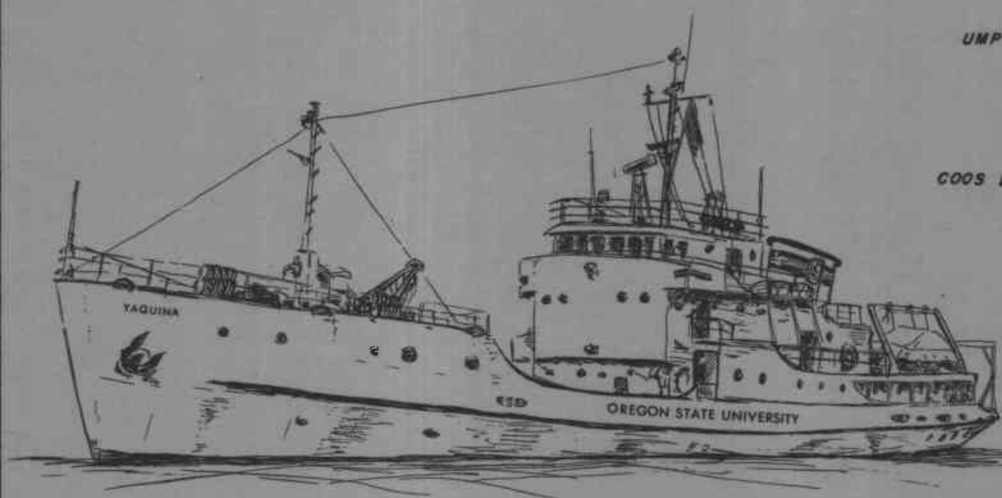
DEPARTMENT of OCEANOGRAPHY

SCHOOL of SCIENCE

OREGON STATE UNIVERSITY





CRUISE REPORT

YALOC 69

Synopsis of the cruise of R/V YAQUINA in the eastern equatorial Pacific Ocean from 2 January to 26 April 1969

Technical Report 150 **Reference 69-21**

September 1969

Department of Oceanography
School of Science
Oregon State University
Corvallis, Oregon 97331

John V. Byrne
Chairman

CRUISE REPORT: YALOC '69

SYNOPSIS OF THE CRUISE OF R/V YAQUINA IN THE EASTERN EQUATORIAL PACIFIC OCEAN FROM 2 JANUARY TO 26 APRIL, 1969

Office of Naval Research
Contract Nonr 1286(10)

National Science Foundation
Grant GA 1252

Chief Scientists

G. F. Beardsley, Jr.	2 Jan. - 6 March
R. Heath	6 March - 29 March
D. Heinrichs	29 March - 19 April
C. Culberson	19 April - 26 April

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INTRODUCTION

A multi-disciplinary oceanographic cruise - YALOC '69 - was carried out by staff of the Department of Oceanography, Oregon State University aboard the R/V YAQUINA. This report describes the observational programs undertaken.

YALOC '69 was motivated by a desire to study the geology, geophysics and physical oceanography of the Panama Basin. Near bottom chemical gradients were investigated at a number of stations along the track line. Hydrographic and optical measurements were also made enroute to the area to obtain data on the geographical distribution of optical properties. The cruise consisted of seven legs extending from Newport, Oregon to Talara, Peru and return, with the three principal working legs in the Panama Basin. Station locations are shown in Figures 1 and 2. The cruise began January 2, 1969 and was completed April 26, 1969. Exceptionally fine weather and following winds produced ideal working conditions. As a result, about 120% of the planned objectives were achieved.

The scientific personnel included four faculty members, nine students, and five technicians from Oregon State University. The scientific complement also included visiting scientists from: U. S. Naval Postgraduate School, Monterey, California; University of Copenhagen, Denmark, and the Ecuadorian Navy. The ship was supported during this period by ONR Grant 1286(10) and NSF Grant GA 1252. Research support is listed under the individual discussions which follow.

CRUISE OBJECTIVES

(a) Marine Geology

The geological portion of the geophysical observations made on legs 4 and 5 of YALOC '69 constitute the first phase of an extended study, by members of the marine geology group, of sedimentation in the Panama Basin (Fig. 3). The study is concerned with process of deep-sea sedimentation adjacent to a continental margin. The Panama Basin was selected because it is topographically closed, thus minimizing leakage of sediment into and out of the study area from bottom-following currents, and because the sediments include all gradations between terrigenous, volcanic and biogenous end members.

The study is being supported by the Office of Naval Research, Contract Nonr 1286(10). Principal investigators are Tj. H. van Andel, G. R. Heath and T. C. Moore, Jr.

(b) Marine Geophysics

The geophysical data obtained on legs 4, 5 and 6 of YALOC '69 constitutes the initial phase of a study of the crustal structures of the Panama Basin, Cocos and Carnegie Ridges, the Peru-Chile trench, and the continental margin off Central America. The major objective is to define the regional crustal structure of the Panama Basin including its defining features, with particular emphasis on the interaction of the active crustal plates which meet in this region.

The study is being supported by the Office of Naval Research, Contract Nonr 1286(10). Principal investigator is Donald F. Heinrichs.

(c) Physical Oceanography

The objectives of the physical oceanography portion of the YALOC '69 cruise include:

1. A study of the properties and spatial distribution of the light scattering particles suspended in the water column over a large span of latitude and in regimes of different oceanographic conditions.

2. The application of optical and classical methods to the equatorial current system and the dynamics of the Panama Basin.

3. The determination of the polarization of the in situ daylight field.

4. The determination of the short wave radiation albedo in the eastern equatorial Pacific.

These studies were supported by the Office of Naval Research Contract Nonr 1286(10). Principal investigators are G. F. Beardsley, Jr. and W. V. Burt. Polarization measurements were also supported by the University of Copenhagen, Institute of Physical Oceanography.

(d) Chemical Oceanography

A study of seawater chemistry near the sea floor was the major objective of chemical oceanography during YALOC '69. Previous work (Wattenberg, 1933; Bruneau, Jerlov, and Koczy, 1953; Sysoyev, 1961) had shown that changes in the concentrations of oxygen, phosphate, silicate, and alkalinity occur just above the sea floor. During YALOC '69 the existence of chemical gradients near the bottom in the eastern Pacific Ocean was investigated. A second objective was to obtain pH and alkalinity data for a series of deep stations, so that the degree of saturation and the amount of solution of calcium carbonate could be calculated over a wide range of latitude.

The principal investigator for the chemical portion of YALOC '69 was Dr. R. M. Pytkowicz. Chemical oceanography was supported by the Office of Naval Research Contract Nonr 1286(10), the National Science Foundation Grant GA 1252, and by a National Science Foundation graduate fellowship to C. Culberson.

ITINERARY 2 January - 26 April 1969

Leg	Depart	Arrive	Hydrographic Stations
1	Newport, Jan. 2	San Diego, Jan. 6	3
2	San Diego, Jan. 7	Puntarenas, Jan. 22	18
3	Puntarenas, Jan. 25	Galapagos Islands, Feb. 1	35
4a	Galapagos Islands	Talara, Peru	13
4b	Talara, Peru, Feb. 14	Talara, Peru, Mar. 6	31
5	Talara, Mar. 7	Puntarenas, Mar. 29	14
6	Puntarenas, Apr. 1	San Diego, Apr. 19	6
7	San Diego, Apr. 21	Newport, Apr. 26	

PRELIMINARY RESULTS

(a) Marine Geology

The marine geology program of legs 4 and 5 was designed to yield information on two aspects of the geology of the Panama Basin (Fig. 3):

1. Gross structure of the Basin and its bounding features. This information was obtained by a reconnaissance geophysical survey carried out by cooperation with OSU geophysicists. The Basin was covered by seven northwest trending traverses and associated tie-lines (see detailed track chart, Fig. 3) to yield more than 6,500 nautical miles of essentially uninterrupted gravity, magnetic, continuous seismic profiler and precision depth recorder data.

These results are being used, in conjunction with existing data, to define the major structural elements of the region; to evaluate their probable effects on sediment dispersal patterns; and as a basis for estimating the influence of tectonic activity on present day and ancient sedimentation regimes.

The application of the geophysical data to problems of crustal structure, and particularly to the interaction of the group of active crustal plates which meet in the Panama Basin area is being treated by the geophysical section.

2. Internal structure and distribution of sediments of the Basin. The analysis of sediment cores taken at 24 locations in and around the Basin (Fig. 3) and of continuous seismic profiler records suggests that sedimentation is controlled by a complex of tectonic, geographic and oceanographic factors. The Basin is an area of active crustal plate movement ("sea floor spreading"). Consequently, the sediments are often deformed and their total thickness in the western portion of the Basin is largely governed by distance from spreading centers (i. e. , by the age of volcanic "basement"). Other factors of obvious importance to the sediment distribution are locations of topographic barriers, distance from the continental margin, location of centers of volcanism, and productivity of calcite- and opal-secreting planktonic organisms. Further factors will almost certainly become apparent as the processing of data proceeds.

The successful completion of the first phase of the marine geology program has provided the reconnaissance data which will allow us to break the original problem into a series of geographically restricted studies dealing with the several dominant sediment types. We now have the information required to select areas to be studied in detail during subsequent cruises to the area.

(b) Marine Geophysics

Legs 4 and 5

The geophysical observations made on legs 4 and 5 are intended to provide data relating to the following crustal and subcrustal problems in Panama Basin region (Fig. 3).

1. Crustal and subcrustal structure of the Panama Basin. Seven northwest trending crossings of the basin at an approximate 2 degree spacing form the basic reconnaissance survey. Over 6, 500 nautical miles of gravity, magnetic, continuous seismic profiles, and bathymetric data were obtained. These results are being used to define the major structural elements of the region, to determine the regional crustal

structure of the basin, and to examine the interaction of the active crustal plates which meet in this region. This data, in particular the seismic and bathymetric information, is being interpreted in cooperation with the marine geologists.

2. Structure and development of the northern Peru-Chile trench. Six crossings of the Peru-Chile trench, and its northern terminus were made between 4° S and 5° N latitude. The interpretation of this data, together with existing data, will provide additional insights into the nature of this major structural feature.

3. Structure and origin of the Carnegie and Cocos Ridges. These ridges form the southern and northwestern boundaries of the Panama Basin. The Carnegie Ridge was traversed seven times at approximately equal intervals between the Galapagos Islands and Ecuador and a longitudinal (east-west) profile was obtained. The Cocos Ridge was crossed five times normal to its trend. Preliminary analysis indicates that a gravity "high" bounds the northern flank of the Carnegie Ridge indicating that the deep structure may be assymmetrical.

The Panama Basin region is a tectonically active area and solutions to the problems listed above will not be independent. The geophysical data obtained on YALOC '69 will also provide control for detailed studies on future cruises to the area.

Leg 6

The geophysical observations made on leg 6 provide information relating to the following structural and tectonic problems in the Central America's region (Fig. 1).

1. Structure and development of the Middle America's trench. Eight crossings of the trench were made with essentially uninterrupted gravity, magnetic and precision depth recorder data obtained. These results are being used to determine the regional crustal and subcrustal structure of the Middle America trench, including the effects of the Guatemala Basin and Tehauntepec Ridge on the trench structures.

2. Structure of the East Pacific Rise. Three traverses of the EPR were made between 13° N and 19° N latitudes to obtain gravity, magnetic, bathymetric, and limited continuous seismic profile data. These results are being used to define the tectonic nature of this part of the major ridge system and its interaction with the continental margin south of Baja California.

(c) Physical Oceanography

Oceanographical distribution of light scattering particles.

Light scattering was measured for samples taken at hydrographic stations from 41° N to 4° S latitudes. The stations between Newport, Oregon and Puntarenas, Costa Rica were located 20 to 100 nautical miles from the coast. Thus the results reveal the effect of latitudes, proximity of the coast, and regional oceanographic conditions. A preliminary analysis on the distribution of the optical properties indicates the following features:

a. The effects of the proximity of the coast is much greater than any latitude effects.

b. The vertical distribution of the optical properties in the surface layer (upper 100 m) was closely associated with the trend of mixing:

1. Weaker nephlocline and homogeneous surface layer in high latitude due to stronger wind stirred mixing (Fig. 4a).

2. Stronger nephlocline in low latitude where wind stirred mixing is weak (Fig. 4b).

c. Due to the solar heating and circulation in the tropical region, a strong pycnocline is found around 50 m depth and a layer of particle maximum is found at this depth (Figs. 5 and 6).

d. Small differences are found in the water below 300 m depth. (Fig. 4 and 6).

e. A broad but distinctive indication of upwelling in the Panama Basin (Fig. 7).

YALOC '69 traversed regions of relatively low particulate concentration east of the Cocos Islands as well as the very rich equatorial upwelling region near the Galapagos Islands. Throughout these various regions the mean particle size of each water sample remained in a range from 2μ to 3.5μ neglecting particles of size smaller than 1μ. In certain regions it is possible to approximate the mean particle size by measurememts of light scattered by the particles. If the optical parameter is called R, Fig. 8 shows the linear relationship between R and the mean particle size D as determined by a Coulter Counter for two oceanic regions.

