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A REVIEW OF SOME ASPECTS OF THE PHYSICAL OCEANOGRAPHY OF THE CONTINENTAL SHELF AND SLOPE WATERS OFF THE WEST COAST OF VANCOUVER ISLAND, BRITISH COLUMBIA

by

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ABSTRACT

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The report includes a review of the major oceanographic programs and the available information on features, conditions and physical processes of the continental shelf and slope waters off the west coast of Vancouver Island, British Columbia prior to 1979. The large-scale circulation systems that have a significant influence on the characteristics of these waters, the seasonal surface circulation patterns and divergent-convergent processes are reviewed. Monthly and annual anomalies in the meteorological and oceanographic time-series data for the length of their records through 1982 are presented and discussed. Listings of these data are included. Temperature, salinity, density and dissolved oxygen data from 20 cruises made during 1957-62 and one in March 1969 are presented in vertical sections, and features and variability are noted. The sections are classified as to the relative strength of convergence or divergence they are considered to reflect. Horizontal distributions of temperature and salinity, at depths of 200 and 500 m, are also presented to indicate their spatial variability along the upper continental slope off the coast of British Columbia.

Key words: Physical oceanography, bathymetry, meteorological factors, Ekman transport, sea level, circulation, temperature, salinity, density, dissolved oxygen, continental shelf and slope, Vancouver Island

RÉSUMÉ

Dodimead, A. J. 1984. A review of some aspects of the physical oceanography of the continental shelf and slope waters off the west coast of Vancouver Island, British Columbia. Can. MS Rep. Fish. Aquat. Sci. 1773: 309 p.

L'auteur passe en revue les principaux programmes océanographiques et l'information disponible avant 1979 sur les caractéristiques, conditions et processus physiques des eaux du plateau et du talus continentaux au large de la côte de l'île Vancouver (Colombie-Britannique). Il traite des systèmes de circulation de grande échelle qui influent beaucoup sur les caractéristiques de ces eaux, de même que des régimes saisonniers de circulation de surface et des processus de divergence-convergence. Il indique les anomalies mensuelles de toutes les séries chronologiques de données météorlogiques et océanographiques enregistrées jusqu'en 1982. La liste des données est présentée. Les données de température, de salinité, de densité et de teneur en oxygène dissous recueillies lors de 20 missions faites de 1957 à 1962 et d'une mission faite en mars 1969 sont présentées en coupes verticales; les caractéristiques et la variabilité sont soulignées. Les coupes sont classées selon l'importance relative de la convergence ou de la divergence qu'elles semblent reflêter. On présente aussi les distributions horizontales des températures et salinités, aux profondeurs de 200 et 500 m, afin de montrer leur variabilité spatiale le long de la partie supérieure du talus continental au large de la côte de la Colombie-Britannique.

Mots clés: océanographie physique, bathymétrie, facteurs météorologiques, transport d'Ekman, niveau de la mer, circulation, température, salinité, densité, oxygène dissous, plateau et talus continentaux, île Vancouver

I. INTRODUCTION

Requests for sources of oceanographic data and for information on currents, water structure, physical processes, and particularly for long-term indices of the ocean climate for the waters off the coast of British Columbia have increased considerably during the past several years. These requests have come from all sectors, federal, provincial, university, and private, but most frequently from fisheries scientists and managers working on the biology of fish, their distribution, behavior and migrations, assessment of year-class strengths, and management of the fisheries. Others specifically involved in impact studies relative to oil exploration and transportation, and in assessment of sites for aquaculture projects have also been making enquiries. More recently, a thrust toward the development of multi-disciplinary and multi-species fisheries oceanography programs has resulted in an increased demand for background oceanographic information.

To meet these requirements, it seemed essential that reviews of the major physical oceanographic programs and research for the British Columbia coastal and the contiguous offshore waters, and that syntheses of past research and historical data were required A prime need is to present those data that have not been exploited fully in the past in a more useable format, other than in their present data record form, or as yet are unpublished. A review of available meteorological and oceanographic time-series data and their significance as indices reflecting the variability and trends in the ocean climate is also required. It was particularly clear that the continental shelf and slope waters were of high priority. A first report of this type for these waters by the author was "A review of the oceanography of the Queen Charlotte Sound-Hecate Strait-Dixon Entrance region" (Dodimead 1980).

In this second report, the author considers the oceanography of the continental shelf and upper slope waters off the west coast of Vancouver Island. It is similar in format to the first report, and includes a review of past research, up to 1979, and of the large-scale atmospheric pressure and associated wind systems. The large-scale circulation systems of the eastern Subarctic Pacific Region that significantly influence the characteristics of the continental slope and shelf waters, the seasonal coastal surface circulation patterns and the divergent-convergent processes are also reviewed. Precipitation and runoff features, 1958-82, monthly means and anomalies of calculated onshore-offshore Ekman transport, 1946-82, monthly anomalies of unadjusted and adjusted sea level at Tofino B.C., 1940-82, and annual and monthly anomalies of sea surface temperature and salinity at Amphitrite Point and Kains Island, 1935-82 are discussed. Listings of monthly and annual means and anomalies, up-dated long-term monthly and annual means and standard deviations, and the number of standard deviations in the monthly and annual anomalies in these data are provided in the Appendix tables. The report also includes presentation and a brief description of vertical sections of temperature, salinity, density (as defined by "σ_t") and dissolved oxygen from some 20 Canadian oceanographic surveys that covered these waters from 1957 through 1962 and one in March 1969. An attempt has been made to classify the vertical distributions as to the relative strengths of the convergent - divergent processes that they are considered to reflect. The relative strengths are considered to be indicated in the monthly means of sea surface temperature at the lightstations, Ekman transport and sea level prior to the surveys. Finally, examples of horizontal distributions of temperature and salinity, at depths of 200 and 500 m, are presented to indicate their spatial variability along the upper continental slope off the coast of British Columbia.

A prime objective of this report is to identify the seasonal and interannual variability in the wind-induced processes of convergence and divergence and the long-term trends, variability and relationships in the meteorological-oceanographic time-series data, as these are considered most significant and applicable to fisheries oceanography and fisheries management models, at least at our present state of knowledge.

II. GEOGRAPHIC AND BATHYMETRIC FEATURES

The western coastline of Vancouver Island, extending from Race Rocks in Juan de Fuca Strait to Cape Scott, is indented by numerous sounds and inlets (Fig. 1). They vary considerably in their dimensions. The largest sound is Barkley Sound; and the longest inlet, and also one of the deepest, is Alberni Inlet which opens into Barkley Sound. Pickard (1963) has provided the salient dimensions of all west coast Vancouver Island inlets of 5 miles (9.3 km) or greater in length; they are presented here for information (Table 1).

The distance along the western coastline from Race Rocks to Cape Scott, as measured directly across the sounds, is about 454 km (245 M (nautical miles)).

The continental shelf break is approximately delineated by the 100 fathom (183 m) isobath, seaward of which lies the continental slope with a much steeper gradient (Fig. 1). To the south, Juan de Fuca Canyon with depths to 350 m (190 fath) transects the shelf in a general southwest-northeast direction with a small spur protruding to the north. The shelf varies in width from about 90 km (50 M) paralleling the northern edge of Juan de Fuca Canyon to only 9 km (5 M) normal to the coast from Cape Cook. Bottom features and gradients of the shelf are generally irregular, particularly immediately seaward of Barkley Sound where an irregular-shaped depression with a maximum depth of about 165 m (90 fath) separates the Sound from the relatively shallow La Pérouse Bank, which shoals to less than 60 m (33 fath) (Fig. 1).

III. METEOROLOGICAL FEATURES

In the section following, sea level atmospheric pressure systems and related winds are reviewed. Annual, seasonal and monthly precipitation and freshwater runoff features and anomalies are noted. The seasons were defined as follows: winter, December-February, spring, March-May, summer, June-August and autumn, September-November.

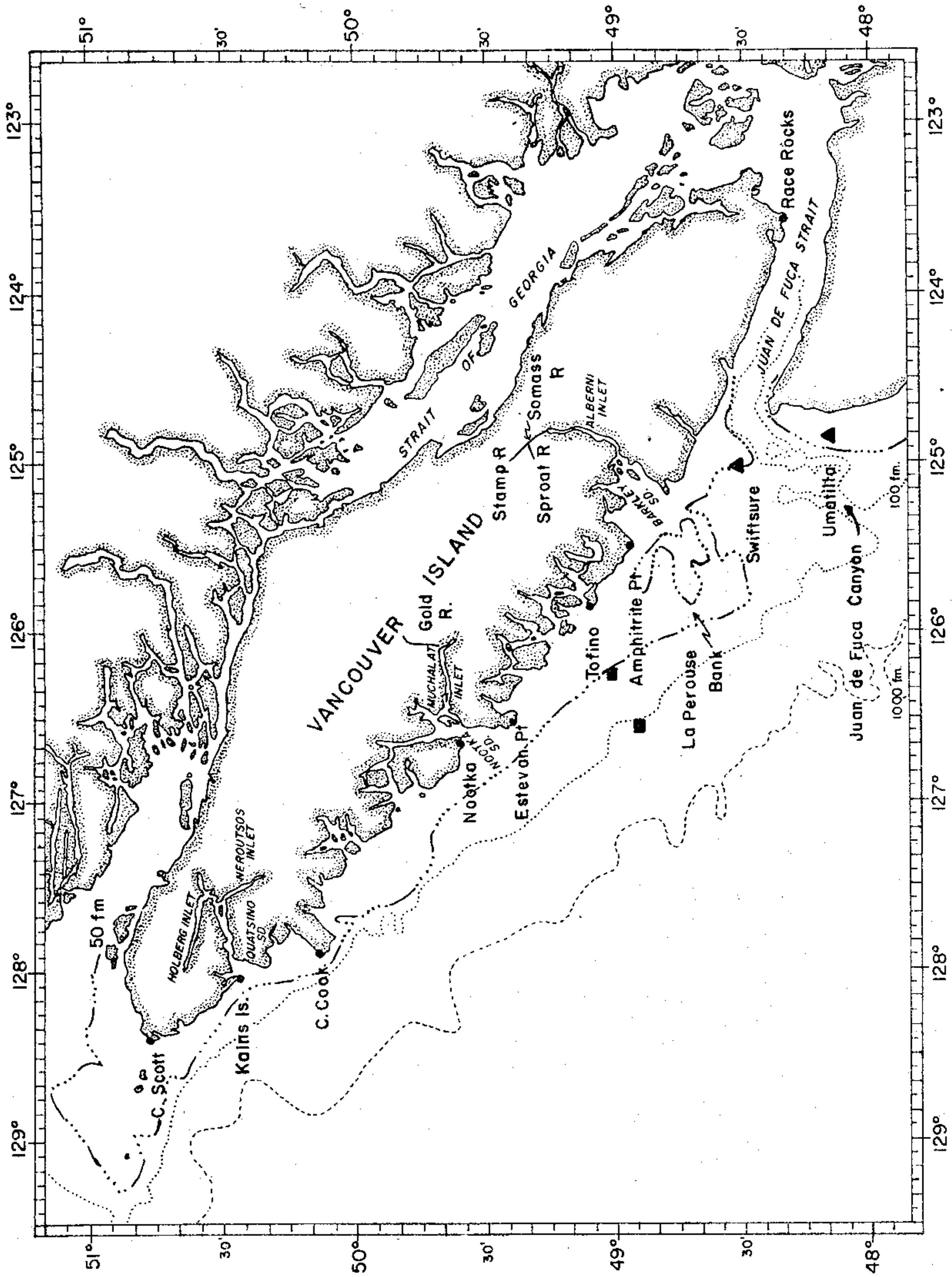

Fig. 1. Geographical area. (■ Location of current meter moorings, November 28, 1974 to April 8, 1975 (Huyer et al. 1976); ▲ location of Swiftsure and Umatilla lightships; removed from service in 1961.)

Table 1. Salient dimensions of the inlets of 5 miles length or more along the west coast of Vancouver Island, British Columbia (from Pickard 1963).

Name	Abbreviation	Length	Mean width	Mean mid-inlet depth	Maximum depth	Outer sill depth (Note 1)	Notes
		Nautical miles		m	m	m	
Holberg Inlet	HOL	18.5	0.7	80	170	18	2
Rupert Inlet	RUP	5.5	0.95	110	165	18	2
Neroutsos Inlet	NER	32	1.2	150	245	78	3
Forward Inlet	FOR	6	0.6	30	65	none	
Klaskino Inlet	KLA	6	0.4	35	65	18	
Ououkinsh Inlet	OUO	7.5	0.65	85	120	60	
Kashutl Inlet	KAS	8.5	0.95	110	225	none	4
Tahsish Inlet	TAHH	15	0.9	185	265	60	
Amai Inlet	AMA	5.5	0.55	105	215	none	
Port Eliza	ELI	6	0.35	50	60	38	
Espinosa Inlet	ESP	7.5	0.7	215	275	220	
Zeballos Inlet	ZEB	16	0.95	195	240	28	5
Nuchalitz Inlet	NUC	8	0.7	25	75	10	
Tahsis Inlet	TAH	21	0.65	135	210	50	6
Tlupana Inlet	TLU	10	0.8	200	265	180	7
Muchalat Inlet	MUC	26	0.8	220	385	50	8
Sydney Inlet	SYD	11	0.7	80	140	24	9
Shelter Inlet	SHE	10	0.7	115	175	24	9,10
Herbert Inlet	HER	12.5	1.1	100	150	8	
Bedwell Sound	BED	18	1.0	50	90	12	11
Tofino Inlet	TOF	21	0.75	70	150	12	12
Pipestem Inlet	PIP	5	0.4	45	70	34	
Effingham Inlet	EFF	9	0.65	95	205	56	
Alberni Inlet	ALB	37	0.7	145	365	88	13
Nitinat Lake	NIT	12.5	0.6	140	205	2	14

Notes to Table 1:

1. All depths are measured relative to chart datum at lowest normal tides: extreme tides may increase the values by 5 m.
2. Holberg and Rupert taken to Quatsino Sound.
3. Neroutsos with continuation along Quatsino Sound.
4. Kashutl taken to junctions with Tahsish.
5. Zeballos with continuation along Esperanza.
6. Tahsis with continuation along Cook Channel to Nootka Sound. Inner sill of 57 m at Tsowwin Narrows in Tahsis.
7. To junction with Tahsis.
8. Muchalat with continuation along Zuciarte Channel to Nootka Sound. Inner sill of 91 m depth in Muchalat.
9. Sydney and Shelter are connected by Millar Channel and Hayden Passage, the sill depth of which is 35 m.
10. To junction with Sydney, sill depth as for Sydney.
11. Bedwell and continuation along Father Charles Channel.
12. Tofino and Fortune Channel to junction with Bedwell. Inner sills of 24 m between Bedwell and Fortune, and of 33 m between Fortune and Tofino.
13. Alberni and continuation along Imperial Eagle Channel: mean width stated only for Alberni proper. Inner sill of 37 m depth at Sproat Narrows.
14. Nitinat Lake has a shallow entrance about 1.5 miles long with several sills. The outer bar is 2 m deep and three inner sills are about 3 m deep (at lowest normal tides). Depths in Nitinat were taken from a bathymetric chart prepared by Dr. T. G. Northcote, Institute of Fisheries, University of British Columbia, from his thirteen echo-sounder cross-sections.