The relative frequency of the particle diameters can be approximated by a gamma distribution as seen by Fig. 9 for the 100 m depth sample from station YPT 41. Although the relative frequencies of all the particle samples cannot be as well approximated by a gamma distribution, they all have a roughly gamma distribution shape with shape parameters α from .3 to .8.

Hydrography

The hydrographic data collection program on legs 3, 4 and 5 of YALOC '69 was designed to yield information on the water budget and deep circulation of the Panama Basin. The basin, a relatively isolated feature, is roughly triangular in form, and is bounded on two sides by the Cocos and Carnegie Ridges, each of which rises approximately 1,000 meters above the surrounding ocean floor, and on the third side by the shores of Central and South America.

On leg 3, 35 hydrographic stations were occupied at approximately 80 mile spacing along the axis of the ridges. Between the stations, GEK observations were made. These data will be used to determine the circulation through the boundaries of the basin. Vertical sections showing the distribution of temperature, salinity and oxygen along these lines are shown in Figures 10 through 15.

On legs 4 and 5, 16 deep hydrographic stations were occupied for the purpose of delineating the deep circulation in the interior of the basin. Temperature-salinity diagrams are plotted for a typical station in this area in Figure 16.

Optical Properties Associated with the Cromwell Current

In an effort to study the influence of the Cromwell Current on the distribution of inherent optical properties, two meridional cross-sections of the equatorial region were taken west of the Galapagos Islands. The cross-sections were taken at 92°00' W longitude and 91°40' W longitude. At each station hydrocasts were taken, and the samples analyzed for salinity, temperature, oxygen content, light scattering, and particle concentrations. A light transmissometer was lowered at each station to approximately 120 m.

The O_2 section across the equator at 92°00' W (Fig. 17) resembles a typical Cromwell Current cross-section as measured for instance by Krauss (Deep-Sea Res., 6(4), 1960). The oxygen maximum is well developed as are the other typical Cromwell Current features. We may thus assume that the Cromwell Current is present at 92°00' W.

The O_2 cross-section at 91°40' W shows the influence of the

Galapagos Islands on the Cromwell Current (Fig. 18). The oxygen maximum at 150 m depth is spreading suggesting a division of the current into a northern and a southern component.

A parachute drogue released at the equator 10 miles west of the Galapagos Islands at 100 m depth drifted in a northeast direction indicating the deflection of the Cromwell Current by the islands.

Cross-sections of the equator at 92°00' W and 91°40' W showing light scattering at 45° ($\beta(45°)$) are given in Figures 19 and 20. The figures show a distinct scattering maximum at the equator down to 100 m. Other maxima occur 30° north and south of the equator. These distinct patterns are the result of meridional circulation, advection of nutrients and oxygen and the Cromwell Current pattern itself. The relationship between these variables and the values of $\beta(45°)$ is to be studied.

Transmissometer lowerings to 120 m give details about layering, and were used to plan bottle spacings. In the Cromwell Current region no distinct minima or maxima were observed.

Geomagnetic Electro-kinetograph Measurements.

The geomagnetic electro-kinetograph (GEK) was operated virtually at all times the ship was underway between Newport, Oregon and Talara, Peru. A total of 105 "zero fix" turns were executed during this period. To insure and monitor the accuracy of the data, two sets of electrodes (silver-chloride) were used on one 200 m long four conductor cable.

Several interesting results can be noted. Most significant, so far, have been the large current velocity values found around the Panama Basin. Both in magnitude and direction this water movement differs from previously published data. A comparison is illustrated in Figure 21.

A few areas along the cruise track produced large anomalous oscillatory patterns in the GEK record for intervals of up to ten hours. The periods of oscillation correspond to a linear distance in the order of one mile. Water movement necessary to produce this type of record is currently under study.

Records were also obtained during long course traverses that closely paralleled the coast. These are being analyzed for tidal components in the open ocean at various distances from the shore.

(d) Chemical Oceanography

Near bottom chemistry was studied at 34 stations at depths from 140 m to 6,200 m. The station locations are shown in Figures 1 and 2.

Near bottom water samples were collected in specially designed plastic water bottles, of the Van Dorn type, that closed automatically when a trip weight touched bottom. The water bottles were constructed of clear plastic tubing, 15 cm long by 7.6 cm inner diameter. Each bottle held 560 ml of seawater. The water bottles were closed by #14 rubber stoppers ground into a hemispherical shape and held together with rubber tubing. Each rubber stopper was held open by a lanyard which was connected to a slack wire release (Fig. 22), consisting of a metal plate and a spring. Tension from a trip weight held the metal plate up and the lanyards pulled free, allowing the rubber stoppers to close.

The bottom bottles were usually spaced 1/2 m, 1 m, 3 m, and 6 m above the bottom. At the beginning of a cast, the first two bottles were connected to the trip weight and the bottles lowered until the connection for the third bottle was reached. A safety line was attached and the bottles were lowered until the safety line took up the tension. The hydrographic line was disconnected and the third bottle was attached. The hydrographic line was reattached to the top of the added bottle and the slack taken up. The safety line was then disconnected and the bottles lowered until the connection for the fourth bottle was reached. The fourth bottle was attached in the same way as the third.

After the bottom bottles had been attached, a series of NIO water bottles were hung on the hydrographic wire above the bottom bottles, and the cast was lowered until the trip weight was 100 m above the bottom. The bottles were then lowered at the slowest winch speed (35 m/min) until the trip weight hit bottom. The decrease in tension when the weight hit bottom (measured with a tensiometer attached to the winch) was used to indicate bottom contact. With this method of detecting the bottom, the depth could be determined to $\pm$ 2 m. After the bottom bottles had tripped, the weight was raised 4 m off the bottom, and a messenger dropped to trip the NIO water bottles.

Each bottom station consisted of a hydrographic cast to 1,500 m, a core, and a deep hydrographic cast to the bottom with NIO bottles spaced every 300 m. A complete station took approximately 5 hours at depths of 4,000 m. Vertical profiles of salinity, oxygen, pH, and alkalinity were measured at each bottom station. Water from the four bottom bottles and from the four NIO bottles nearest the bottom was analyzed for salinity, oxygen, pH, alkalinity, phosphate, silicate, and nitrate. Sediment samples were taken at each bottom station and the cores were frozen for analysis ashore.

SCIENTIFIC PERSONNEL

	Newport	San Diego	Puntarenas	Galapagos	Talara	Talara	Puntarenas	San Diego	Newport
Dr. Wayne V. Burt		x	x	x	x				
Dr. George Beardsley, Jr.	x	x	x	x	x	x			
Lyndal Brixius	x	x	x	x	x	x	x	x	x
Kendall Carder	x	x	x	x	x				
Charles Culberson	x	x	x	x	x	x	x	x	x
Tom Curtin	x	x	x	x	x				
Bo Lundgren	x	x	x	x	x	x	x		
D. McKeel	x	x	x	x	x	x	x	x	x
Hasong Pak	x	x	x	x	x				
William Plank	x	x	x	x	x	x			
Thomas Sholes	x	x	x	x	x	x			
Jim Washburn	x	x	x	x	x	x	x	x	x
Ron Zaneveld	x	x	x	x	x	x			
Steve Tucker		x	x	x	x				
Dr. Donald Heinrichs					x	x	x	x	
Dr. Ross Heath					x	x	x		
Robert Beer					x	x	x		
Robert Hodgson					x	x	x		
Mike Gemperle					x	x	x		
Robey Banks						x	x	x	

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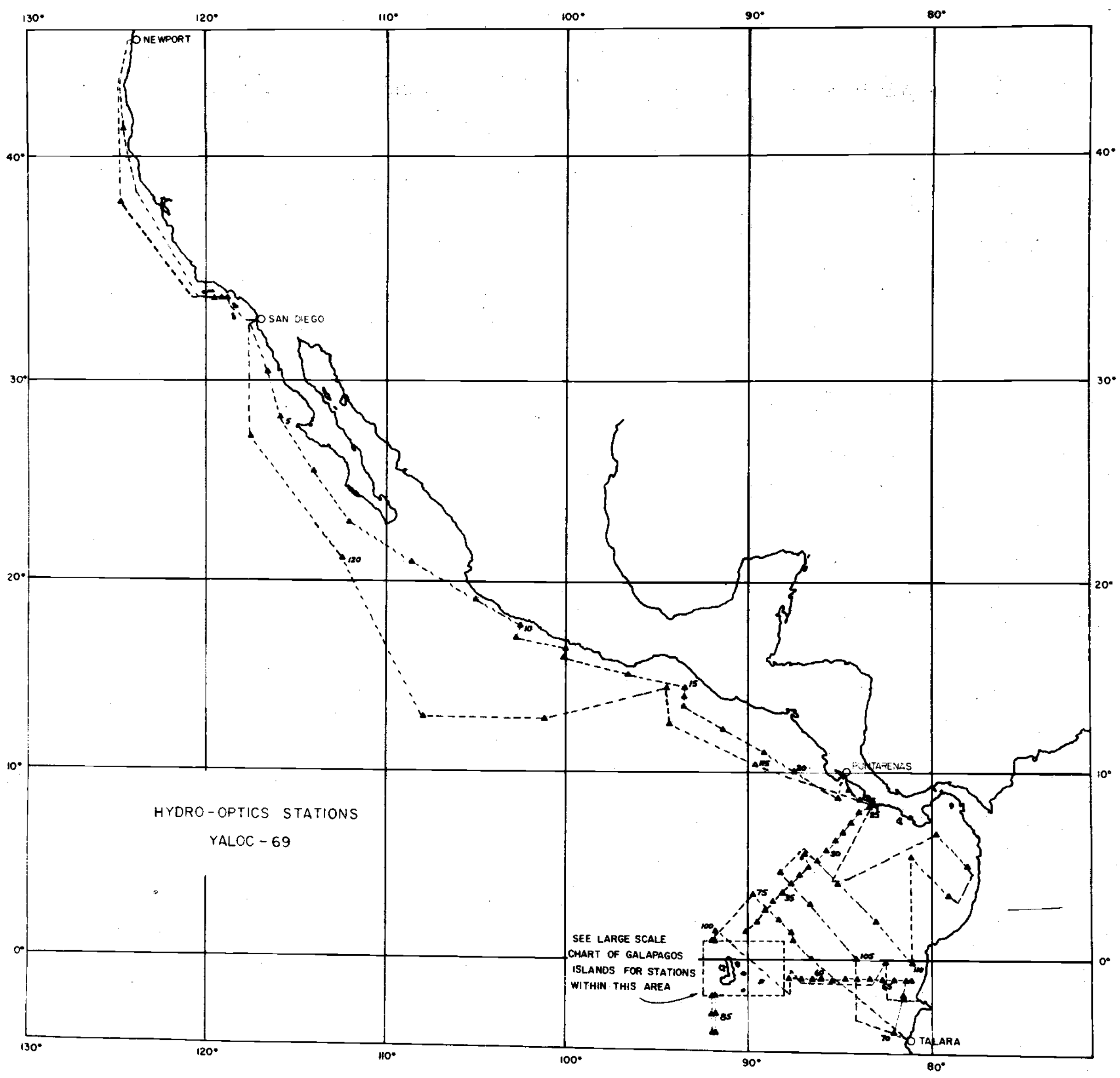

Figure 1. YALOC '69 stations.

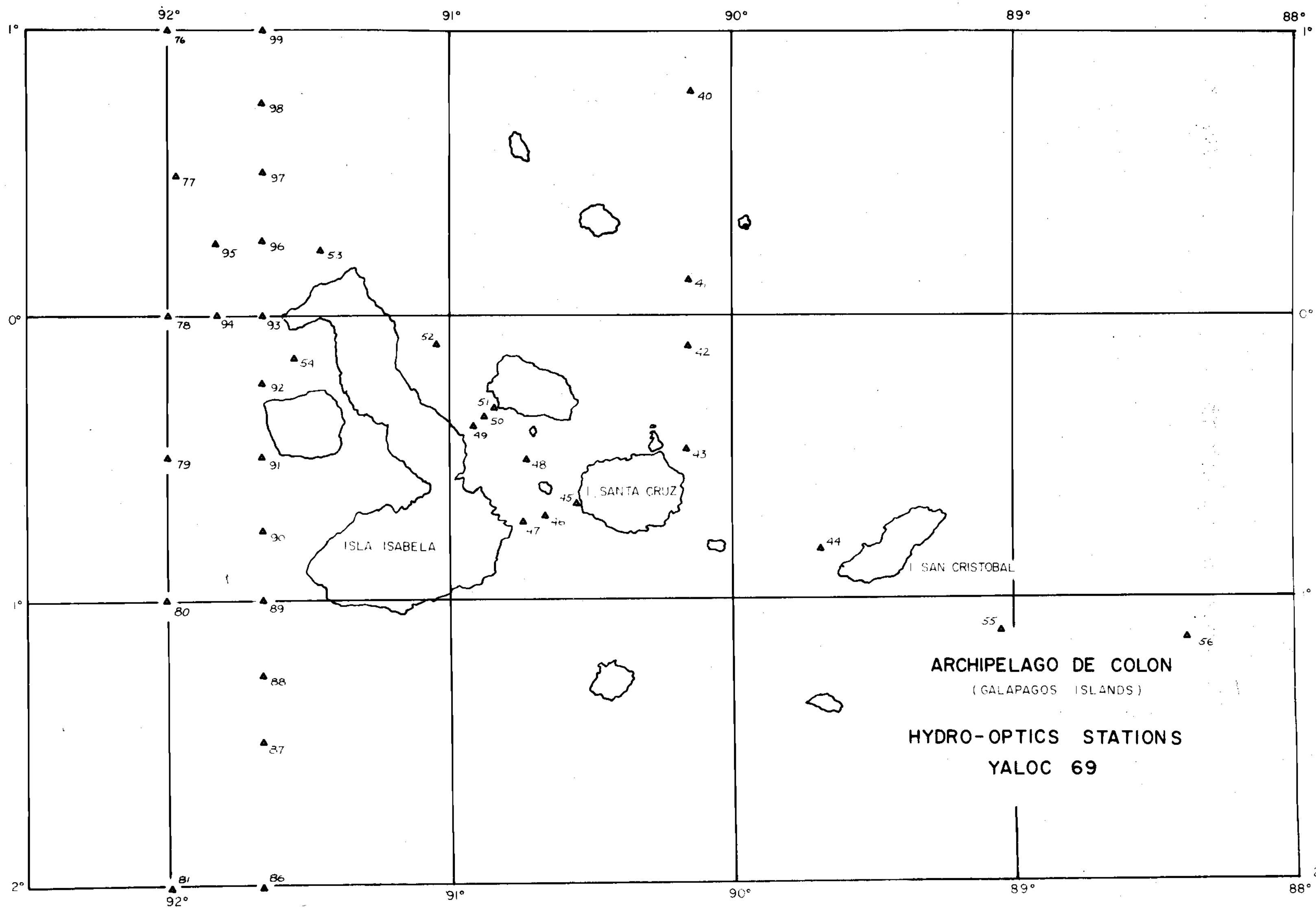

Figure 2. Stations around the Galapagos Islands.

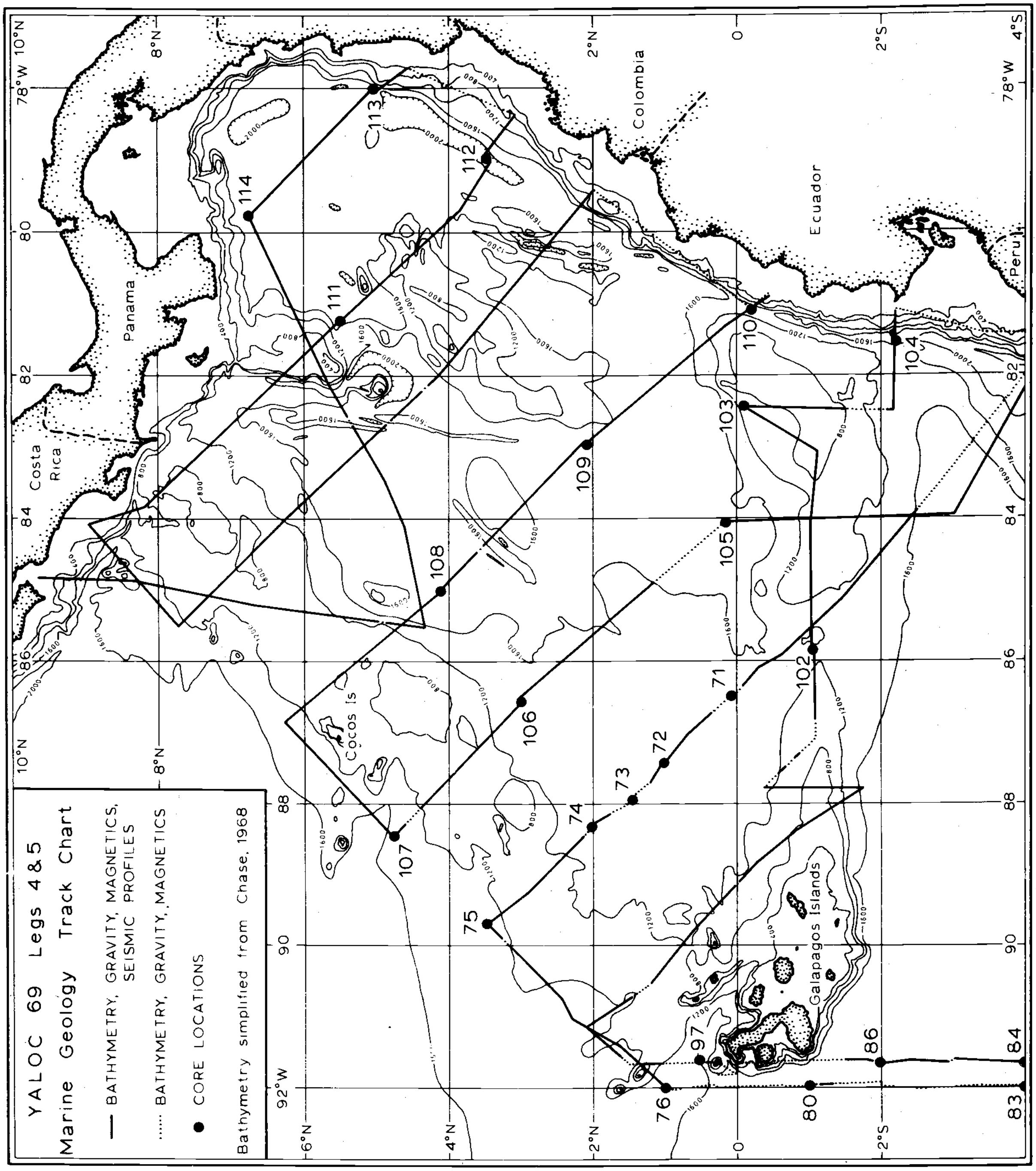

Figure 3. Marine geology track chart in Panama Basin

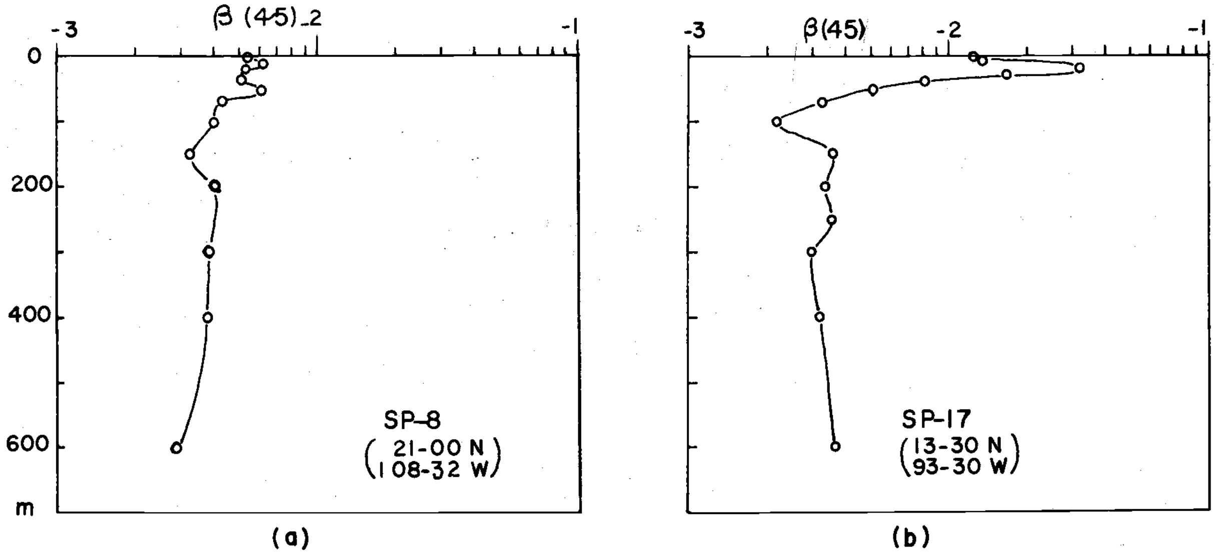

Figure 4. Vertical profiles of β (45) at SP-8 and SP-17.

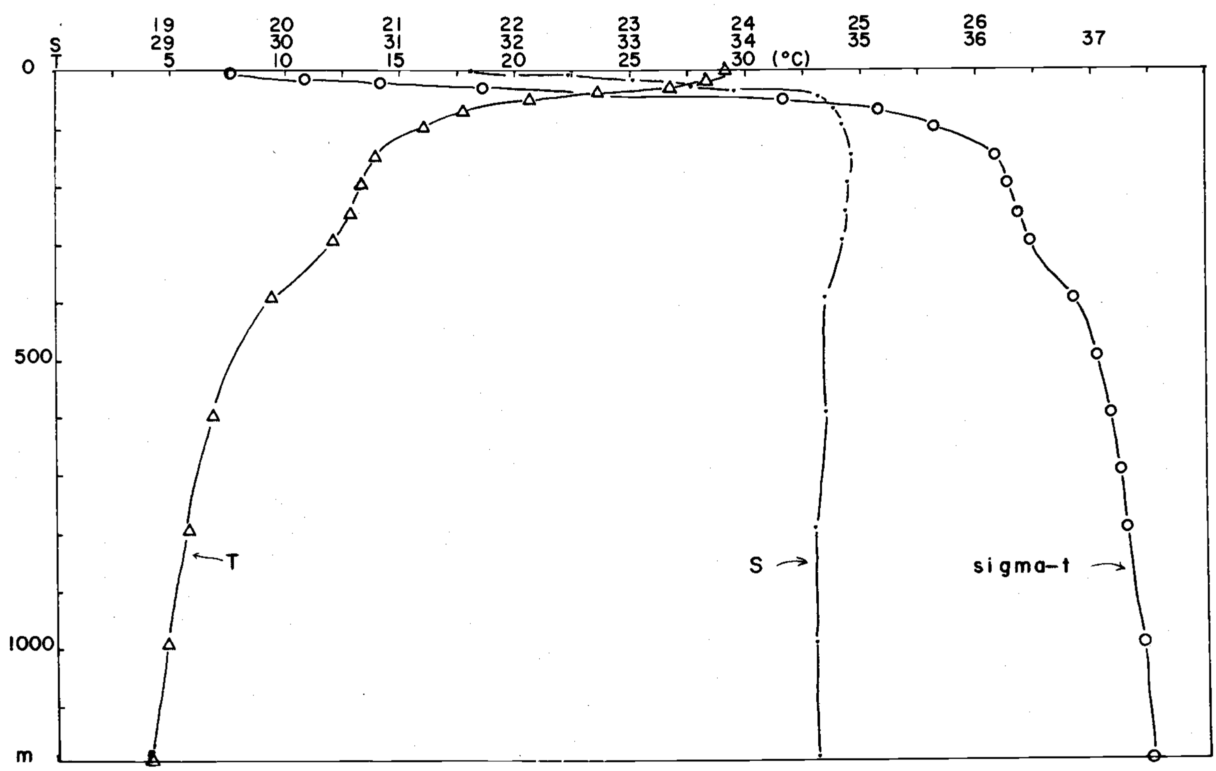

Figure 5. Vertical profiles of T. S., and sigma-t at SP-21.