1. Sea Level Atmospheric Pressure Systems and Winds

A general description of the semi-permanent large-scale atmospheric pressure systems that govern the oceanic wind regimes off the Pacific coast can be found in Favorite et al. (1976) and Thomson (1981). The Aleutian low pressure system, which is evident year-around (except in July), generally increases in intensity from August until January; from August to December its center moves southeastward from the northern Bering Sea to the Gulf of Alaska, but shifts abruptly to the western Aleutian Islands in January, after which the system progressively weakens until it is no longer evident in July (Fig. 2). The eastern Pacific high pressure system, which is present year-around off the coasts of California and Baja California, reaches maximum intensity during June-August, at which time it encompasses the whole or most of the Gulf of Alaska. The combined pressure patterns produced by these two systems result in predominantly southeast to southwest winds from late August to early spring along the British Columbia coast as air circulates anticlockwise around the dominant Aleutian Low. From May through September, the combined effect of a greatly weakened Aleutian Low and an intensified Pacific High results in a clockwise flow over the ocean. Winds at this time are predominantly from the northwest along the British Columbia coast.

The prevailing winds off the west coast of Vancouver Island are considerably stronger in winter than in summer; average wind speed in winter (January) is 33 km/hr (17.9 knots) from the southeast, and in summer (July) is 25.6 km/hr (13.8 knots) from the northwest. Within 45 km (24 M) of the coast, wind speeds exceed 40 km/hr (25 mi/hr) between 10 and 15% of the time during winter, but only 5% of the time during summer (Faulkner and Schaefer 1978).

The variability in synoptic weather patterns and associated wind conditions for the Pacific northwest is clearly evident from the classification of synoptic weather patterns in the 731 daily surface weather maps for 1964-65 (Maunder 1968). He identified seven anticyclonic (highs) weather patterns (Fig. 3), nine cyclonic (lows) weather patterns (Fig. 4), and one miscellaneous weather pattern (not presented) as being significantly different; 54% were a low pressure pattern, 38% a high pressure pattern, and 8% a miscellaneous pattern. A summary of the daily occurrence by month and the percentage days in midseason months is provided in Tables 2 and 3, respectively. Some of his observations are noted in the following.

The first 4 high pressure patterns, all dominated by the North Pacific High, were accompanied by northwesterly flow of air over Vancouver Island (Fig. 4); these patterns occurred 28% of the time. Pressure pattern H-5 was accompanied by a southwest flow, and was usually associated with a low pressure system in the Gulf of Alaska, but only 2% were of this type. H-6 and H-7 were associated with high pressure systems over land; H-6 was accompanied by southerly flow and H-7 by easterly flow over Vancouver Island. Both types occurred 7% of the time.

Two main classifications in the low pressure patterns were considered, those with low pressure centres near Vancouver Island (L-1 - L-5) and those with centres generally well to the northwest in the Gulf of Alaska (L-6 - L-9) (Fig. 3). Patterns L-1 and L-4 produced air flows from the south, generally southwesterly with L-1, and south to southeasterly with L-4. L-1 was the most frequent of the 16 patterns, 10% of all days and 18% of all low

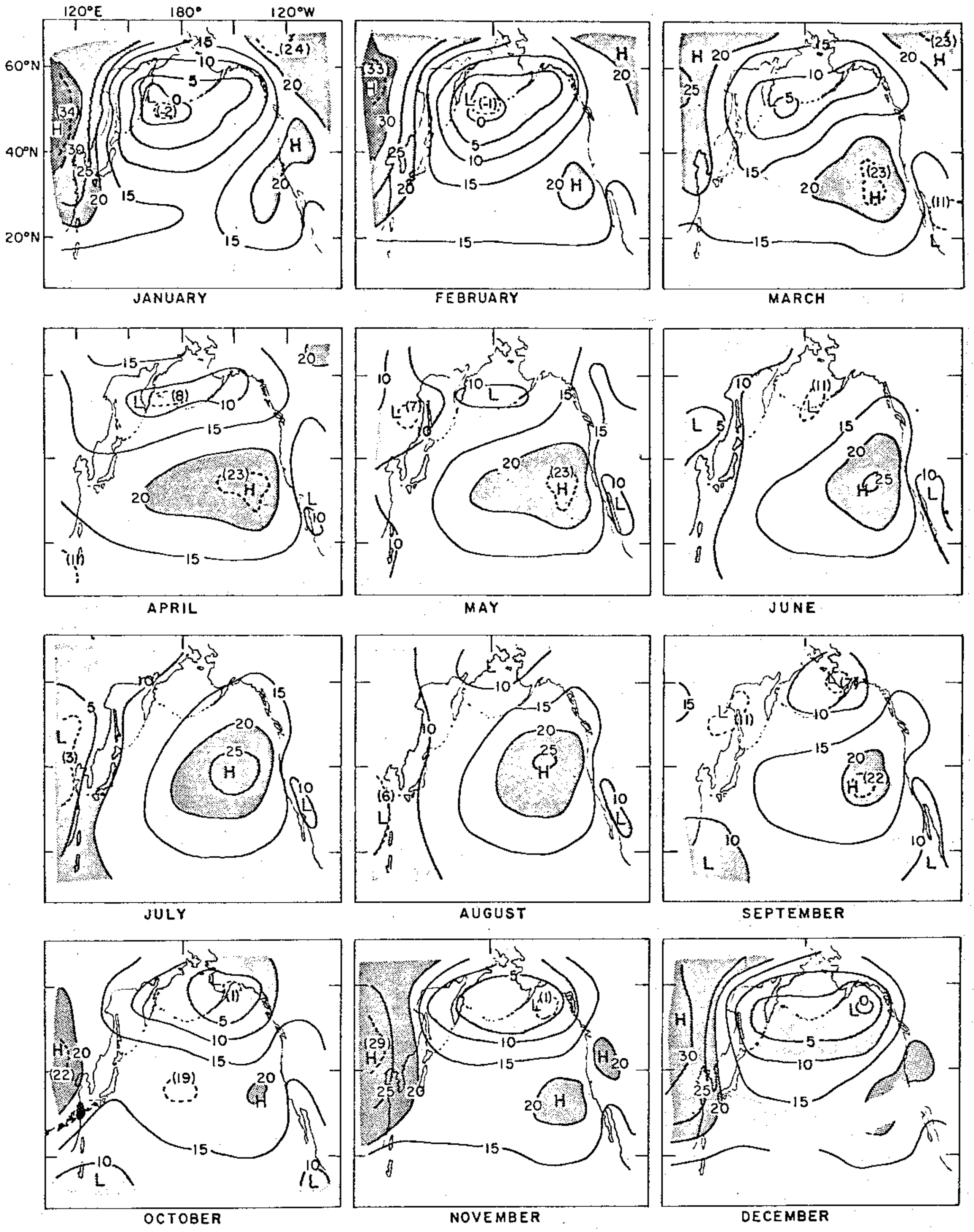

Fig. 2. Monthly mean air pressure at sea level (value +10,000)/10=mb (based on U.S. National Climatic Centre, Tape Data Family - 11; 1951-70) (from Favorite et al. 1976).

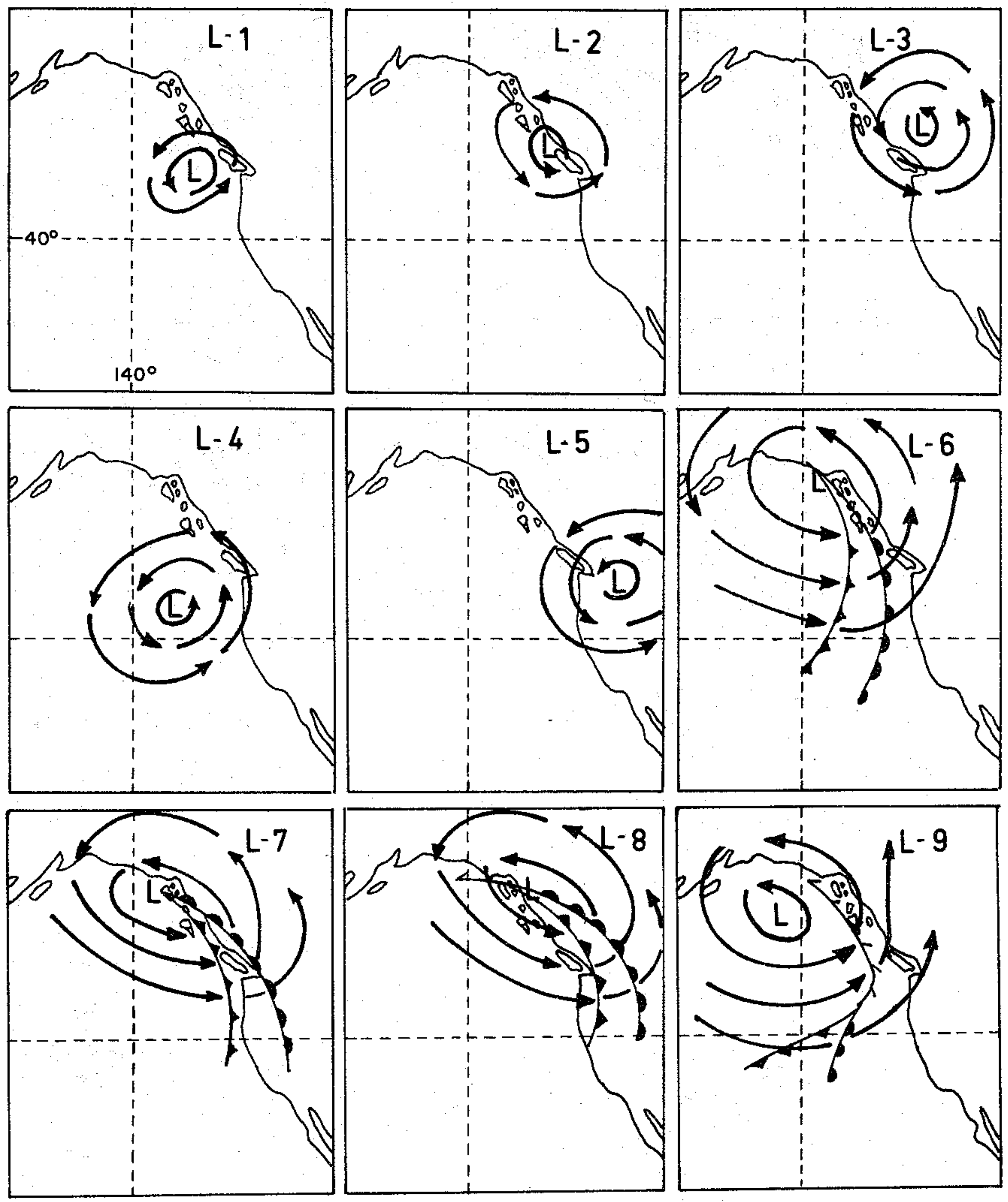

Fig. 3. Classification of daily low pressure patterns occurring in 1964-65 (after Maunder 1968).

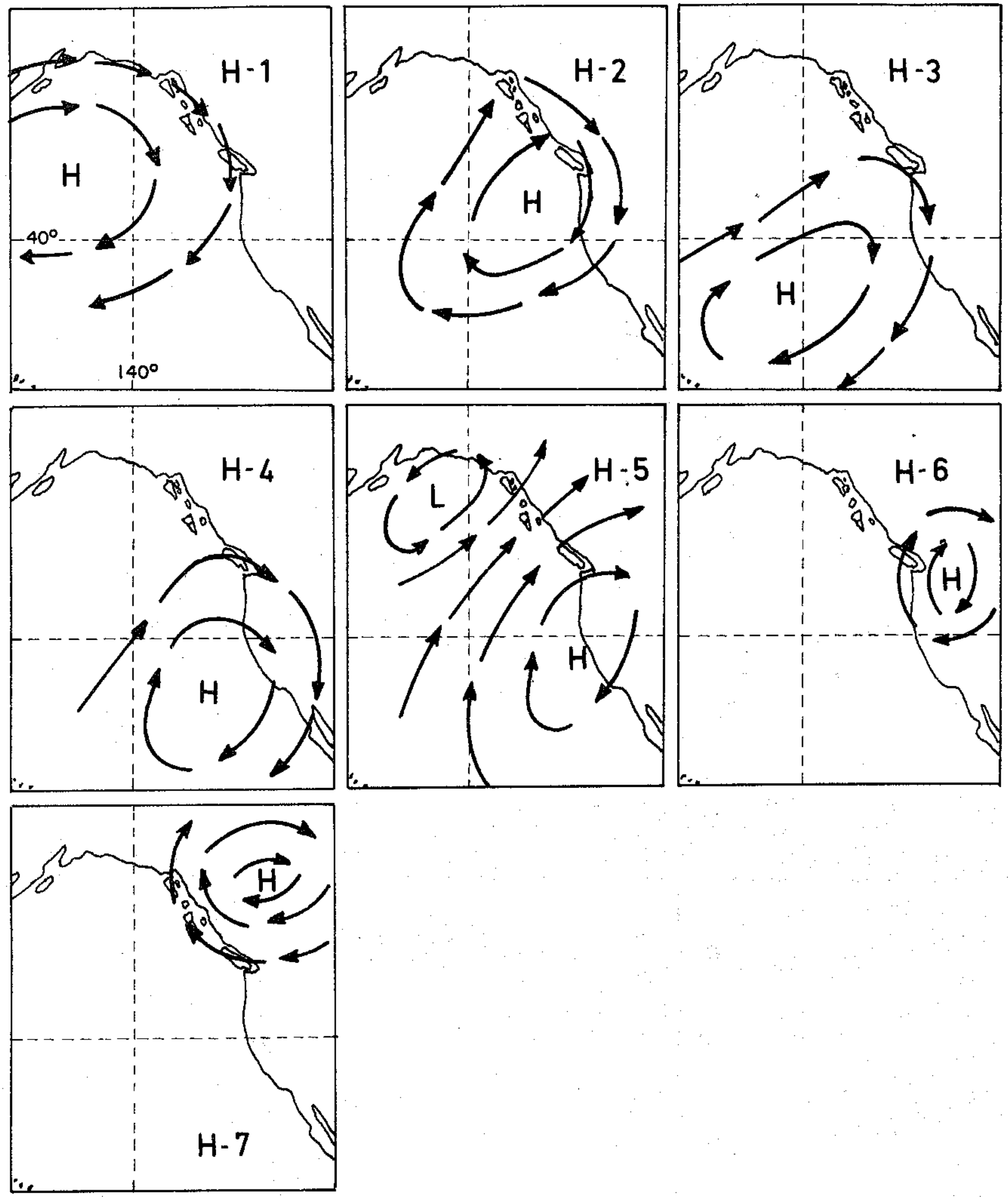

Fig. 4. Classification of daily high pressure patterns occurring in 1964-65 (after Maunder 1968).