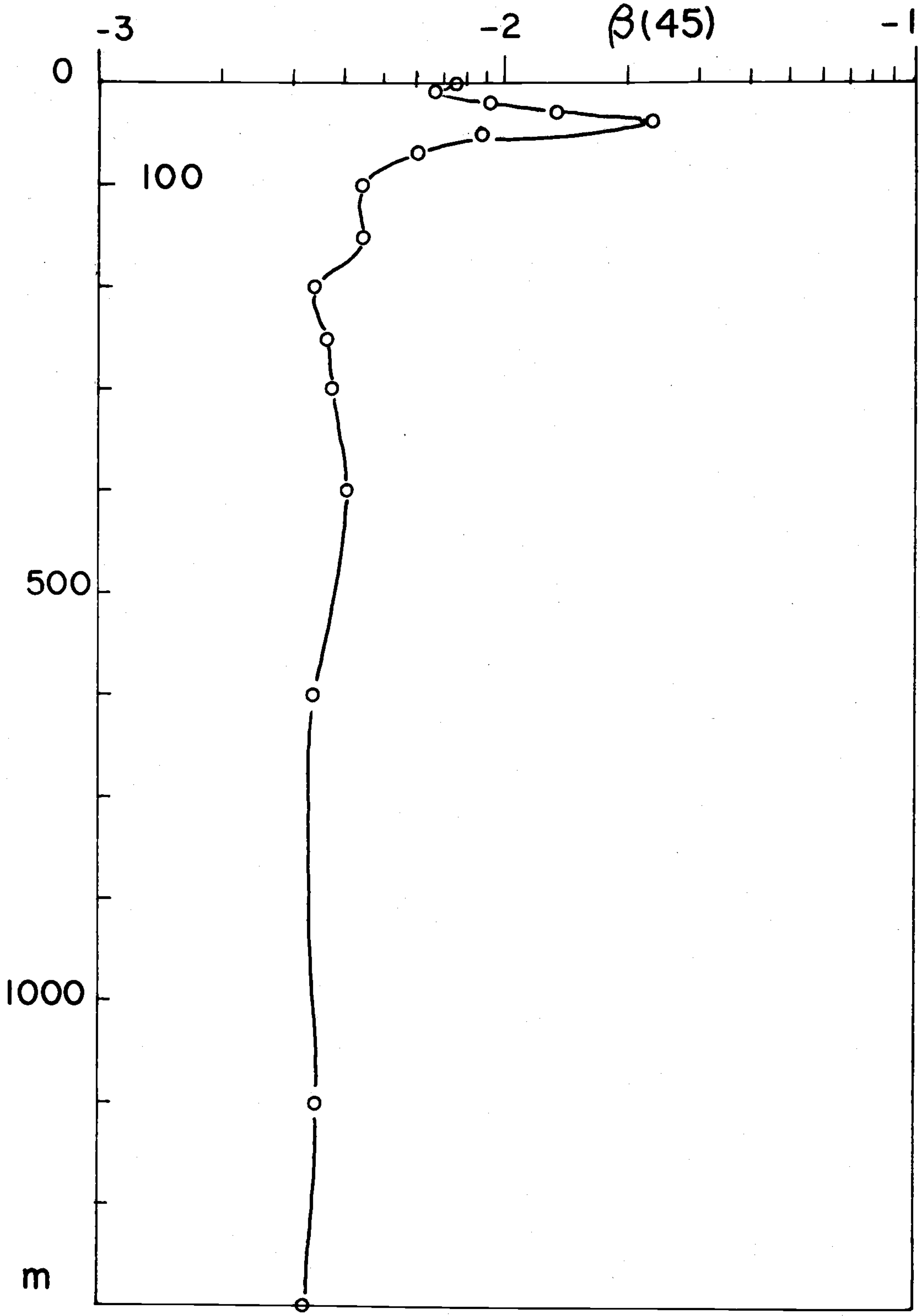

Figure 6. Vertical profiles of (45) at SP-21.

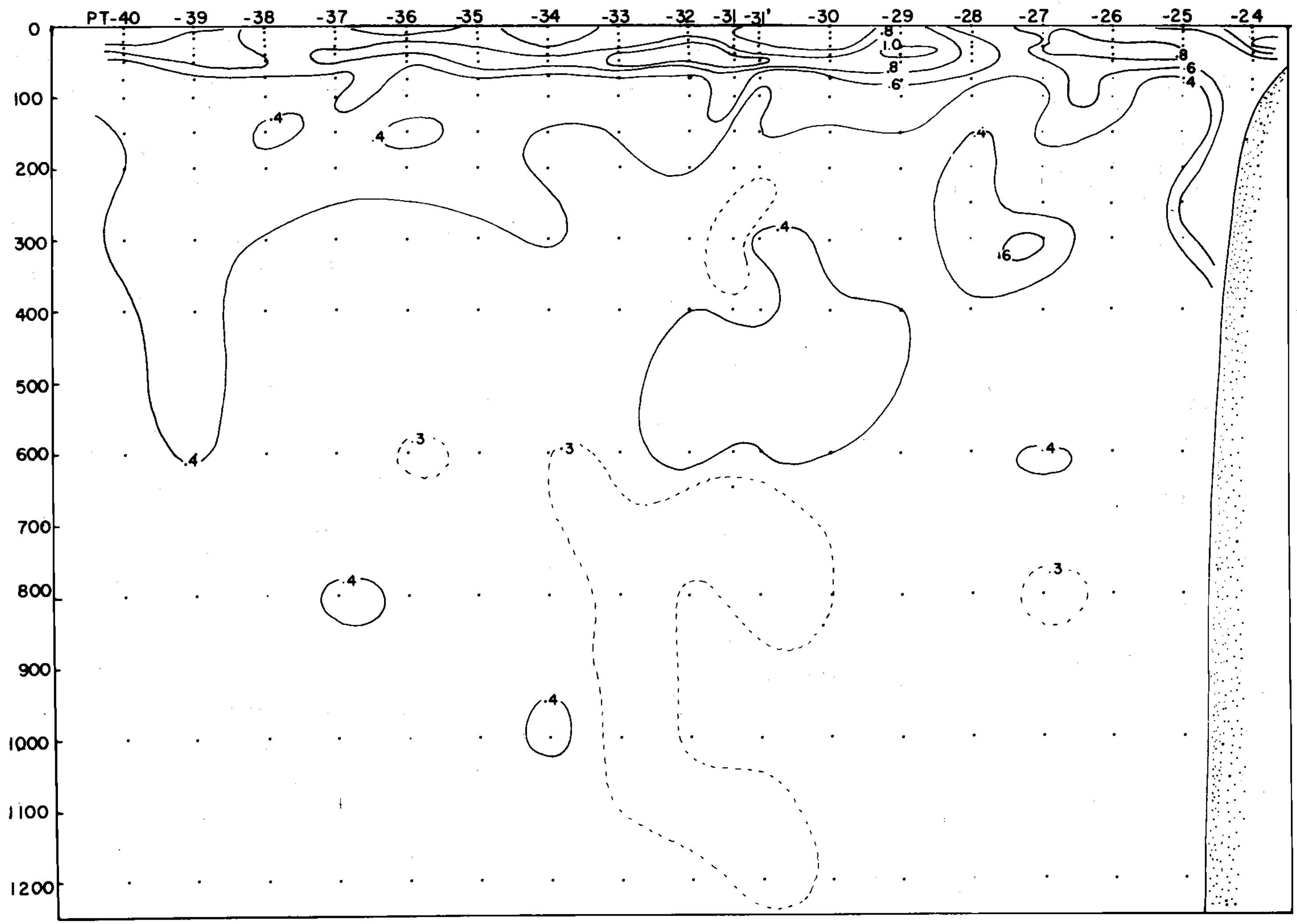

Figure 7. Distribution of β(45) on the vertical section along a line from Puntarenas, C. R. to the Galapagos Islands.

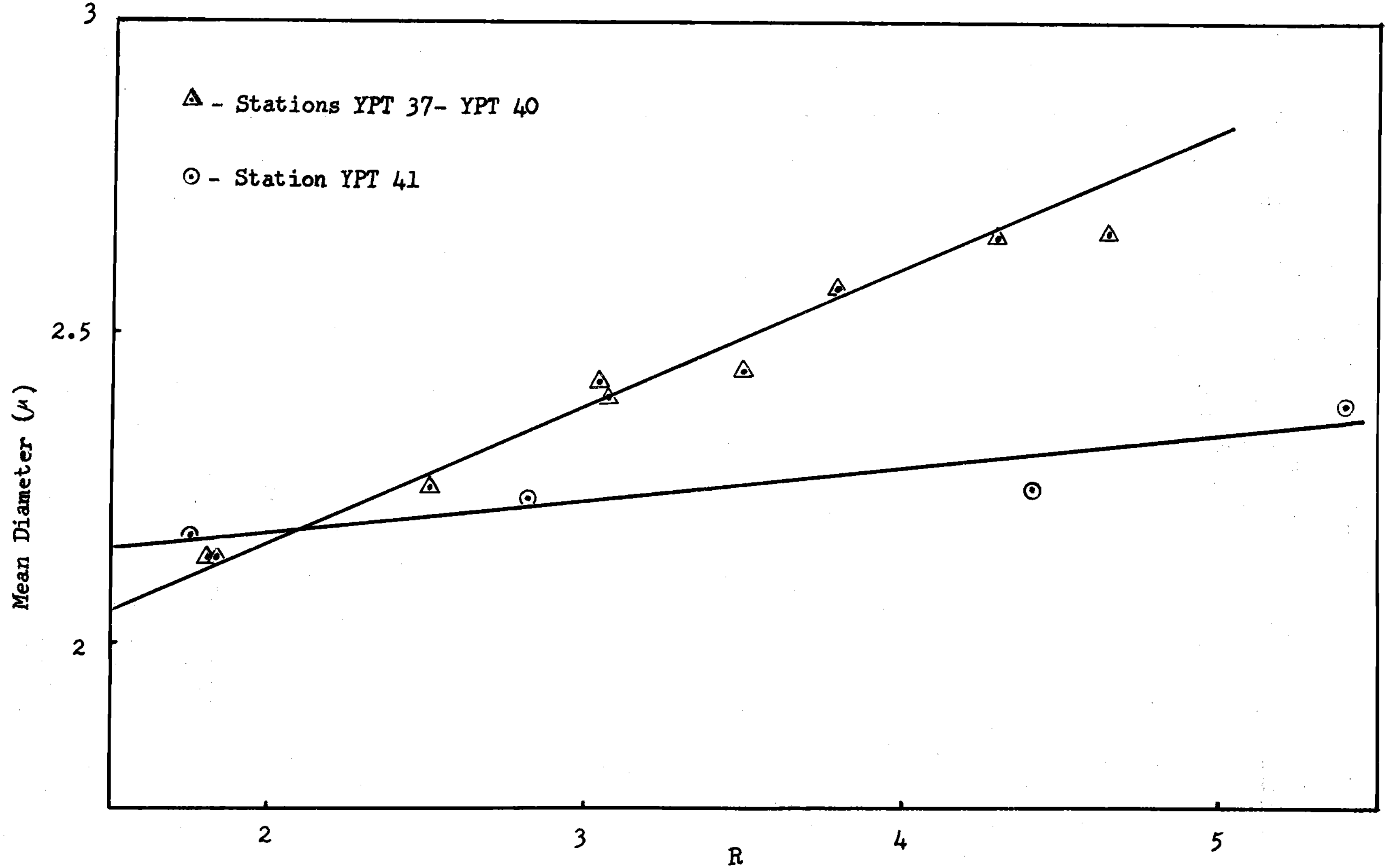

Figure 8. Optical parameter R as a particle size indicator for two Equatorial Pacific regions.

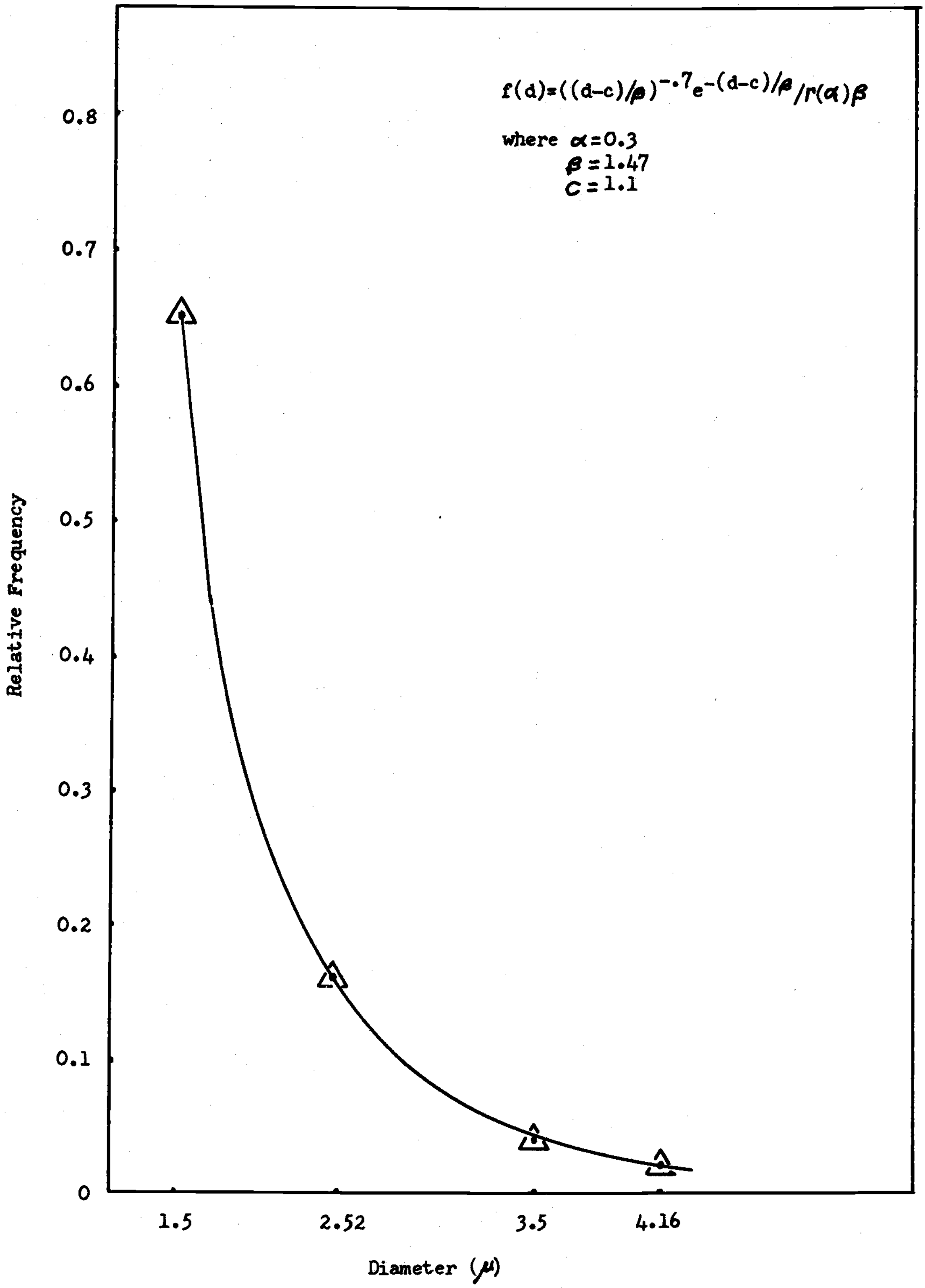

Figure 9. Gamma distribution approximation of the relative frequency of particle diameters at YPT-41, 100m.