Table 2. Number of days with various synoptic weather patterns[1] (from Maunder 1968).

	Month												
Weather pattern	J	F	M	A	M	J	J	A	S	O	N	D	Year
H1 + H2 + H3 + H4	2	20	15	11	25	29	31	27	28	8	4	6	206
H5	4	7	0	2	0	0	0	0	3	1	0	0	17
H6 + H7	8	3	6	0	1	1	1	2	5	11	6	8	52
All high pressure patterns	14	30	21	13	26	30	32	29	36	20	10	14	275
L1 + L4	10	3	7	8	3	5	0	3	1	6	16	11	90
L2	5	1	1	2	4	1	4	1	3	0	3	7	32
L3 + L5	2	3	14	10	4	5	4	9	8	1	6	3	69
L6 + L7 + L8 + L9	27	19	14	24	13	8	10	10	9	27	20	26	207
All low pressure patterns	44	26	36	44	28	20	23	27	21	37	45	47	398
Miscellaneous patterns	4	1	5	3	8	10	7	6	3	5	5	1	58
Totals	62	57	62	60	62	60	62	62	60	62	60	62	731

[1] In 1964 and 1965.

Table 3. Percentage of days in midseason months with selected synoptic weather patterns[1] (from Maunder 1968).

January		April		July		October	
All lows	72	All lows	62	All highs	51	All lows	60
L6+L7+L8+L9	44	L6+L7+L8+L9	40	H1+H2+H3+H4	49	L6+L7+L8+L9	43
L9	23	All highs	21	All lows	36	All highs	33
All highs	22	H1+H2+H3+H4	18	H1+H2	30	H6+H7	18
L1+L2	19	L1+L2	18	H1	19	H1+H2+H3	13
H5+H6	17	L3+L5	16	L6+L9	16	L1	13

[1] In 1964 and 1965.

pressure days. By contrast, only 5% of low pressure days were of type L-4. Type L-2 was accompanied by variable air flows, 4% of the total period. Types L-3 and L-5 were generally accompanied by northerly-northwesterly flow and northerly-northeasterly flow, respectively, over Vancouver Island. These were 17% of the low pressure patterns. L-6 to L-9 were associated with a large and extensive pressure area in the Gulf of Alaska, with accompanying frontal systems in the vicinity of Vancouver Island; L-6 and L-7 were accompanied with westerly flows over Vancouver Island, L-8 with westerly or northwesterly flow, and L-9 where the main frontal passage was in the form of an occlusion or trough of warm air aloft. These patterns occurred 28% of the time; 17% of all low pressure days were category L-6, 9% L-7, and 8% L-8.

The effects of these winds on the coastal circulation can be translated into a "surface" flow (Ekman transport) computed from surface wind stress. The onshore-offshore components of this transport and associated oceanographic conditions are reviewed in a later section.

2. Precipitation

Monthly and annual values of total precipitation and the long-term monthly and annual means and standard deviations for Amphitrite Point,1958-82 and Cape Scott, 1966-82 are presented in Appendix tables 1 and 2, respectively. Monthly and annual anomalies (monthly (annual) mean minus long-term monthly (annual) mean), and the numbers of standard deviations (arbitrarily reported to the nearest one tenth) in the anomalies are also provided (Appendix tables 3 and 4). The latter numbers provide a classification index to the anomalies, permitting a quick identification of significantly large variations in each of the monthly and annual anomalies. They also permit a simple examination for relationships to other parameters when presented in the same format, as has been done through this report. Tabata (1957) and Hollister (1964) used a similar approach for the classification of monthly anomalies of sea surface temperature and salinity at the coastal lightstations, except the classification index was based on integral multiples of the standard deviations. Large anomalies in the annual and monthly means of precipitation and for the periods of mid-autumn through early spring (October-March) and summer (June-August) are noted, similarly for the other time-series data that are presented.

Total precipitation varies markedly along the west coast of Vancouver Island. In the south (Amphitrite Point) the long-term annual mean precipitation approaches 3100 mm, whereas in the north (Cape Scott) annual precipitation is about 2800 mm (Appendix tables 1 and 2). The annual cycles at these locations show similar features: a maximum in December (Amphitrite Point), in November-December (Cape Scott), and a minimum in July (Fig. 5). The greatest variability occurs in mid-autumn through early spring (October-March) and the least in summer (June-August), as indicated by the magnitudes of the standard deviations. (In this report, the standard deviation is defined as the square root of the mean of the squares of the deviations from the long-term mean.)

Annual total precipitation at Amphitrite Point was highest in 1962, closely followed by 1961, then 1967 and 1968, during the period 1958-82

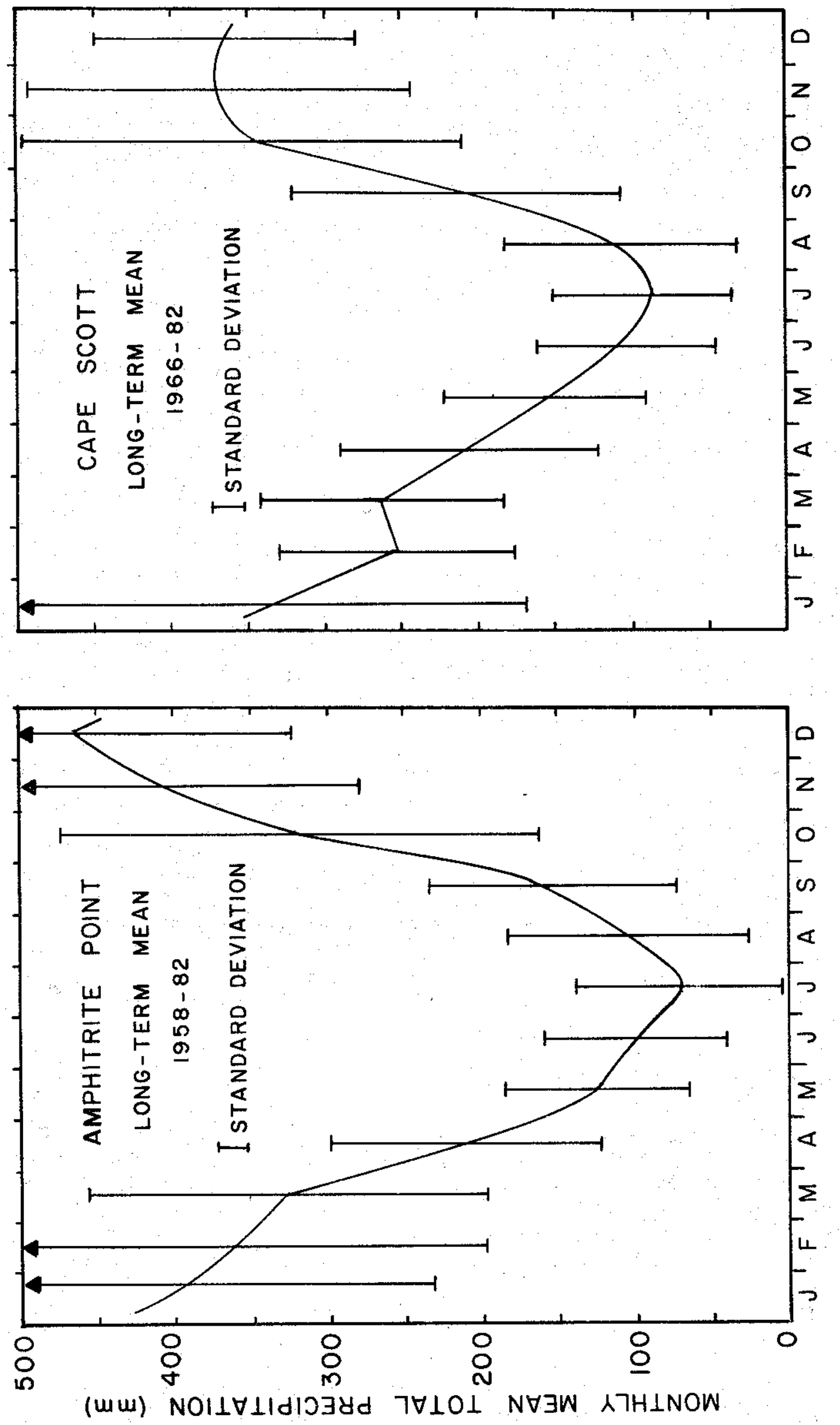

Fig. 5. Annual cycle of precipitation (mm), Amphitrite Point and Cape Scott, Vancouver Island.

(Appendix table 1). The driest year was 1970, followed by 1978, then 1958 and 1979.

Precipitation conditions during the 6-month mid-autumn-early-spring period (October-March) were generally above average (positive anomalies) in 1960-61 (but anomalously low in Dec), 1962 (Oct-Dec), 1963-64, 1965-66, 1966-67, 1967-68 (but anomalously low in Nov), 1973-74, 1975-76 and 1981-82 (Appendix table 3). On the other hand, precipitation was generally low (negative anomalies) during this period in 1959-60, 1961-62, 1964-65, 1969-70, 1974-75, 1976-77, 1978-79, 1979-80 and 1980-81 (but anomalously high in Nov, Dec).

The driest summer period (June-August) at Amphitrite Point occurred in 1958, with a total precipitation of 76 mm. Other relatively dry summers were 1965 (146 mm), 1967 (136 mm), 1970 (156 mm), and 1982 (181 mm). There were no summer periods during which precipitation was persistently anomalously high; the most significant positive anomaly occurred in July 1964, followed by June 1981.

During the 1958-82 period at Amphitrite Point, the most significant positive monthly anomalies (anomalously high precipitation) (based on an arbitrary classification of anomalies equal to or greater than 1.5 standard deviations as being highly significant in these data) occurred in May 1960, February 1961, April, August, November 1962, July, September 1964, October 1965, December 1966, January, October 1967, March, July 1972, January, May, June 1973, February, May 1974, August, October 1975, May 1977, August 1978, September, December 1980, April, June 1981, and February 1982 (Appendix table 3). On the other hand, the most significant negative monthly anomalies (anomalously low precipitation) ($\geq$ 1.5 standard deviations) occurred in December 1960, January 1963, December 1964, March 1965, February 1970, October 1972, April 1973, September 1975, and November 1976.

Generally, precipitation anomalies at Cape Scott paralleled those at Amphitrite Point, although the index values were sometimes very different or opposite in sign (Appendix table 4), indicating that precipitation along the west coast of Vancouver Island is variable.

3. Runoff

The monthly and annual mean discharges and the long-term monthly and annual means and standard deviations for the Somass-Stamp River system are presented in Appendix table 5. Monthly and annual discharge anomalies and the number of standard deviations in the anomalies are presented in Appendix table 6.

The runoff characteristics for most of the rivers contributing freshwater to the west coast inlets of Vancouver Island and the continental shelf waters have been described generally as a large runoff from October to June with a peak in December, falling from July to September to one-fifth to one-tenth of the winter rate with a minimum in August or September (Pickard 1963). Rivers such as the Gold and Stamp rivers, because they drain at relatively high levels, receive snow-melt resulting in a second maximum in May. These features are reflected in the annual runoff cycle of the

Somass-Stamp River system (Fig. 6), as an example, which flows into Alberni Inlet (Fig. 1). The large year-to-year variations in the monthly means of runoff are indicated by the standard deviations, with the greatest variability generally occurring in the October-March period, similar to that of precipitation.

The highest annual mean discharge occurred in 1968, followed by 1958 and and 1966, 1974, 1963 and 1975. The lowest annual discharge occurred in 1978, followed by 1976, 1965, 1964, 1959 and 1977, and 1979.

Runoff within the October-March period was relatively large in 1961 (Jan-Mar), 1962-63, 1963-64, 1965-1966, 1967-68, 1980-81 and 1981-82. However, runoff was generally low in 1959-60, 1964-65, 1970-71, 1974-75, 1976-77 and 1978-79.

Runoff was persistently large in the summers (June-August) of, 1964, 1971, 1974, 1976, and small in the summers of, 1958, 1963, 1965, 1970, 1977 and 1981.

Monthly runoff was well above average (based on the number of standard deviations in the anomalies, $\geq$ 1.5) in Feb, Dec 1958, May 1959, Apr 1960, Jan, Feb 1961, Feb 1963, Jul 1964, Dec 1966, Oct 1967, Jan, Oct 1968, Sep 1969, May, Jul, Aug 1971, Mar 1972, Apr, Jun, Jul, Aug 1974, Nov 1975, Sep 1978, Sep 1979, Dec 1980 and Nov 1981. Comparable negative anomalies (below-average runoff) were relatively few, in Aug 1958, Mar 1962 and Dec 1971.

Annual and monthly anomalies in precipitation at Amphitrite Point and in runoff of the Somass-Stamp River system generally follow similar patterns in the majority of the anomalies. However, there are some marked discrepancies, some of which are explainable. Heavy rainfall near the end of a month will, in part, be reflected in discharge in the following month. During winter, a time lag of several months may occur between precipitation and its effect on river discharge, as occurs when precipitation falls as snow and does not thaw until spring. Also, both the Stamp and Somass discharges are controlled, so that there can be a quenching of extremes of runoffs.