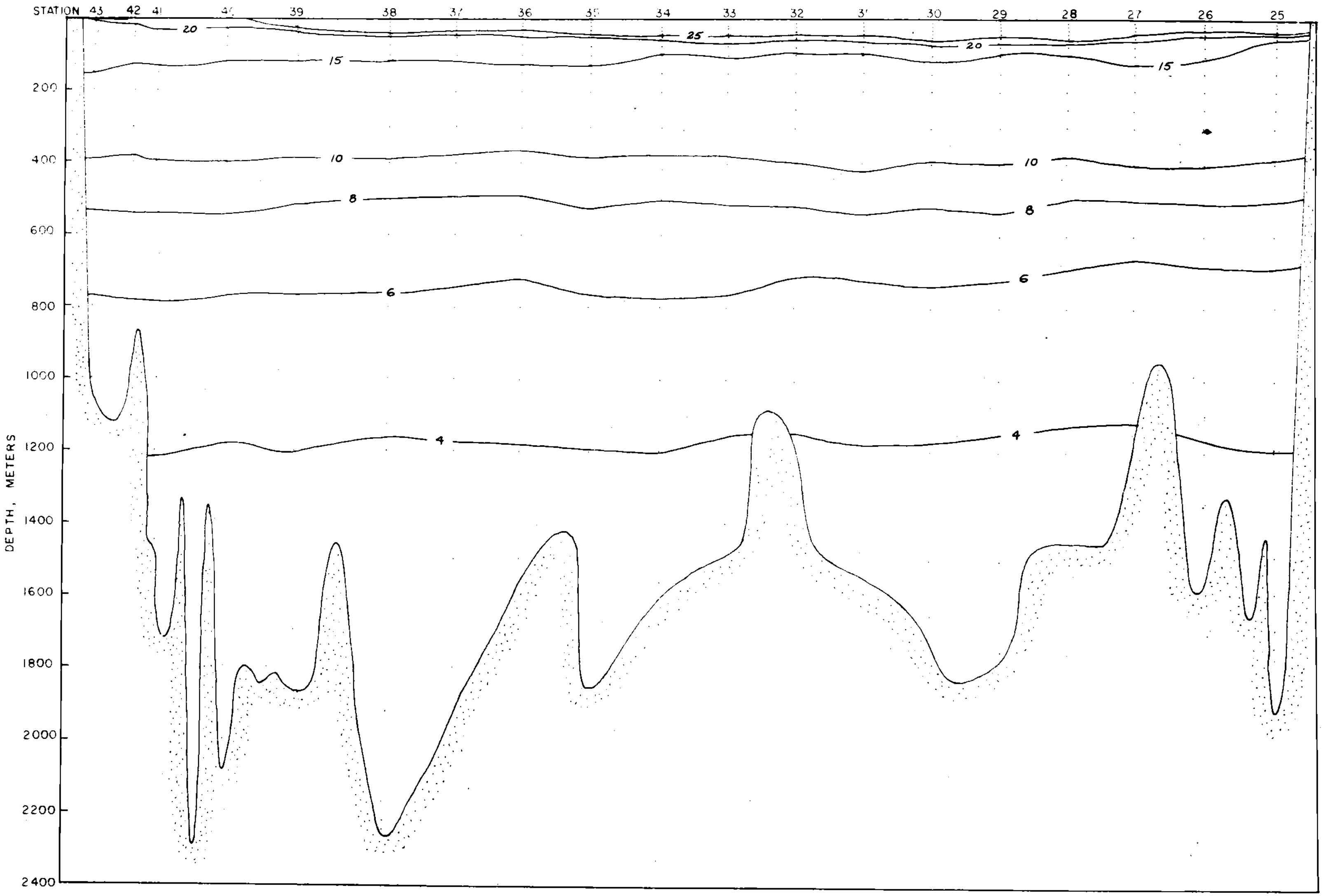

Figure 10. Temperature distribution on the vertical section along a line from Puntarenas, C. R. to the Galapagos Islands.

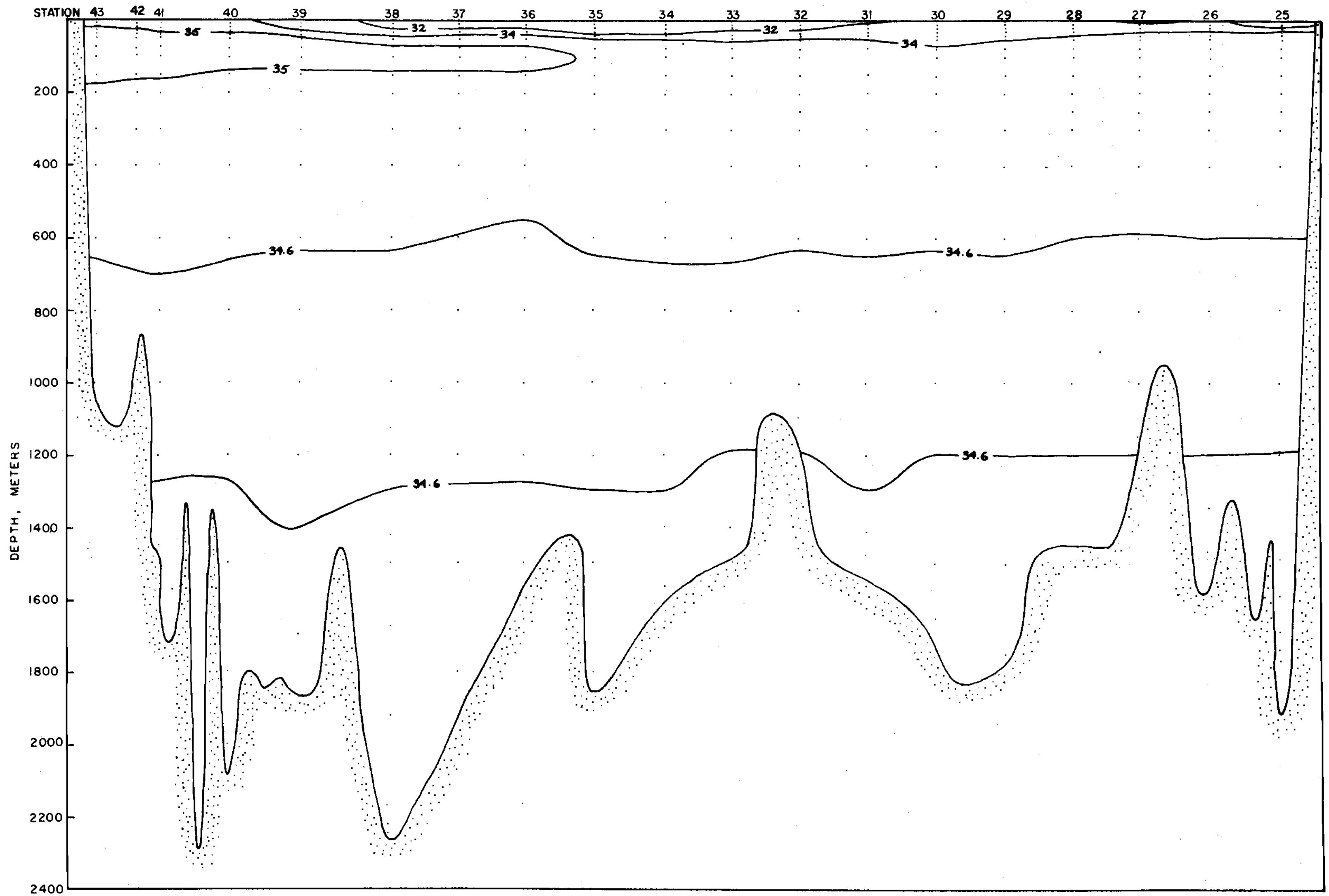

Figure 11. Salinity distribution on the vertical section along a line from Puntarenas, C. R. to the Galapagos Islands.

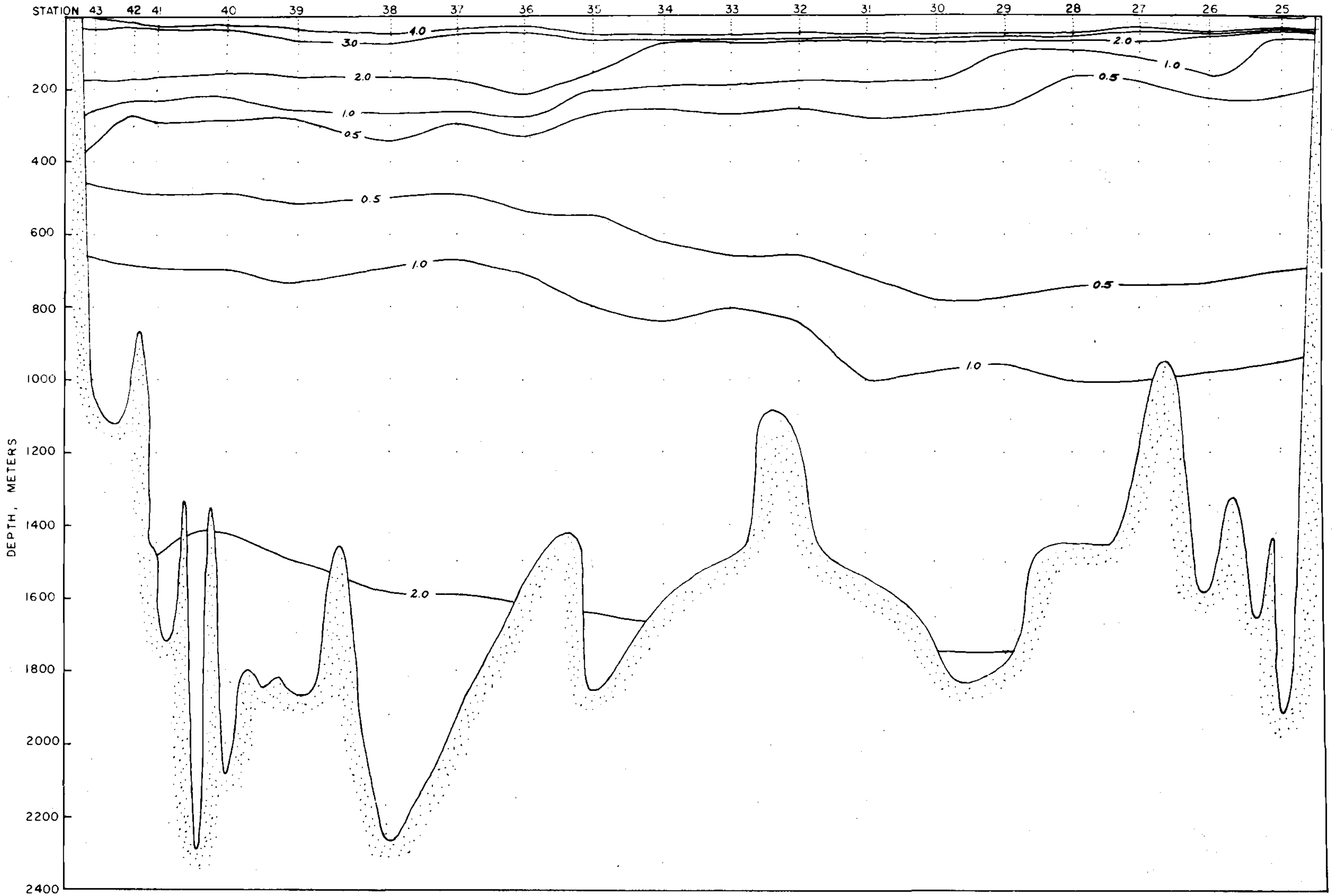

Figure 12. Oxygen distribution on the vertical section along a line from Puntarenas, C. R. to the Galapagos Islands.

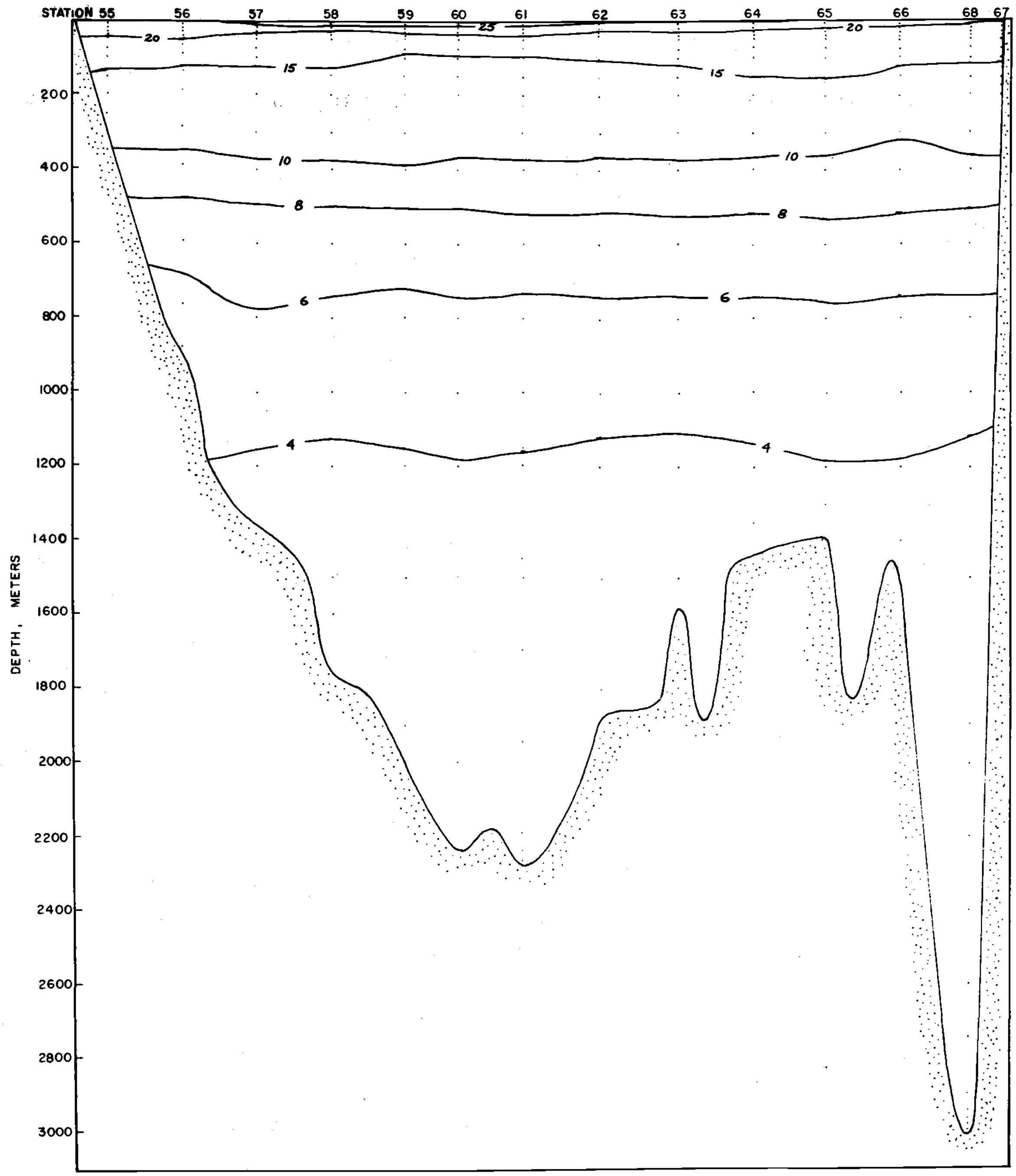

Figure 13. Temperature distribution on the vertical section along the track from the Galapagos Islands to Talara, Peru.

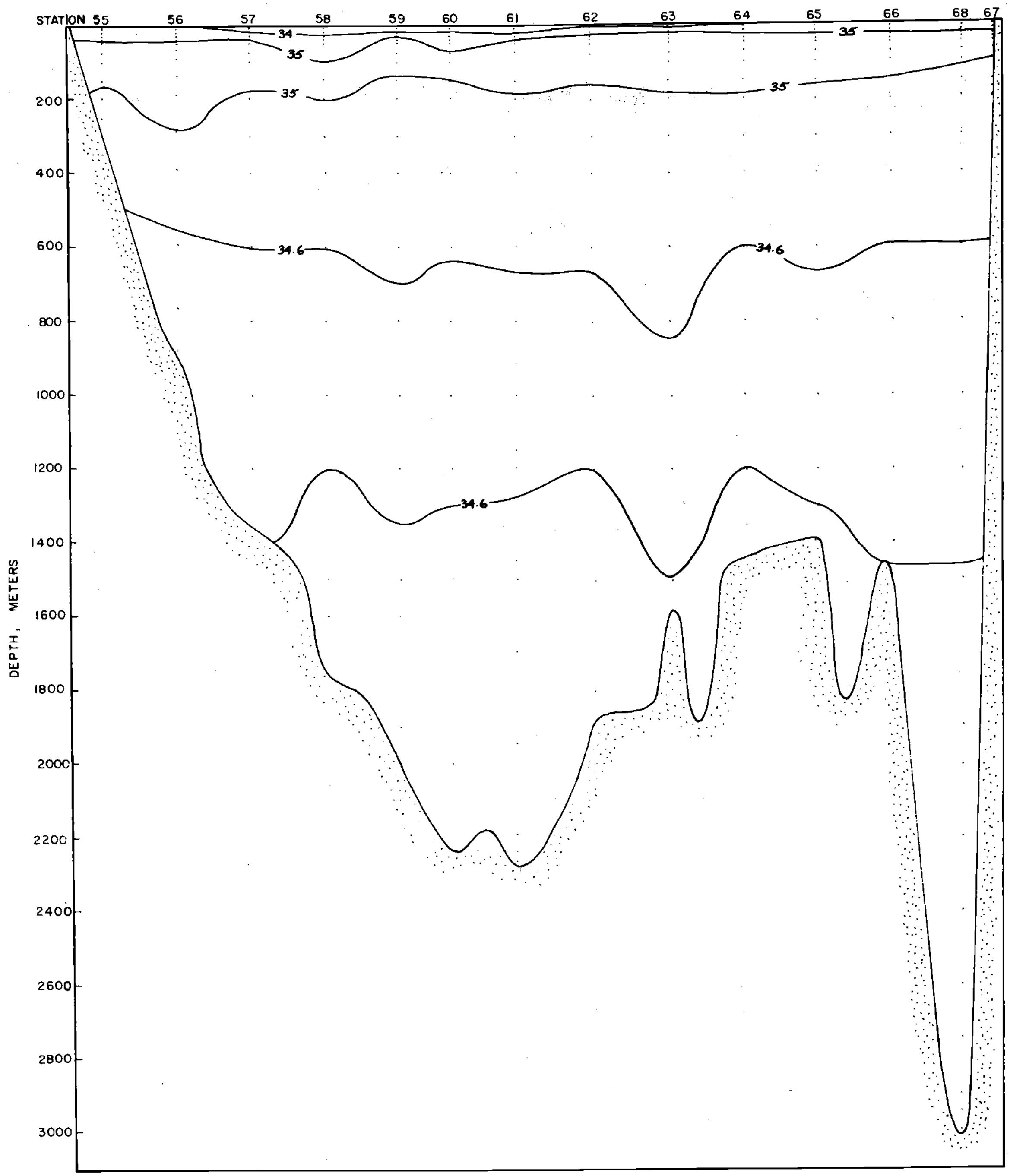

Figure 14. Salinity distribution on the vertical section along the track from the Galapagos Islands to Talara, Peru.

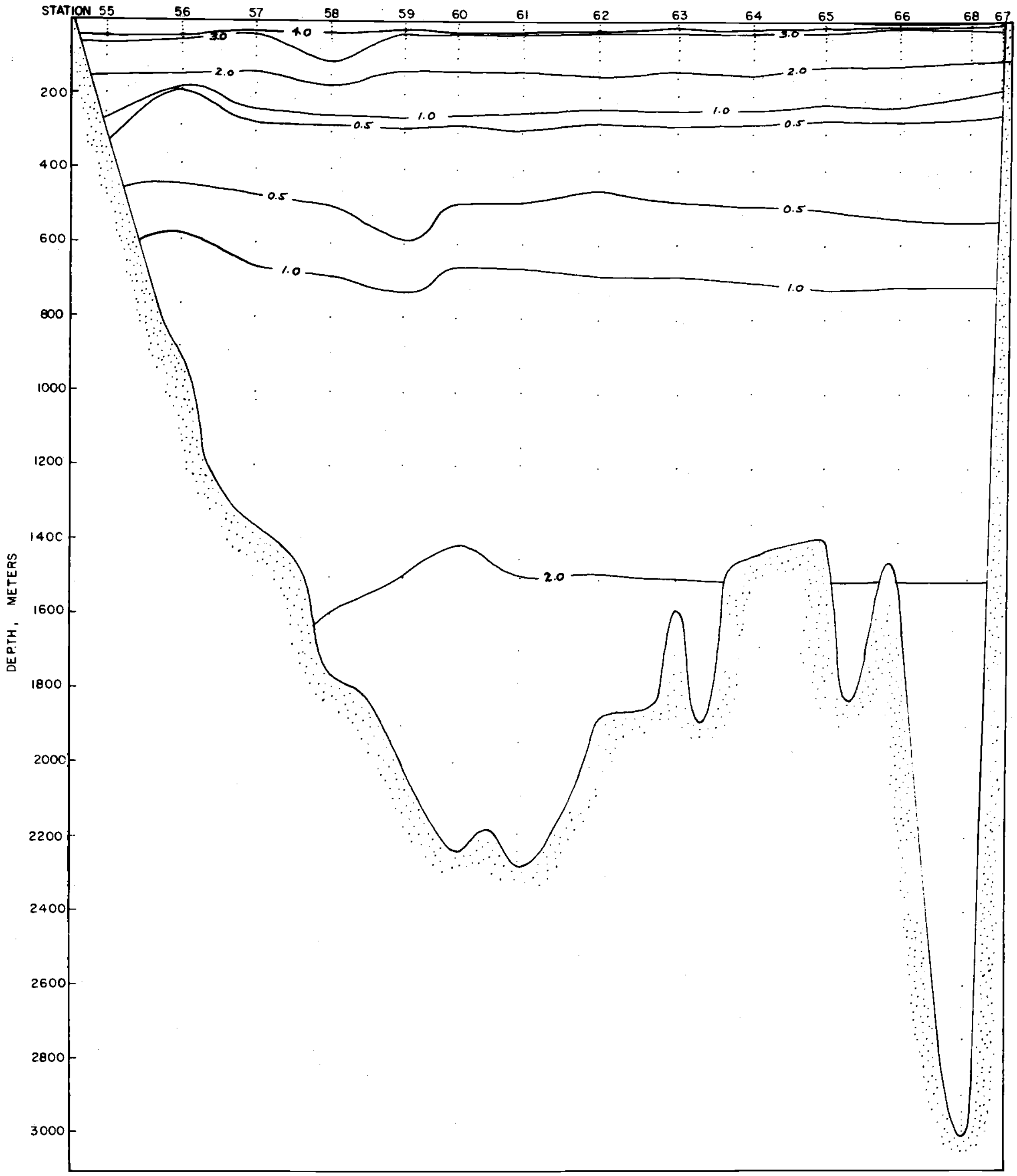

Figure 15. Oxygen distribution on the vertical section along the track from the Galapagos Islands to Talara, Peru.