IV. HISTORY OF PHYSICAL OCEANOGRAPHIC RESEARCH

In this section, a brief narrative of the major physical oceanographic research programs conducted on the continental shelf and slope waters off the west coast of Vancouver Island to the end of 1978 is provided. The choice of 1978 as the cutoff date for this report was not completely arbitrary. In 1979, there was again a major expansion in physical and biological research of the continental shelf and upper slope waters off the west coast of Vancouver Island and of other British Columbia continental shelf waters. The collection of continuous current data at selected depths and many locations to define the current structure and mechanisms for these waters continues to be a major undertaking. The effort directed to the further development of other techniques for the collection and analysis of data, e.g. ships-of-opportunity, satellite imagery has also increased substantially. Also, prior to 1979, regular large-scale quasi-synoptic surveys were the major

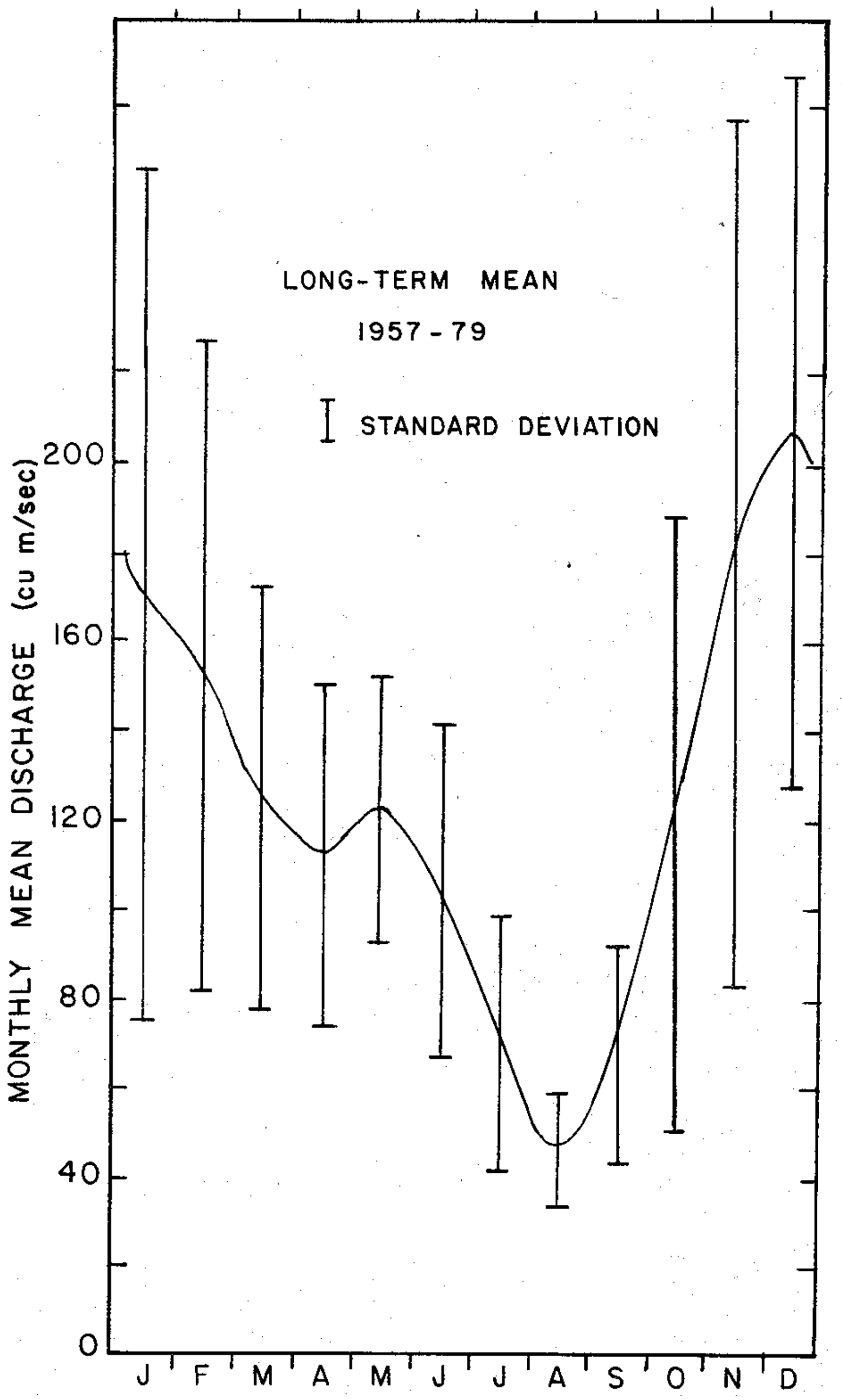

Fig. 6. Annual cycle of runoff (cu m/sec) of the Somass - Stamp River system.

undertakings; whereas considerable effort is now being directed to process-oriented studies which are usually confined to relatively small and specific geographic areas over time periods of 12-18 months. Some of these recent research programs are briefly noted, and others are referenced in other sections of the report.

Physical oceanographic research on these waters dates back more than half a century. The first major study provided a description of the tidal and nontidal flows at several lightship stations off the Pacific coast, one of which was Swiftsure lightship station located near the seaward entrance to Juan de Fuca Strait (Fig. 1) (Marmer 1926). In 1927, further studies of the surface flow of the shelf waters was undertaken by salmon investigators of the Biological Station, Nanaimo, B.C. by the release of drift bottles off the southwest coast of Vancouver Island (Waldichuk 1963). This was followed by drift bottle releases in the adjacent oceanic waters in 1931 and 1932 by investigators of the International Fisheries Commission. The latter returns provided information on the surface transport of the oceanic waters onto the continental shelf, and the seasonal latitudinal shift in the division of these waters (Thompson and Van Cleve 1936).

In the early 1930's, Canadian oceanographers initiated studies of these waters. In 1933 and 1936-38, quasi-synoptic oceanographic surveys were undertaken, with the major emphasis on the shelf waters off the southwest coast of Vancouver Island. The data, except those for 1933, are available in Pacific Oceanographic Group (1950, 1956) and Scripps Institution of Oceanography (1961). From analyses of these data, Tully (1938, 1942) provided major contributions to the physical oceanography of these waters. Also, in 1934, the number of shore stations was increased at which daily observations of sea surface temperature and salinity were being made by establishing the program at Amphitrite Point and Nootka lightstations, and in 1935 at Kains Island (Fig. 1). Observations at Nootka were subsequently discontinued in 1953, but have been maintained at the other two stations. The daily data continue to be published regularly (e.g. Giovando 1980) and a summary of monthly and annual means and standard deviations through 1970 is available in Hollister and Sandnes (1972). Webster and Farmer (1976) and Associated Engineering Services Ltd. (1977) have reported on results of analyses of data from these and other lightstations.

Because facilities were diverted to naval purposes from 1943 to 1947, and later, initiation of studies directed primarily to the oceanic waters (Doe 1955), participation in NORPAC in 1955 (Dodimead 1956, Bennett 1959), followed by similar extensive surveys of the eastern Subarctic Pacific Region in support of the research programs of the International North Pacific Fisheries Commission (Dodimead et al. 1963, Uda 1963, Favorite et al. 1976), and expansions of the oceanographic programs at Ocean Station P (lat. 50°N, long. 145°W) in 1956 (Tabata 1961, 1965), and along Line P in 1959 (Fofonoff and Tabata 1966), little effort was expended in the coastal waters, except as extensions of some of the above programs. A monitoring program was established, however, at the Swiftsure lightship station in 1954. Semi-daily bathythermograph casts to 45 m depth, sea surface temperature and meteorlogical observations, and daily surface salinity observations were made until 1961, when the lightship was discontinued. The program also included similar observations at the Umatilla lightship station, 1954-59 (Fig. 1). These data are published in Pacific Oceanographic Group (1958a, b, 1959) and in Hollister (1960, 1961). A summary of conditions has also been provided (Hollister 1966). These are the only lengthy and available time-series data reflecting the variability in the temperature structure and the bottom-water temperatures on the inner continental shelf, at least to 1979.

A major expansion in Canadian oceanographic programs occurred in 1957 with the initiation of regular surveys of the continental shelf and oceanic waters off the coast of British Columbia. In all, 20 cruises that included the waters adjacent to the west coast of Vancouver Island were made to March 1962 (see Data Sources, 1957-62). Lane (1962, 1963) analysed these data to provide a review of the temperature and salinity features, and to identify the major seasonal features and ranges in the temperature and salinity structures in relation to the large-scale processes of wind, precipitation and insolation.

During the next five years, most of the Canadian effort was again directed to the oceanic waters of the Subarctic Pacific and to other coastal areas of British. Two United States cruises which covered the area within about 200 km (108 M) of the coasts of Washington and Vancouver Island, however, were made in spring and autumn, 1963, providing information on the seasonal and spatial variability in water properties, and on the northward extension of the California Undercurrent along the continental slope of Washington and Vancouver Island (Ingraham 1967).

In 1967, the author initiated a program to study the physical, chemical and biological features of the continental shelf and oceanic waters generally extending to about 370 km (200 M) off the British Columbia coast. Seven cruises were made, 3 in autumn (September- October) and 4 in early spring (March-April) during 1967-71. A salinity-temperature-depth (STD) system was used on these cruises. A less extensive survey was made in March 1969, using standard (non-STD) oceanographic equipment. Although these data have not been published, some have been presented in the Annual Reports of the International North Pacific Fisheries Commission (INPFC 1969-73), in Favorite et al. (1976), in Dodimead (1980) and in this report. A more complete analysis of the 1967-71 data is currently in progress. In 1967, temperature, current and meteorlogical observations were initiated from the drilling rig SEDCO 135F (Southeast Drilling Company) on contract to Shell Canada Ltd., when it was in operation on the continental shelf off the coast of British Columbia. The observations were continued until May 1969, at which time drilling operations were concluded in this area, However, these data have not been completely analyzed or published as yet (Herlinveaux, pers. comm.). These latter projects were essentially the last major projects to be undertaken in these waters by the Pacific Oceanographic Group (officially established as a unit of the Fisheries Research Board of Canada in 1946) with the transfer, in 1970, of oceanographic activities and personnel to another federal agency.

In September 1973, personnel of the Pacific Marine Environmental Laboratory, NOAA, Seattle, WA undertook a survey of the contintental slope and oceanic waters off the coasts of Washington and Vancouver Island to lat. 49°N, with the main emphasis on identification of the California Undercurrent (Reed and Halpern 1976). The first Canadian program under the newly established agency included continuous current observations at two locations on the continental shelf west of Tofino, B.C. (Fig. 1) in November 1974-April 1975

(Huyer et al. 1976). Then in August-September 1977, an extensive United States-Poland fishing and oceanographic survey was undertaken along the west coast of Vancouver Island from California to lat. 50°N off the west coast of Vancouver Island (Ingraham and Love 1978).

Other physical oceanographic data collected over the past several years include temperature profiles (mechanical and expendable bathythermograms) during fisheries research surveys conducted by the Pacific Biological Station, Nanaimo, B.C. These data are now more accessible, as they have been collated and archived in Marine Environmental Data Service, Fisheries and Oceans, Ottawa. Some of the recent data have also been reported (Ballantyne 1978, Douglas and Wickett 1978, Dodimead et al. 1979a, b, Dodimead and Ballantyne 1980). The 1980-81 data and a description of conditions are now published (Dodimead and Ballantyne, 1984).

V. REVIEW OF PHYSICAL OCEANOGRAPHIC STUDIES, 1926-1978

Fairly comprehensive reviews of most research studies pertaining to structure and flow characteristics and their seasonal and annual variability of the continental shelf and slope waters off the west coast of Vancouver Island, and published during the period 1926-78, are provided in this section. Other relevant studies during this 53-year period are noted in other sections of the report.

Marmer (1926) reported that surface tidal currents at Swiftsure lightship station (Fig. 1) were rotary, with a minimum velocity of 0.33 knots (17 cm/sec), and a velocity at strength of 0.75 knots (38.6 cm/sec), on average. The direction of rotation was clockwise, strength of flood setting southeasterly and strength of ebb northwesterly. The nontidal current averaged 0.47 knots(24.2 cm/sec), setting 316°, or almost due northwest. The velocity of the nontidal current appeared to be greatest during the autumn and winter months, and was attributed to the prevailing winds, from the east during autumn and winter, and from the west or southwest during spring and summer.

A major study of the dynamics of the waters off southwest Vancouver Island was made by Tully (1942). He concluded that the nontidal surface flow in the western approach to Juan de Fuca Strait represented a balance between a wake stream from the Strait, which is directly related to the volume of land runoff, and the independent wind-driven currents, which in turn are due to the prevailing local coastal winds. He noted that the wake stream from Juan de Fuca Strait must veer right after leaving the Strait and approach the Vancouver Island shore. During this travel, it absorbs water from seaward and ejects it in the form of eddies along the shore, dissipating its energies and becoming broader in the process. Since the wind-driven currents set usually either northwestward or southeastward, they act with (southerly winds) or against (northerly winds) the wake stream. The force of either current may vary, and depending on the dynamic balance, a wide variety of current trajectories may result within the two types of circulation. He presented dynamic fields and descriptions of four typical states and the causative factors.

The first is for a typical winter condition; -land drainage is at a minimum and prevailing winds are moderate southeast to easterly. The resulting current shows no evidence of wake stream influence since the flow from Juan de Fuca Strait is too small to be effective (Fig. 7). A series of eddies develop between the main current and the shore which represents the water transported across the current. There is no countercurrent under these conditions, at least not within the limits of the survey.

The second is for an early summer period; -land drainage is at a maximum and winds are atypical, moderate southeast to easterly. The wake stream has maximum force, and the drift current is very small (Fig. 8). The well-developed wake stream from the Strait veers to the right around Swiftsure Bank to Cape Beale where it encounters the land-drainage waters from Barkley Sound. A countercurrent is clearly indicated by the southward flow of the offshore waters against the wind. Between these currents, there occurs an area of maximum density indicating a zone of upwelling.

The third condition is for typical spring conditions; -runoff is less than average and the northwesterly winds are well established. The wake stream is overpowered before it reaches Swiftsure Bank, and a very rapid circulation is set up around a well-developed centre of upwelling (Fig. 9).

The fourth condition is for similar northwesterly winds, but land drainage is greater than average. The wake stream is much stronger than in the previous examples, persisting as far as Barkley Sound where it is regenerated by the land-drainage waters from that area (Fig. 10). The zone of upwelling shifts seaward, and the velocity around the eddy is not so rapid. The return current is of the same magnitude as the wake stream.

These examples indicate that during southeast winds, the flow is wide, continuous and northward paralleling the Vancouver Island coast. A large eddy may form between the seaward side of the wake stream and the countercurrent, if land drainage is at a maximum and the wind force is small, but the velocity of the countercurrent is never as great as that of the wake stream. During northwesterly winds, a large cyclonic eddy is formed, owing to the reaction of the wake stream and the drift current; the velocities on all sides of the eddy are similar in magnitude. With increasing strength of flow from the Strait, the resultant current flows further and further to seaward before veering to the right. When the wake stream is at a minimum, the current follows the Vancouver Island coast closely; when it is at a maximum, the wake stream passes well to the westward of Swiftsure Bank and eddies arise between the stream and the shore. When the stream is opposed by the wind, the centre of the characteristic cyclonic eddy shifts further seaward as the strength of the stream increases.

Studies of this area since 1978 have confirmed the existence of the wake stream and the area of upwelling, and have shown high primary productivity associated with the gyre (Borstad and Louttit 1980, Freeland and Denman 1982). However, an alternate mechanism for the upwelling has been given; it is attributed to the effect of irregular topography of the Juan de Fuca Canyon on the flow of the California Undercurrent along the continental slope (Freeland and Denman 1982).

Waldichuk (1963) also reported on the surface current features for

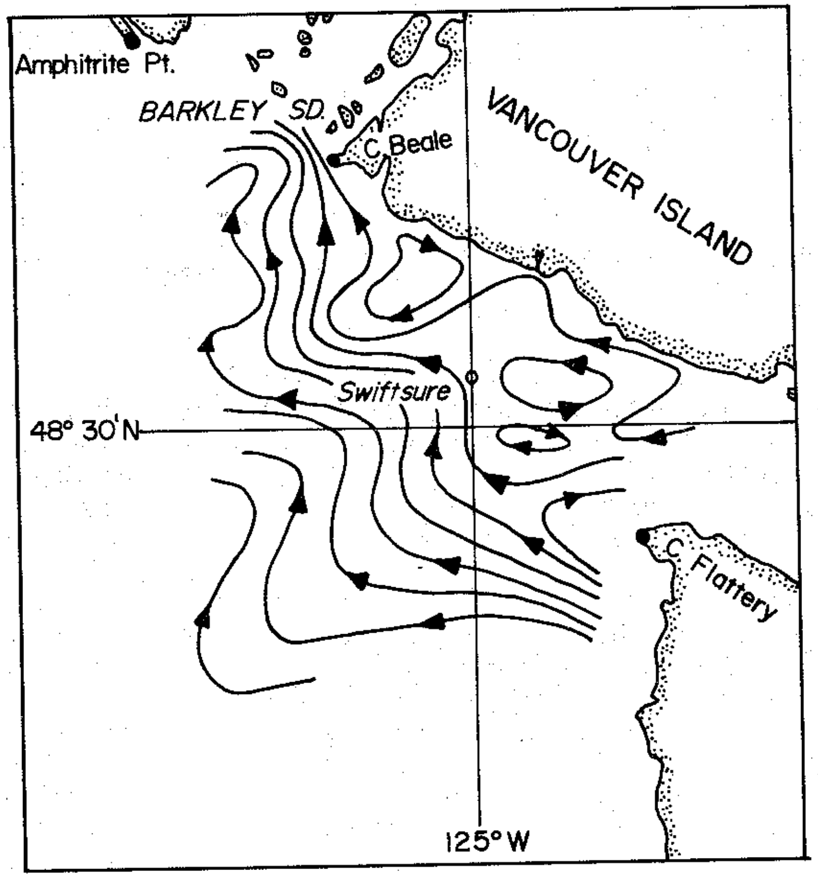

Fig. 7. Surface circulation off the southwest coast of Vancouver Island in winter during a period of small runoff and moderate southeast to easterly winds. Arrows indicate direction of flow (adapted from Tully 1942).

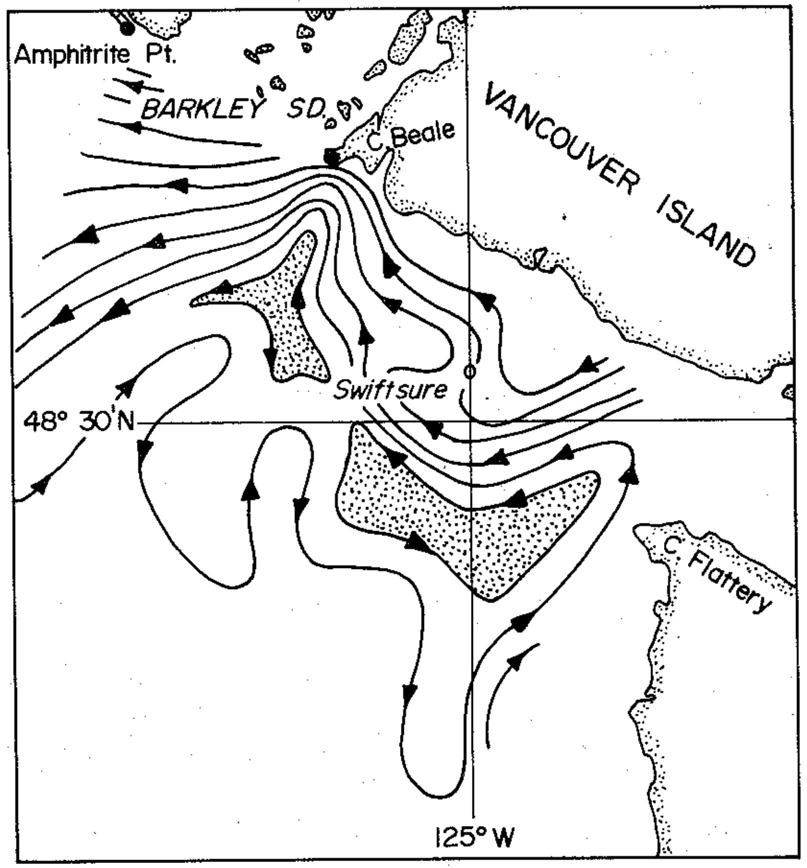

Fig. 8. Surface circulation off the southwest coast of Vancouver Island in early summer during a period of maximum runoff and moderate southeast to easterly winds. Arrows indicate direction of flow and stipling denotes areas of upwelling (adapted from Tully 1942).

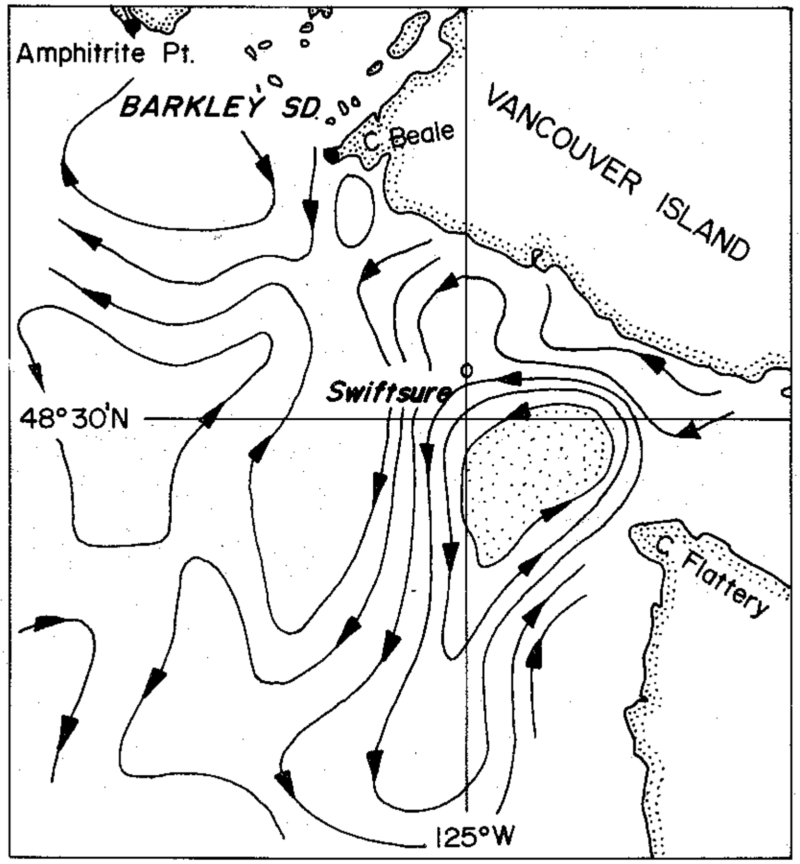

Fig. 9. Surface circulation off the southwest coast of Vancouver Island in spring during a period of average runoff and moderate westerly winds. Arrows indicate direction of flow and stipled area denotes upwelling (adapted from Tully 1942).

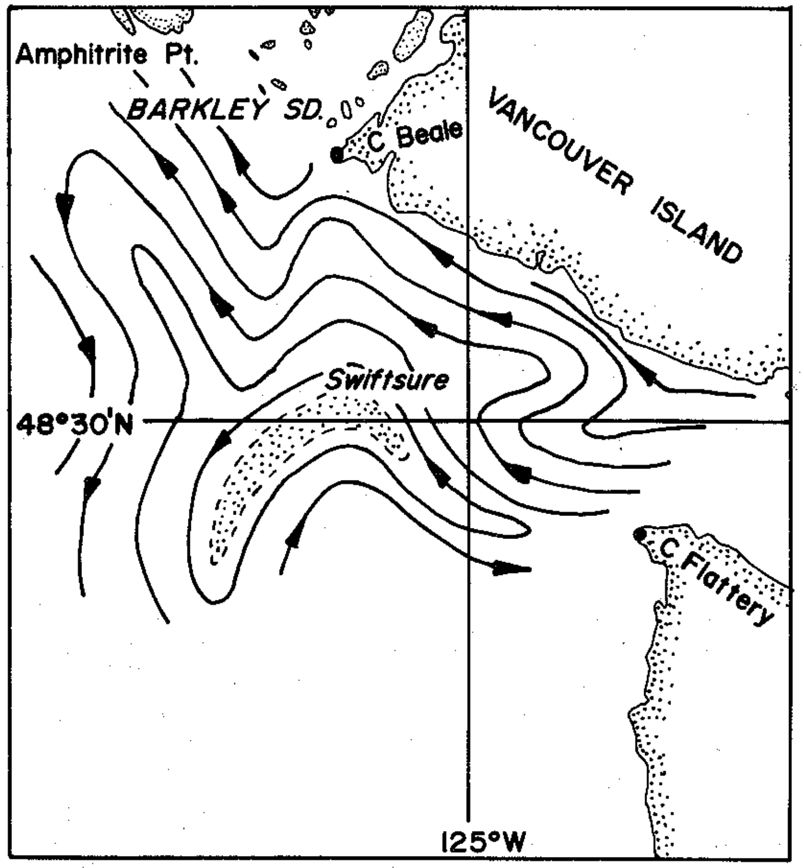

Fig. 10. Surface circulation off the southwest coast of Vancouver Island in late summer during a period of greater than average runoff and fresh northwesterly winds. Arrows indicate direction of flow and stipled area denotes upwelling (adapted from Tully 1942).

this area as deduced from drift bottle releases: (1) a marked northwestward drift for bottles released within 20 miles (37 km) of shore; (2) a southwestward drift toward the State of Washington at distances greater than 20 miles from shore (Fig. 11 and 12). He noted that these features were consistent with those reported by Tully (1942) for this area.

Major studies of the vertical structure and variability of these waters were reported by Lane (1962, 1963). In the first paper, he reviewed the available oceanographic and meteorological data and identified features in the vertical and horizontal structures of temperature and salinity and associated meteorological conditions. He noted that, although coastwise continuity in the vertical and horizontal structures of temperature and salinity is real, there is considerable variation in short distances and short times, which complicate and frequently negate the basic trend. In addition, short-term variations are often as great or greater than the seasonal or interannual variations. In the second report, Lane (1963) selected on an area seaward of Amphitrite Point (Fig. 13) in which there were adequate data to define the gross seasonal states. He identified 5 stages of seawater structure in the temperature and salinity data, which were related to the seasonal variations in runoff, heating and cooling, and winds. These were considered to be the prime factors determining the seasonal character of these waters.

It is noted here that the mechanisms associated with convergent, divergent and relaxation conditions that are referred to by Lane (1963) are reviewed in a later section.

Stage 1 (December through March) is generally a period of strong southeast winds, minimum insolation, maximum cooling and maximum runoff from local precipitation. The strong southeast winds lead to a condition of convergence and vertical mixing. These, coupled with cooling, lead to a relatively narrow, accelerated northward flow of cool, well-mixed and brackish water along the coast. The relative intensities of wind and discharge determine the width of the brackish coastal belt.

During this stage, the oceanic upper zone (OU) is 50-70 m thick with a characteristic salinity range of 32.2-32.6°/oo in the slope region (Fig. 14). The oceanic halocline (OH) extends to about 200 m depth. At this limit, the salinity is 33.8-33.9°/oo. Below the halocline, the salinity of the oceanic lower zone (OL) increases slightly towards the bottom. The outer continental shelf is normally a transition region containing a modified coastal upper zone (mCU) and a modified coastal halocline (mCH) extending to the bottom (Plot II, Fig. 14). The salinity is 31-32°/oo in the upper zone, and increases in the halocline to 32.2-32.6°/oo. At times, low-salinity coastal water occurs in the oceanic upper zone over the continental slope, a condition attributed to infrequent periods of offshore surface flow created by northwesterly winds (divergence). Also, the oceanic upper zone may intrude over the continental shelf because of strong convergence when southerly winds are strong. When this occurs, the water over the continental shelf becomes homogeneous.