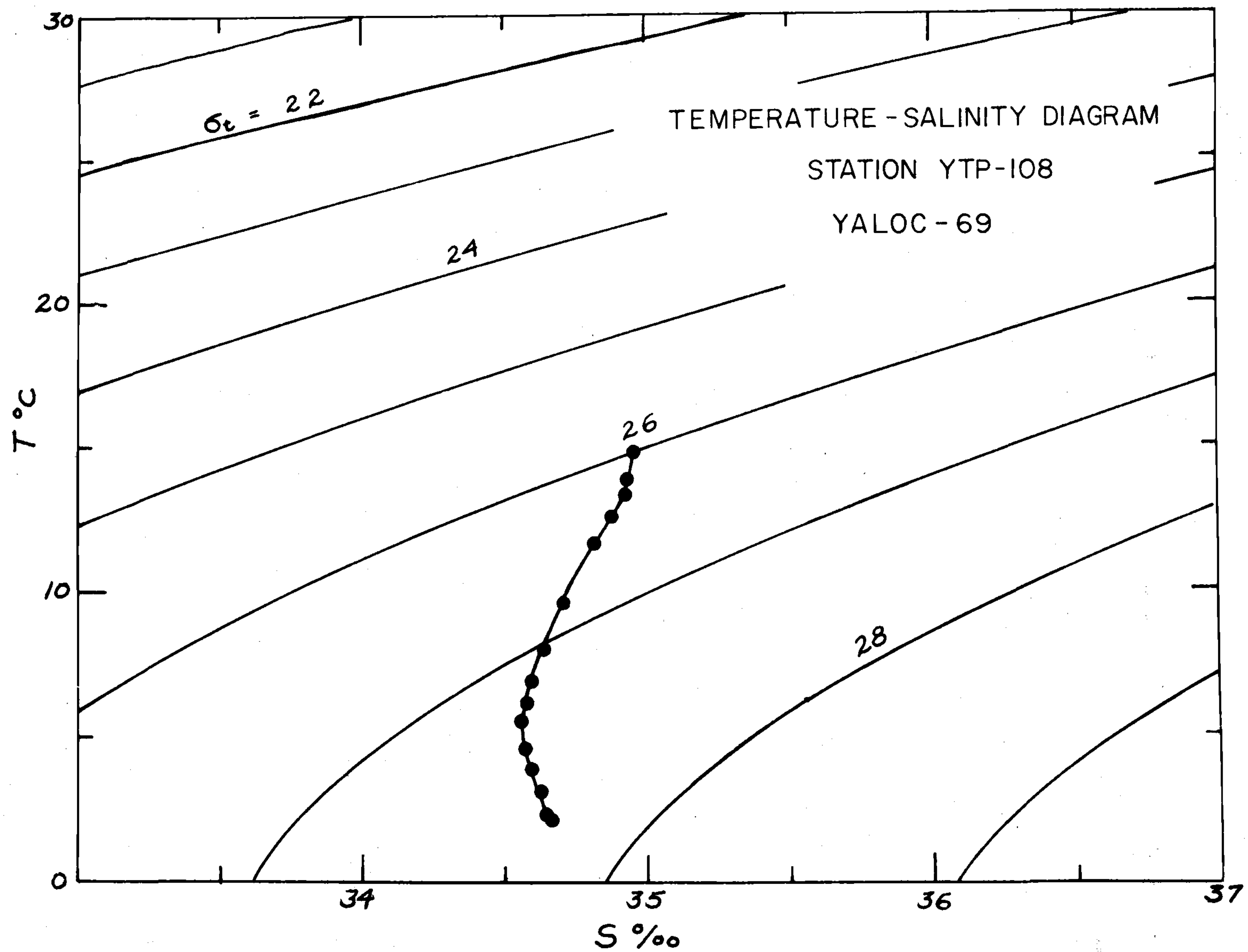

Figure 16. The T-S diagram for a typical station in the Panama Basin.

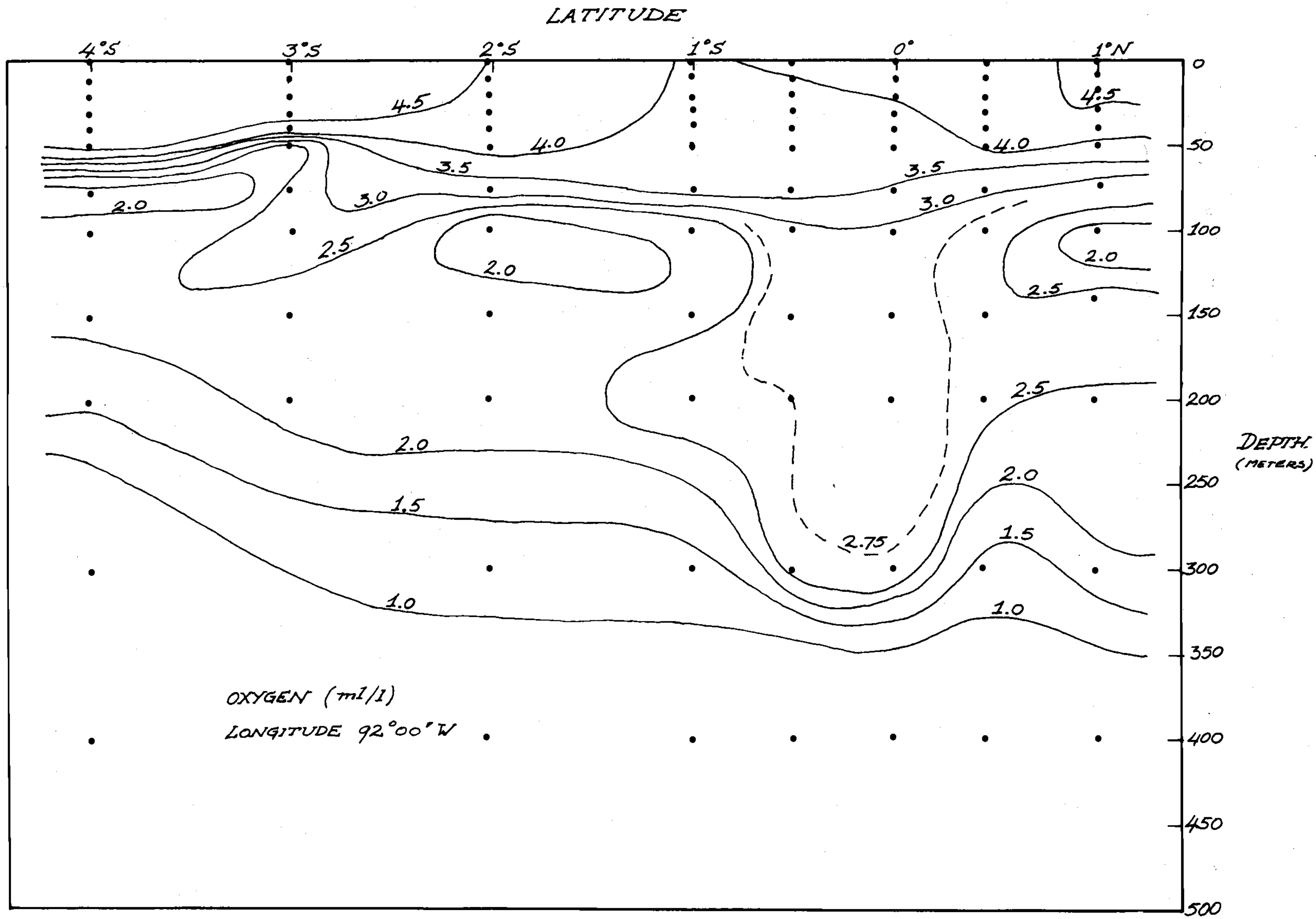

Figure 17. Oxygen distribution on the vertical section across the equator at 92°00.0 W.

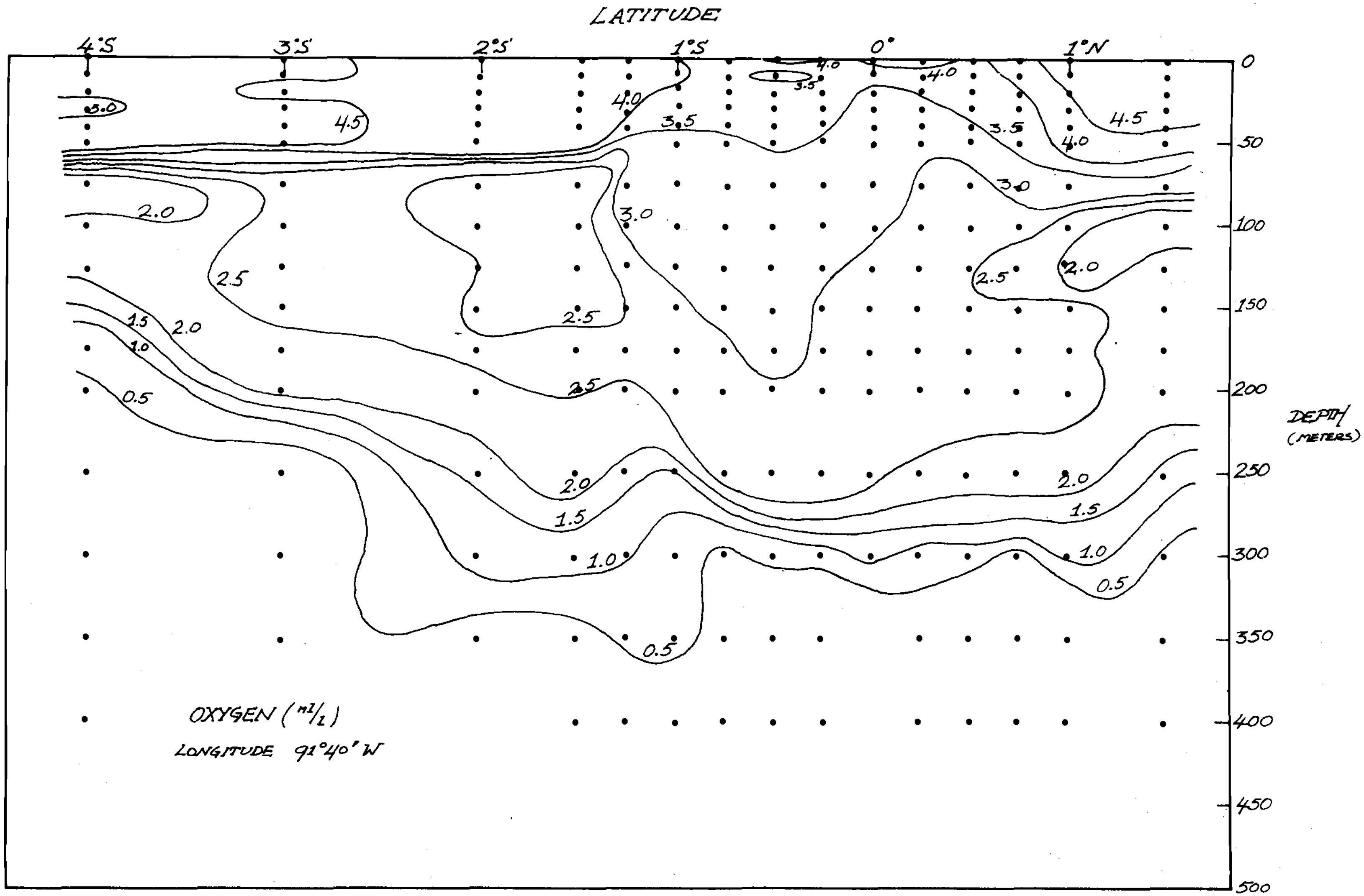

Figure 18. Oxygen distribution on the vertical section across the equator at 91°40.0 W.

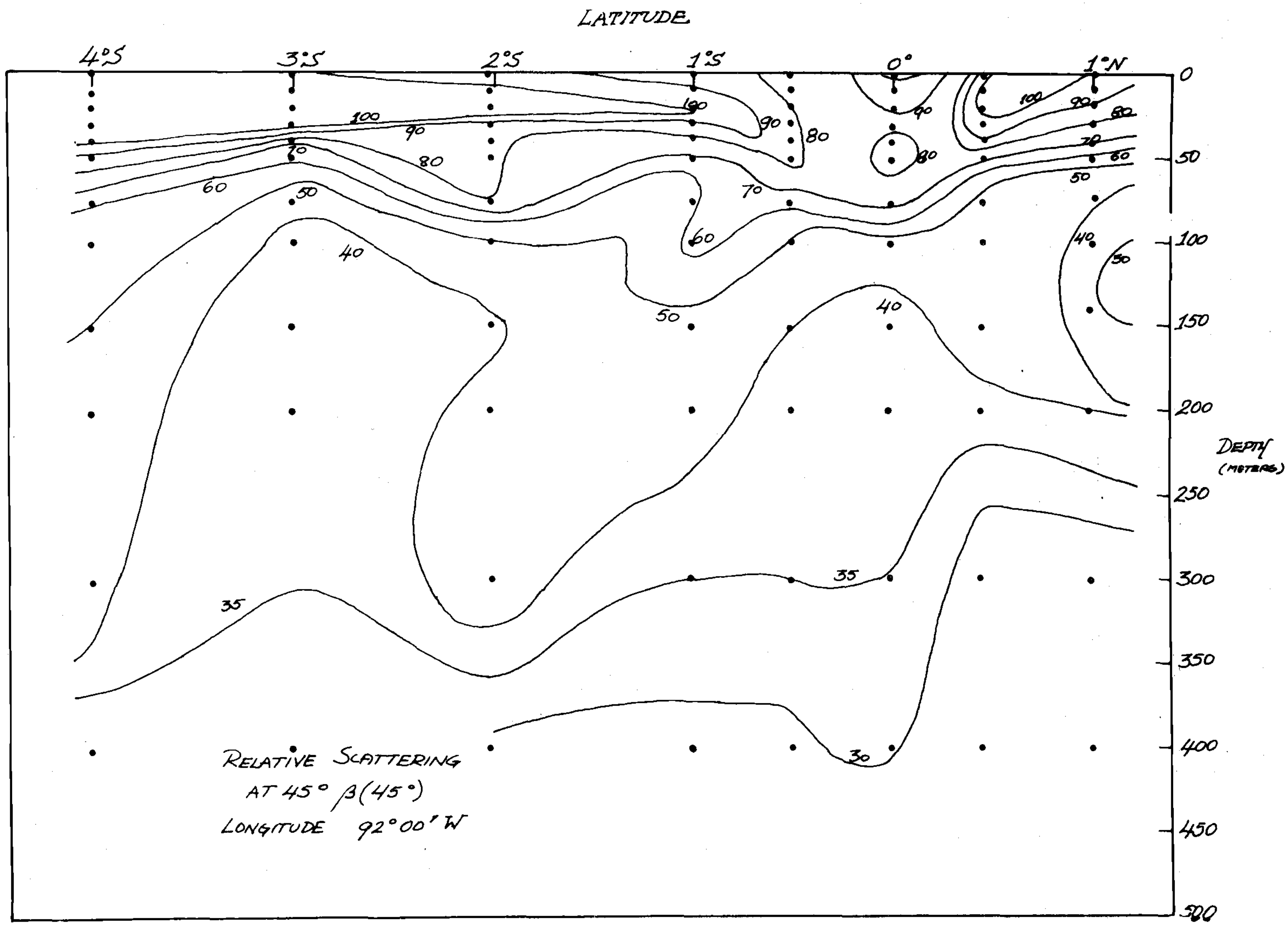

Figure 19. Light scattering at 45°, β (45), on the vertical section across the equator at 92° 00.0 W.