Stage 1 temperatures are low (Fig. 14). Inshore stability inhibits mixing over the continental shelf so that temperatures usually decrease shoreward. In the outer shelf and slope area, there is an isothermal upper zone, more than 50 m thick, coincident with the salinity oceanic upper zone

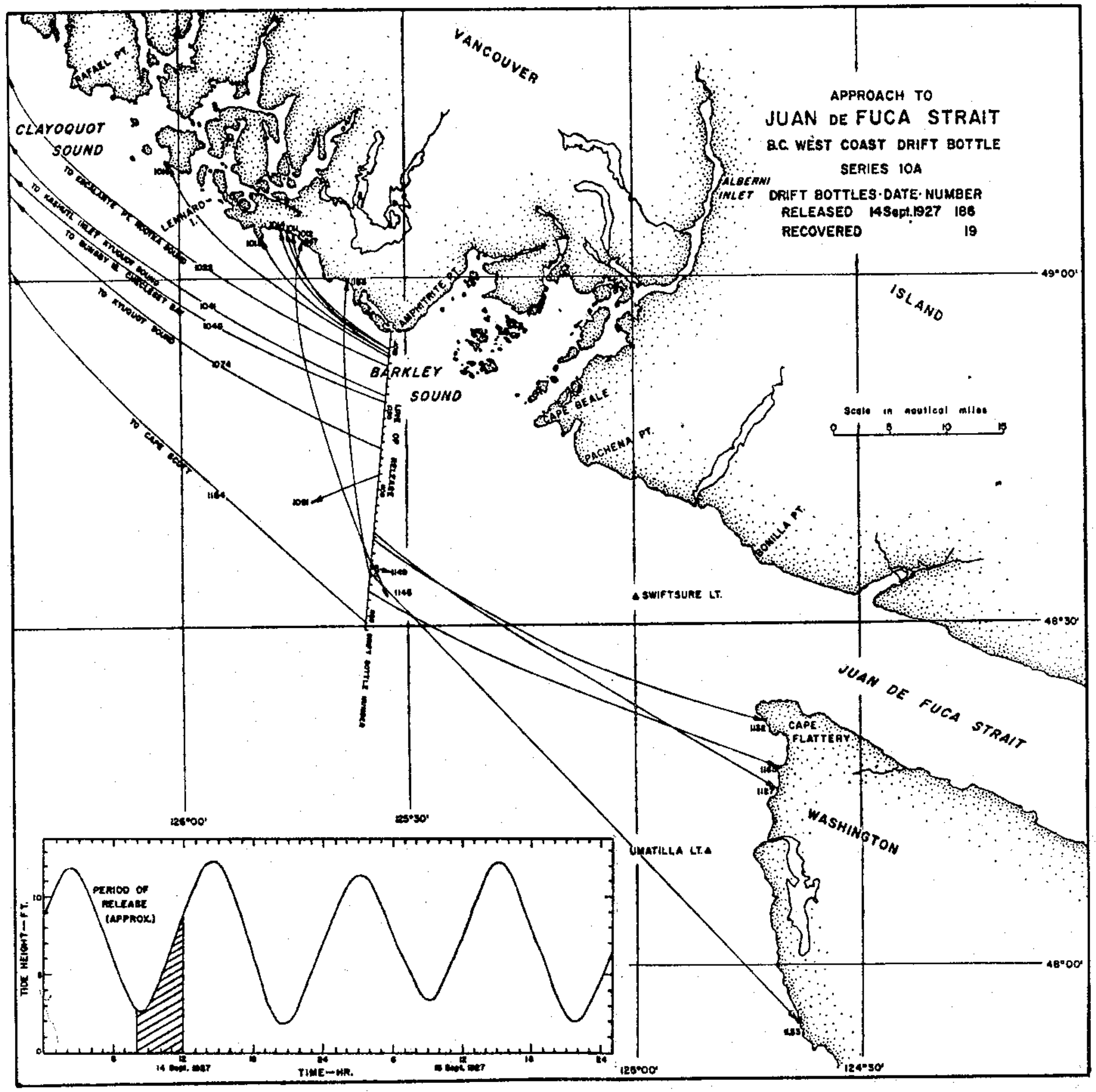

Fig. 11. Drift bottle releases and returns off the southwest coast of Vancouver Island, September 14, 1927 (from Waldichuk 1963).

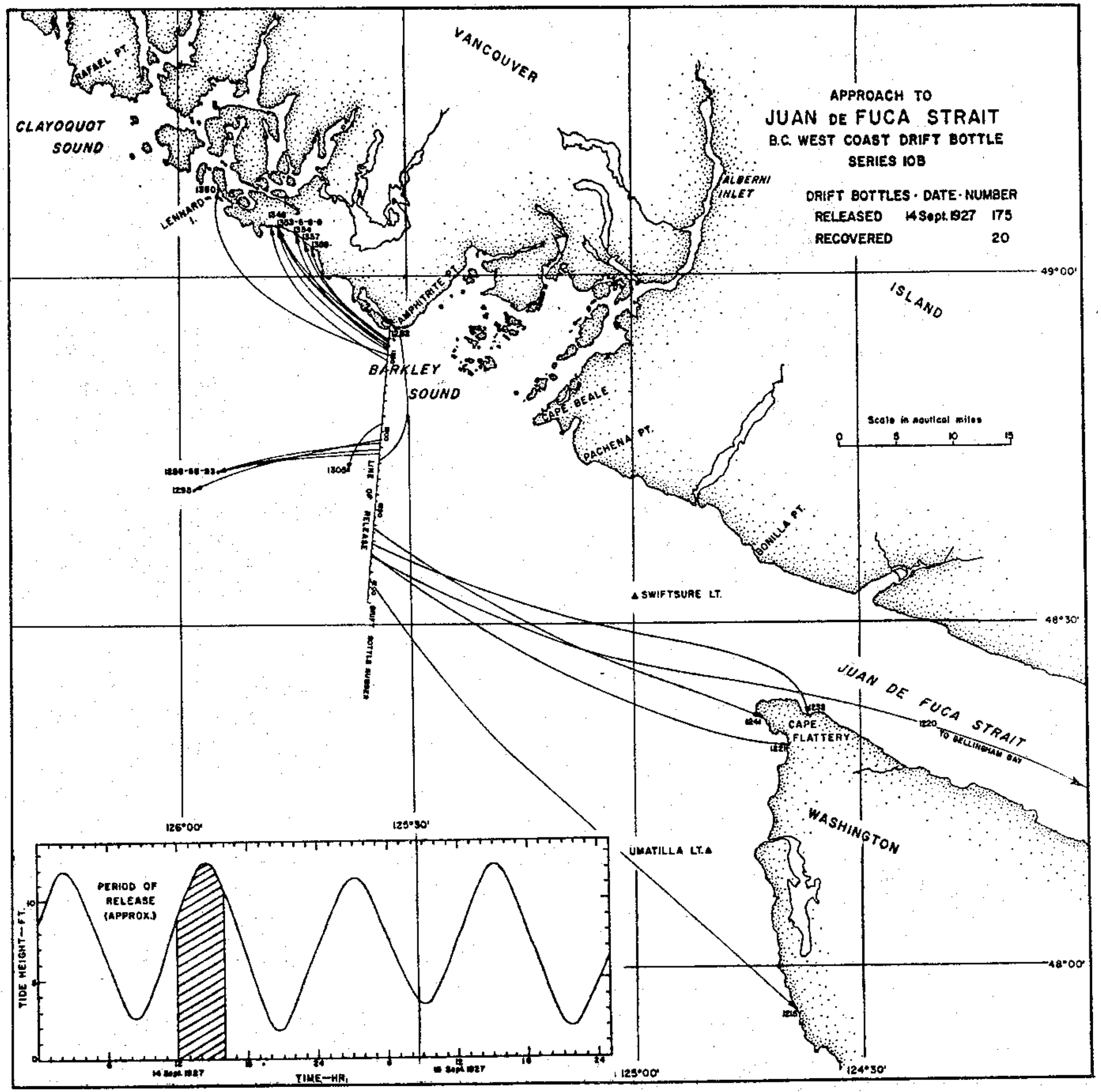

Fig. 12. Drift bottle releases and returns off the southwest coast of Vancouver Island, September 14, 1927 (from Waldichuk 1963).

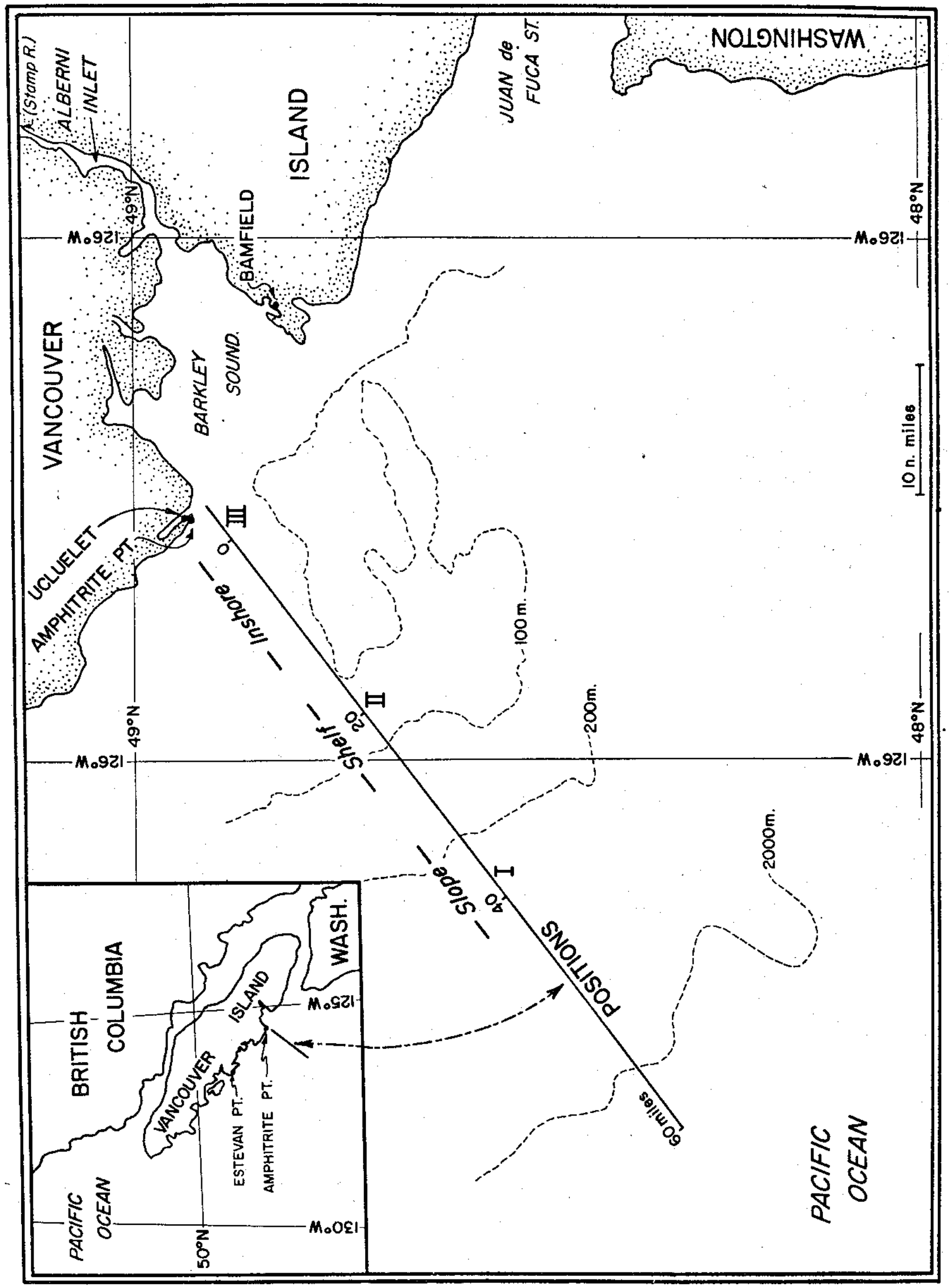

Fig. 13. Geographical area described in Lane (1963).

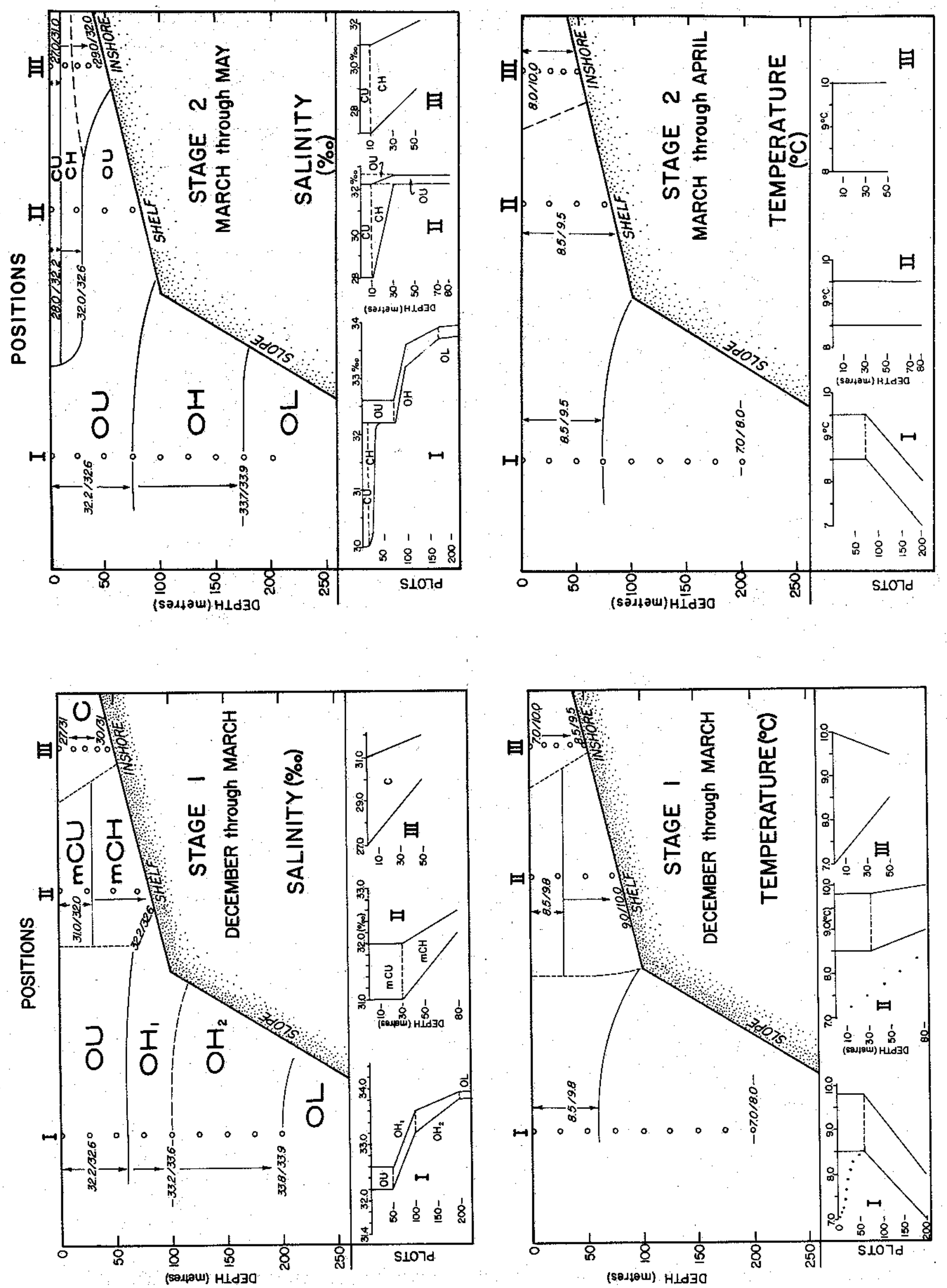

Fig. 14. Model of seawater structure seaward of Amphitrite Point, Vancouver Island - Stages 1 and 2 (from Lane 1963).

(OU). Temperatures range from 8.5 to 9.8°C. At the bottom of the upper zone, there is frequently a temperature maximum. Below this zone, temperatures decrease uniformly with depth to values between 7 and 8°C at 200 m. Over the remainder of the shelf, the structures are isothermal or temperatures increase with depth; the positive temperature structure appears to be more common. The temperatures of the bottom waters are at their annual maximum during this period. In the shelf area, the upper zone (0-30 m) may be as cold as 7°C when estuarine water is present. More frequently, the values range from 8.5 to 9.8°C. Bottom temperatures range from 9 to 10°C. In the inshore area, a wide range of temperatures may be found; the temperature range at the surface is 7-10°C, and at the bottom, 8.5 to 9.5°C.

Stage 2 (March through May) is a period in which coastal runoff is less than during Stage 1 and insolation increases. Wind velocities remain large but the direction is variable because this is a period of change from dominant southeast to dominant northwest winds. This results in a relaxation of the convergent mechanism, and allows surface waters to extend seaward.

In Stage 2, the oceanic upper zone extends to about 75 m depth and is continuous over the shelf (Fig. 14). Below this, the oceanic halocline extends to about 175 m depth. The rise from a depth of 200 m in Stage 1 is attributed to the relaxation of the winter convergent mechanism. In Stage 2, the coastal waters (CU and CH) may extend further seaward and override the oceanic upper zone in the outer shelf and slope areas. The coastal water column contains a shallow (10 m) homogeneous upper zone (CU) and a halocline which extends to about 30 m depth. Thus, there may exist one halocline (OH) or two haloclines (OH and CH) over the shelf. In the inshore area, surface salinities are low (27-31°/°°). Below these waters, the coastal halocline (CH) water extends to the bottom. The inflow of brackish estuarine water (runoff) maintains an intense halocline.

The Stage 2 (March through April) temperature model is shorter by one month from the Stage 2 (March through May) salinity model. Lane noted that while the shelf salinity structure may undergo marked changes during this period, the temperature remains quite similar to that shown in Stage 1 through April. In the slope area, the isothermal upper zone reaches its maximum depth (~75 m) coincident with the oceanic upper zone; temperatures range from 8.5 to 9.5° (Fig. 14). Below this, temperatures decrease to roughly 7-8°C at 200 m depth. Inshore, the temperature structure is more closely associated with the salinity structure. The stability inherent in this structure prevents the downward displacement of heat. Hence, any temperature increase, slight though it may be, is conserved in the upper 10-20 m depth. Temperatures range between 8 and 10°C.

Stage 3 (May through July) is a period during which the large mainland rivers are in freshet due to melting snow in the mountains. This reaches the region as an increased outflow from Juan de Fuca Strait. A lesser contribution of runoff comes from the secondary maximum (May) of local runoff, also due to snow-melt. The predominant winds are moderate and generally from the northwest. Hence, the convergent mechanism is fully relaxed, and some instances of divergence may be expected. Insolation and heating are a maximum.

During Stage 3, the coastal water (CU and CH) frequently extends seaward of the continental slope and occupies most of the depth of the oceanic upper zone (Fig. 15). There is a thin upper zone (CU) 10-20 m thick extending from the inshore area seaward of the shelf. At any position, it is vertically isohaline due to normal wind mixing, but its salinity increases seaward due to entrainment. The coastal halocline is continuous throughout the section. In the slope and shelf areas, it extends to 30-40 m depth, and is limited by salinity, 32.2-32.6°/oo. In the slope area, this is underlaid by the remnants of the oceanic upper zone (OU) which separates the coastal and oceanic haloclines. If the coastal water does not extend into the oceanic area then the oceanic upper zone water occupies the upper 50 m of depth. In any case, below the oceanic upper zone, the oceanic halocline extends down to 150 m depth; its lower limit is marked by a salinity of 33.7-33.9°/oo. The rise of the oceanic halocline towards and onto the shelf is attributed primarily to the entrainment mechanism associated with the brackish upper zone. The condition of moderate winds, predominantly from the northwest, allows the convergent mechanism to relax, but wind conditions may be sufficient to create a divergent situation. During Stage 3, it is most probable that coastal (C) rather than oceanic (O) water occurs in the upper 40 m over the shelf. Below this, oceanic halocline water extends to the bottom. Inshore, the coastal upper zone and halocline occupy the whole depth. Ocean halocline water is seldom found inshore during this period.

During Stage 3, an isothermal upper zone is formed to the depth of local wind mixing (Fig. 15). The depth is limited to the pycnocline inherent in the halocline. In this upper zone, the temperature increases progressively and the thermocline associated with the halocline grows in magnitude. Below this, the temperature of the water is not directly affected by local surface heating. When oceanic (OU) water is dominant in the offshore area, the upper temperature zone is 10-20 m thick and the thermocline extends to about 60 m. However, if coastal (CU and CH) waters extend beyond the continental slope prior to the development of the temperature structures, then the temperature and salinity structures are coincident.

The wind-induced convergent system has relaxed, and coincidently there is a marked decrease in sub-thermocline temperature in the slope area, although there is little change in salinity during Stage 3 (Fig. 15). The rise of the isotherms is considered to be associated with relaxation of the convergent condition and/or the beginning of wind-induced divergence during this period. Over the shelf area, the upper zone and shallow (seasonal) thermocline are coincident with the CU and CH zones. The intensity of the pycnocline inherent in the halocline restricts the downward transfer of heat. As a result, the surface waters are usually warmer in the shelf than in the slope and oceanic parts of the section. As this stage develops, the thermal influence on density becomes greater than the haline influence and dominates the stability of the pycnocline consisting of temperature and salinity effects. The decrease in temperature of the waters below the thermocline is attributed to the migration of the cooler deeper water onto the shelf. The thermocline may extend to near-bottom, or it may be more intense in the upper 10-20 m depth.

During Stage 4 (July through October), precipitation and land drainage from coastal and mainland rivers are low or minimal. Insolation wanes and the rate of heat gain diminishes rapidly. Winds are predominantly from the northwest and their strength is less than the annual average. They

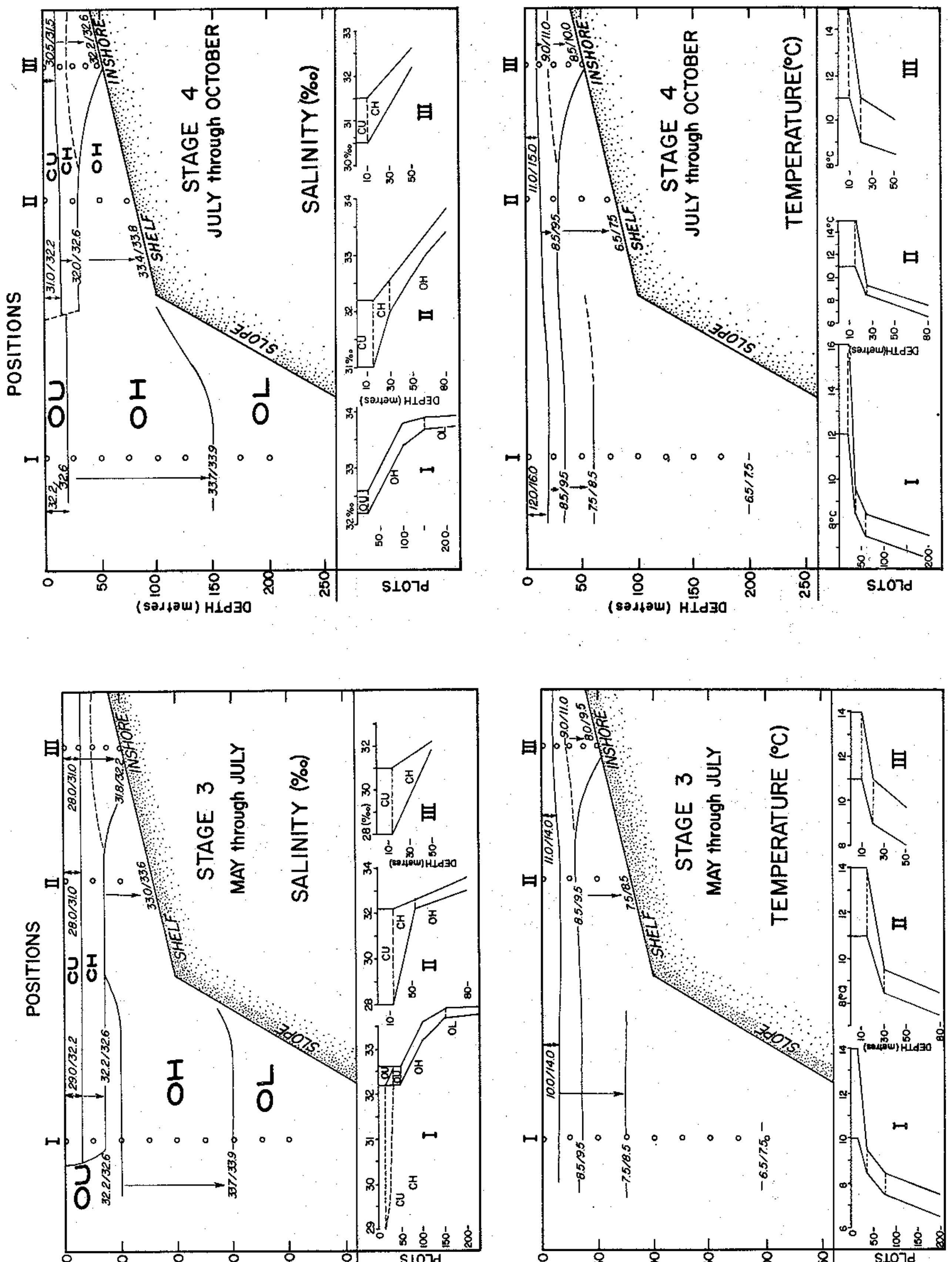

Fig. 15. Model of seawater structure seaward of Amphitrite Point, Vancouver Island - Stages 3 and 4 (from Lane 1963).

induce a dominant but weak divergent mechanism, and localized upwelling occurs. In October, the occurrence of southeast winds increases so that their frequency is about the same as that of the northwest winds.

The occurrence of distinctive coastal (CU and CH) water beyond the shelf is rare during Stage 4 (Fig. 15). The oceanic structure contains a relatively thin (20 m) upper zone, a halocline extending to about 150 m depth and a lower zone. The thinness of the upper zone (OU) is attributed to the divergent mechanism which dissipates water seaward, and induces uprising of the deeper waters. Because the winds are not steady these conditions are variable. Over the continental shelf, the coastal upper zone is about 15 m thick. Below it, the coastal halocline extends to 20-30 m depth. The oceanic upper zone does not occur over the shelf. Rather, the oceanic halocline exists below the coastal halocline water. Frequently, the demarcation becomes indistinct and the halocline is nearly continuous through the CH and OH zones. Inshore, the upper zone is about 10 m thick. Although the oceanic halocline may penetrate this far inshore below 30 m depth, the general case shows that the coastal halocline (CH) is continuous to the bottom, with an intensification in its upper portion. Although there is an upward inclination of isohalines from the oceanic waters toward the continental shelf, the inclination is generally downward toward the shore in the shelf and inshore areas. The crest of the isohalines occurs over the outer shelf. Lane (1963) reasoned that the upper inclination would be continuous to the surface or to the shore if part of the demand for divergent water was not provided by freshwater runoff. The crest of the inclined isohalines marks the division between the shoreward part of the section where the demand is met by freshwater runoff, and the seaward part where the major contribution is from the underlying waters.

Surface temperatures increase from shore to a maximum seaward of the continental slope during Stage 4 (Fig. 15). The seasonal thermocline is continuous and increases in magnitude seaward. Below this, there is considerable temperature structure in which gradients and the inclination of the isotherms are coincident with the haline structure. The waters are generally warmest in the offshore upper zone which extends to about 20 m depth. In the oceanic and slope areas, the seasonal thermocline occurs in two segments; the more intense thermocline extends to 35 m, about the same as during Stage 3. The shallow thermocline is not so intense in the shelf area, because of the movement of surface-warmed waters seaward. The deeper thermocline is more intense than in Stage 3 owing to the divergent mechanism at the edge of the shelf. Over the shelf, it blends with the lower halocline and is continuous to the bottom owing to the rise of isotherms onto the shelf from the sub-thermocline oceanic waters. Over the shelf, the upper thermocline extends to about 30 m depth early in this stage (July). Later (October), it rises to about 20 m depth. This rise is attributed to an increase of divergence. Inshore, the 11 to 15°C upper zone is about 10 m thick or non-existent. The thermocline coincides with the halocline with occasional intensification in the upper 20 m depth.