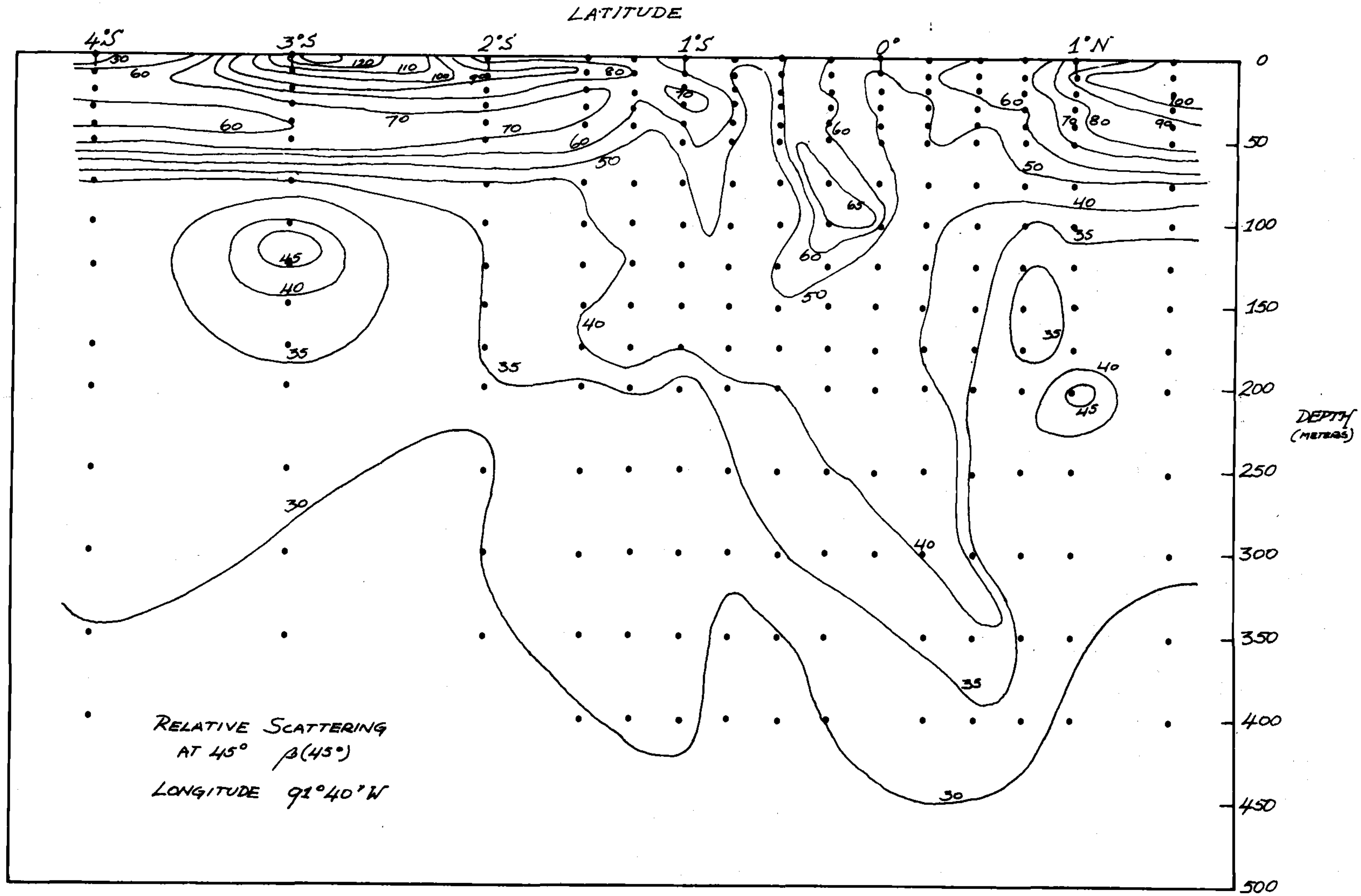

Figure 20. Light scattering at 45°, β (45), on the vertical section across the equator at 91° 40.0 W.

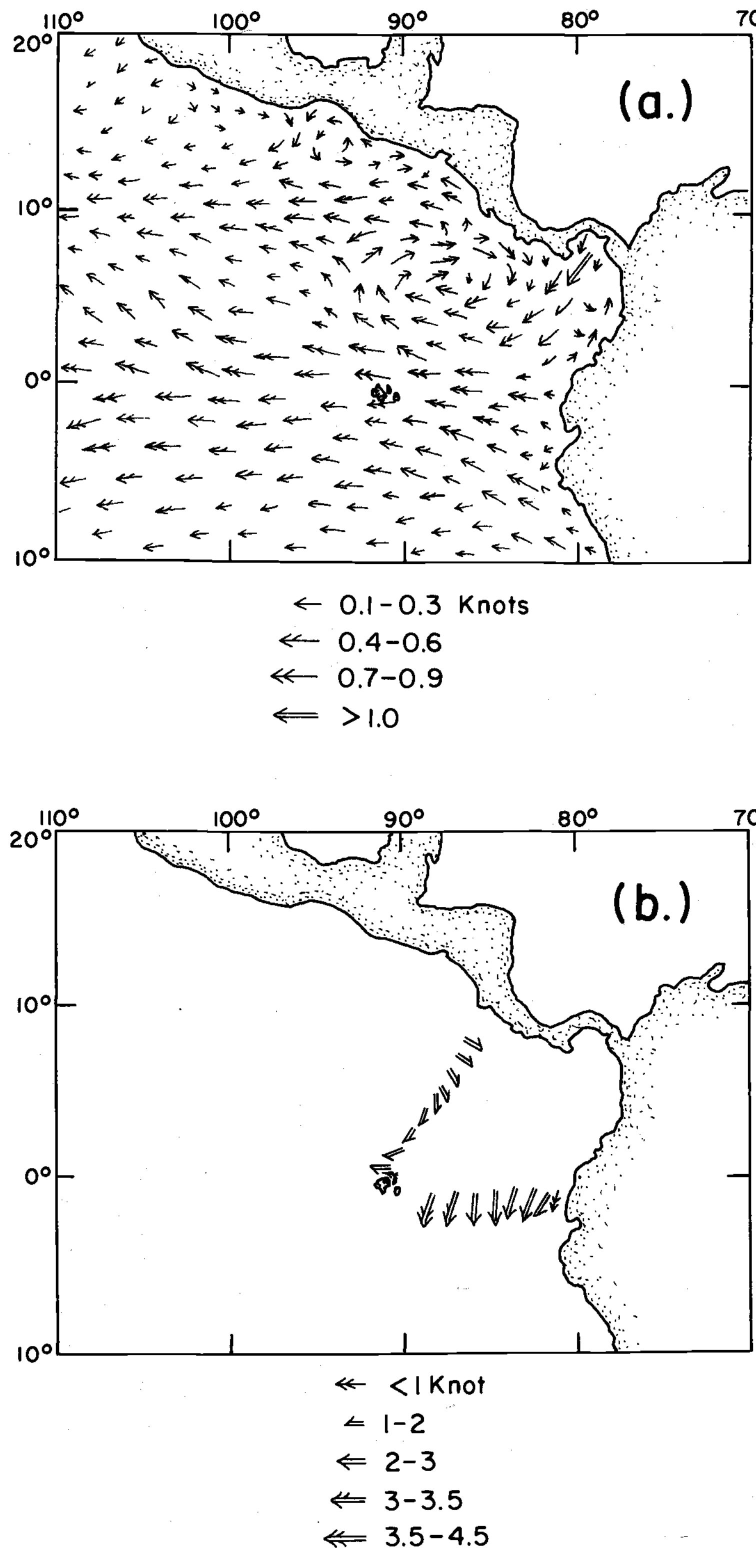

Figure 21. Current pattern for the East Tropical Pacific Ocean.
(a) Pattern as previously compiled by BCF.
(b) Contrasting strong surface currents recorded by GEK.

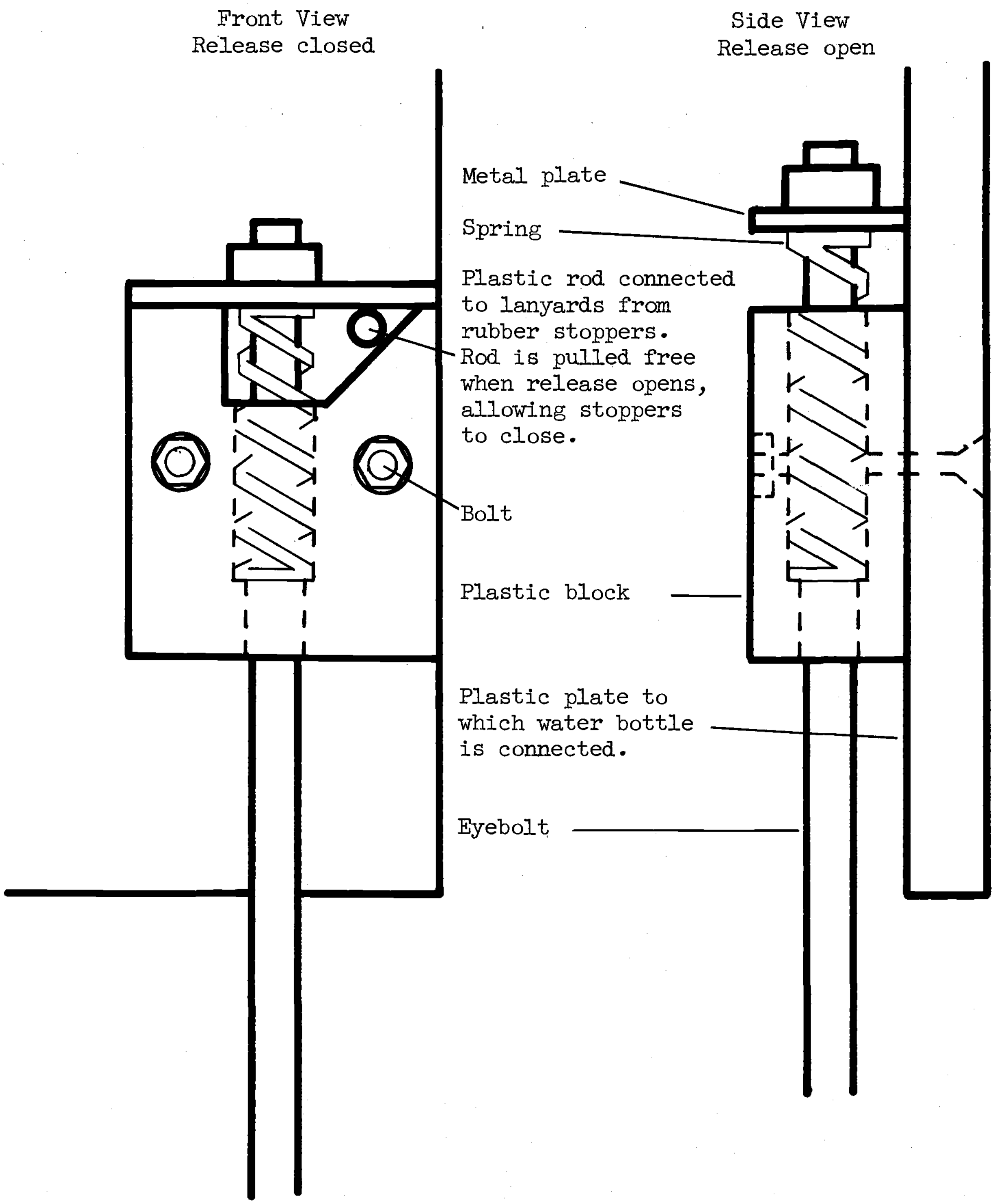

Figure 22. Release mechanism for bottom tripping water bottles.