Stage 5 (October through December) is a period when runoff from the mainland sources is small but is a period of increased runoff from local streams associated with maximum coastal precipitation. The winds are predominantly southeast and of moderate intensity. The oceanic upper zone (OU) thickens to about 40 m (Fig. 16). This results in an intensification of

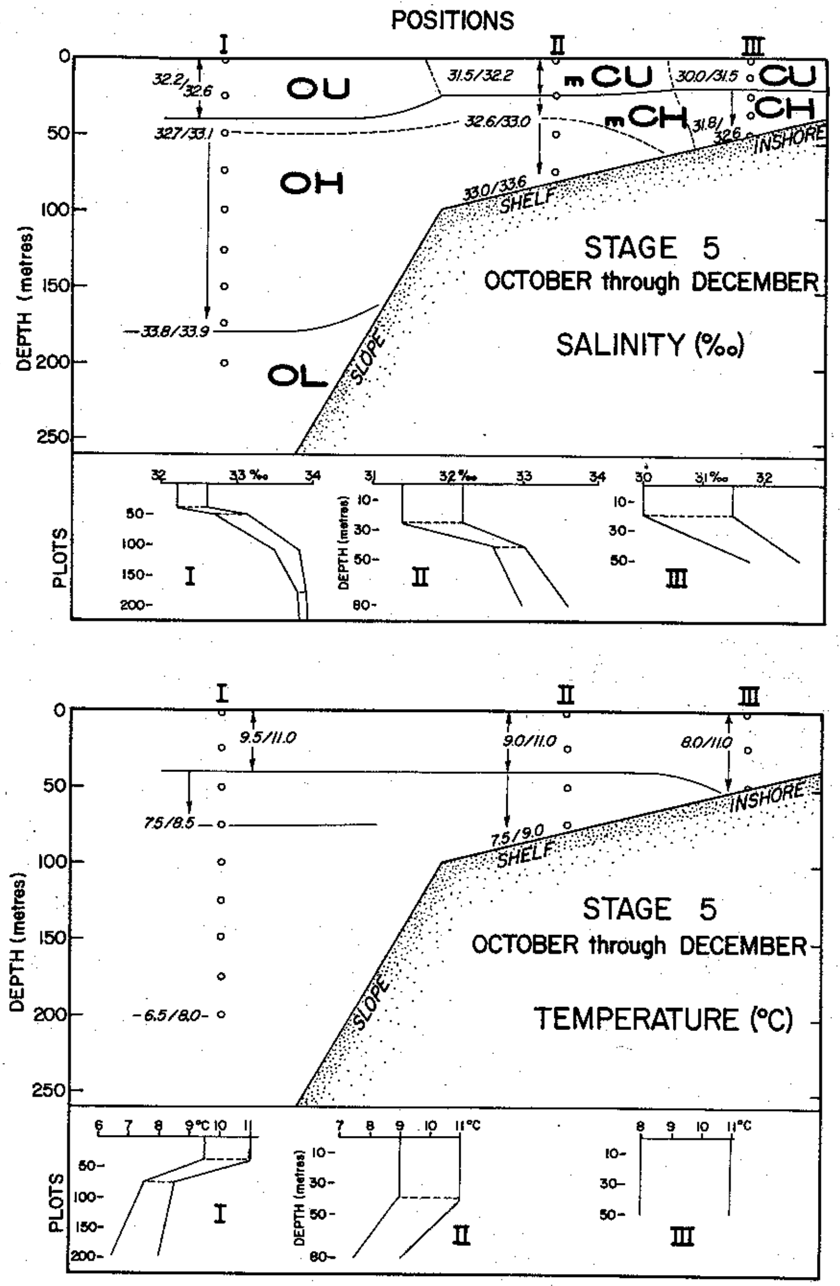

Fig. 16. Model of seawater structure seaward of Amphitrite Point, Vancouver Island - Stage 5 (from Lane 1963).

the top of the oceanic halocline (OH). Its base descends to about 180 m owing to the advent of the convergent mechanism. In the shelf area, the coastal upper zone (CU) extends to a depth of 20-30 m. It may or may not cover the whole shelf but never extends to the slope area. It is slightly more saline than during Stage 4, which is attributed to deeper mixing. The halocline is at a depth of 25 to 35 m. Inshore, the coastal upper zone is 10 to 30 m thick, and below it, the halocline (CH) extends to the bottom.

Isolation decreases and cooling becomes the dominant process in the heat budget during Stage 5. The thermocline decays, sinks and is compressed as heat is lost from the sea surface. Surface waters become colder than the underlying waters, and convective overturn (and mixing) occurs unless prevented by haline stability. There is an isothermal zone, coincident with the low-salinity upper zone (OU) extending to a depth of about 40 m in the offshore area (Fig. 16). The decaying thermocline extends down to a depth of about 75 m. The deepening of the base of the thermocline, and the slightly higher temperatures at 200 m, compared to Stage 4, signify the relaxation of the summer divergent condition. Also, temperatures in the sub-halocline waters increase. Over the shelf, the isothermal layer may be deeper than the low-salinity upper zone (CU), suggesting that the source waters have temperatures similar to the halocline waters at this time, or that the surface waters have been cooled to the same temperature as the waters in the halocline. Inshore, a variety of temperature structures may be found. Depending on the relative influence of wind, surface cooling and the temperatures of the estuarine and ocean waters, the structure may be positive, negative or isothermal.

Hollister (1966) has also provided information on the variability in the temperature structure, but only for the inshore coastal waters, from bathythermograph data collected at Swiftsure Bank (1954-61) and Umatilla Reef (1955-60) (Fig. 1). Tables of monthly means and graphs of 7-day equally-weighted means for selected depths (0, 10, 20, 30, 40, 45 m) were presented and discussed. Seasonal changes in the temperature structures in the vicinities of the lightships were similar to those described for the inshore area seaward of Amphitrite Point by Lane (1963). During winter, the vertical temperature structure of these waters was isothermal, or had a slightly positive gradient (temperature increasing from surface to bottom). Surface heating and mixing in spring and early summer resulted in the establishment of a thermocline extending from top to bottom. With additional summer heating, the magnitude of the thermocline increased. During periods of high insolation and light winds, a transitory, thin (5 m) isothermal upper zone occasionally appeared. Reduced solar heating followed by cooling, as well as increased mixing due to stronger winds, decreased the magnitude of the thermocline, and returned the temperature structure to the isothermal or positive-gradient winter conditions. The positive structure generally occurred from December through mid-March. Hollister (1966) noted that short-term heating and cooling were usually effective throughout the whole water column (45 m in depth) at these locations. However, occasionally phase differences in the temperatures at shallow depths (0-20 m) and those at greater depths (40-45 m) occurred abruptly, and were attributed to intrusions of cold deep water. These features were apparent in graphs of 7-day equally-weighted means.

The monthly mean values at all selected depths show considerable annual variation during the 8-year period, 1954-61 (Table 4). The coldest

Table 4. Monthly mean seawater temperatures (°C) at several depths at Swiftsure Bank lightship station, 1954-61 (from Hollister 1966).

Depth (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1954												
0							11.3	11.2	14.0	11.1	11.4	9.6
1955												
0	8.1	7.6	6.8	8.1	9.2	10.1	11.2	11.2	10.9	10.7	8.8	7.4
5	8.2	7.6	6.8	8.0	9.1	9.7	10.8	10.8	10.7	10.5	8.8	7.4
10	8.2	7.7	6.9	7.8	8.8	9.3	10.3	10.1	10.3	10.3	8.8	7.6
20	8.3	7.7	7.0	7.6	8.3	8.6	9.4	9.1	9.3	9.8	8.8	7.6
30	8.3	7.8	7.1	7.4	7.9	8.0	8.6	8.3	8.5	9.3	8.6	7.6
40	8.4	7.8	7.2	7.3	7.6	7.7	8.0	7.6	7.8	8.3	8.6	7.6
45	8.4	7.9	7.2	7.3	7.5	7.6	7.8	7.4	7.6	8.0	8.4*	7.5*
1956												
0	8.5	7.6	7.6	8.8	9.9	11.7	11.7	11.8	11.6	11.2	9.9	8.3
5	8.6	7.6*	7.6*	8.6	9.7	11.2	10.9	11.2	11.3	11.2	9.9	8.3
10	8.7	7.6*	7.5*	8.1	9.1	10.5	10.2	10.5	10.8	11.1	9.8	8.3
20	8.8	7.7*	7.5*	7.7	8.3	9.6	9.1	9.4	10.0	10.8	9.7	8.2
30	8.8	7.8*	7.4*	7.3	8.0	8.8	8.3	8.5	9.0	10.3	9.3	8.1
40	8.9	7.9*	7.4*	7.1	7.8	8.1	7.6	7.8	8.2	9.4	8.6	7.9
45	8.9	7.9*	7.4*	7.0	7.7	7.8	7.2	7.6	7.9	8.9	8.4	7.8
1957												
0	7.1	6.6	7.9	11.1	11.3	11.8	13.1	13.1	13.1	13.1	11.3	10.3
5	7.1	6.6	7.8	9.3	10.7	10.9	11.4	12.7	12.7	13.0	11.5	10.3
10	7.2	6.6	7.7	9.0	10.2	10.4	10.8	12.2	12.2	12.9	11.5	10.4
20	7.2	6.8	7.7	8.6	9.3	9.6	9.9	11.3	11.1	12.4	11.3	10.3
30	7.3	6.9	7.5	8.2	8.8	9.1	9.3	10.3	10.1	11.6	11.0	10.3
40	7.4	7.1	7.4	7.9	8.5	8.6	8.7	9.6	9.2	10.6	10.8	10.0
45	7.4	7.1	7.5	7.8	8.4	8.4	8.4	9.2	8.7	10.3	10.3	10.0
1958												
0	9.6	10.4	9.5	10.0	10.8	12.9	12.4	12.8	12.4	11.2	10.5	9.7
5	9.6	10.4	9.4	9.9	10.4	12.3	11.8	12.2	12.2	11.1	10.5	9.7
10	9.7	10.4	9.4	9.8	10.1	11.6	11.2	11.5	11.9	11.1	10.6	9.8
20	9.7	10.3	9.3	9.6	9.6	10.6	10.3	10.4	11.1	10.6	10.6	9.8
30	9.7	10.2	9.3	9.5	9.1	9.9	9.4	9.1	10.3	9.8	10.4	9.8
40	9.7	10.1	9.4	9.5	8.7	9.2	8.6	8.2	9.1	9.2	9.8	9.7
45	9.7	10.2	9.4	9.5	8.6	9.0	8.4	7.9*	8.6	8.8*	9.6	9.8

Table 4 (cont'd)

Depth (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						1959						
0	8.7	8.4	8.2	9.4	10.8	12.4	11.9	11.8	12.1	11.2	8.9	9.0
5	8.7	8.4	8.2	9.3	10.6	12.0	11.5	11.4	12.0	11.1	8.9	9.0
10	8.7	8.4	8.2	9.1	10.2	11.5	10.9	10.8	11.8	11.0	8.9	9.1
20	8.8	8.5	8.2	8.9	9.7	10.5	10.0	9.7	11.0	10.4	8.8	9.1
30	9.0	8.6	8.2	8.8	9.3	9.6	9.3	8.7	10.1	9.6	8.5	9.1
40	9.0	8.8	8.2	8.7	9.0	8.8	8.5	7.9	9.2	9.0	8.4	8.8
45	9.0	8.9	8.3	8.7	8.9	8.6	8.2	7.5	8.6	8.6	8.2	8.7
						1960						
0	8.1	8.5	8.2	10.0	11.3	11.0	11.6	11.9	10.8	11.1	10.7	9.4
5	8.2	8.5	8.2	10.0	11.1*	10.6*	11.1	11.5	10.5	11.1	10.7	9.5
10	8.2	8.5	8.2	9.8	10.7*	10.0*	10.5	10.9	10.2	11.0	10.7	9.5
20	8.3	8.5	8.2	9.5	10.2*	9.1*	9.5	9.8	9.6	10.6	10.6	9.6
30	8.4	8.6	8.2	9.0	9.6*	8.4*	8.6	8.6	9.0	9.8	10.2	9.8
40	8.5	8.7	8.3	8.7	9.2*	7.8*	7.9	8.2	8.1	9.1	9.4	9.9
45	8.5	8.7	8.4	8.6	9.1*	7.6*	7.6*	7.9*	7.8*	8.7*	9.1*	10.0*
						1961						
0	9.1	9.1	9.4	9.4	11.0	12.1						
5	9.1	9.2	9.4	9.3	10.8	11.8						
10	9.0	9.1	9.2	9.1	10.5	11.3						
20	9.1	9.1	9.2	9.0	9.8	10.4						
30	9.2	9.1	9.1	8.9	9.2	9.6						
40	9.3	9.2*	9.2	8.9	8.7	9.0						
45	9.4*	9.3*	9.3*	8.9*	8.5	8.6						
						1955-1960						
0	8.4	8.2	8.0	9.3	10.5	11.6	11.8	12.1	11.8	11.4	10.0	9.0
5	8.4	8.2	8.0	9.2	10.3	11.1	11.2	11.6	11.6	11.3	10.0	9.0
10	8.4	8.2	8.0	8.9	9.8	10.6	10.6	11.0	11.2	11.2	10.0	9.1
20	8.5	8.2	8.0	8.6	9.2	9.7	9.7	10.0	10.4	10.8	10.0	9.1
30	8.6	8.3	8.0	8.4	8.8	9.0	8.9	8.9	9.5	10.1	9.7	9.1
40	8.6	8.4	8.0	8.2	8.5	8.4	8.2	8.2	8.6	9.3	9.3	9.0
45	8.6	8.4	9.0	8.1	8.4	8.2	7.9	7.9	8.2	8.9	9.0	9.0

*Estimated temperature.

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year was 1955, except in January and February. The warmest period commenced in August 1957 and extended through July 1958. The warm anomalies prevailed at all depths from 0 to 45 m. Near-bottom (45 m) monthly mean temperatures ranged from a low of 7.2°C in July 1956 to a high of 10.2°C in February 1958, a range of 3.0°C. It is noted here that these were periods of anomalously large offshore Ekman transport and large onshore transport, respectively; these features are discussed in a later section.

The long-term monthly means indicate that the periods of maximum temperatures generally occurred later with increasing depth, at 0 and 5 m in August, at 10 m in September-October, at 40 m in October-November and at 45 m in November-December (Table 4) (Hollister 1966).

Ingraham (1967) provided information on the spatial distributions of temperature, salinity and dissolved oxygen, and on features of the geostrophic flow and the extension of the California Undercurrent along the continental shelf and slope of Washington and Vancouver Island during spring and autumn, 1963. Along the 55 m (30 fath) isobath, near-bottom salinities were uniform, 31.9-32.0‰ north of Juan de Fuca Strait, but increased off Washington, 33.4‰ near the mouth of the Columbia River in spring (Fig. 17). The temperature range was 1.0°C (8.86-9.92°C), the maximum occurring off the Columbia River. Values of dissolved oxygen were lowest (0.273 mg at/L, 3.1 mL/L) off the mouth of the Columbia River to values of 0.544 mg at/L, 5.6 mL/L off Barkley Sound in spring (Fig. 18).

In spring, the range of salinity at 183 m (100 fath) was much smaller, 33.67-33.95‰, than that at 55 m, but the range of temperature was the same, 1.0°C (Fig. 17). The range of dissolved oxygen was also smaller, 0.194-0.275 mg at/L (2.2-3.1 mL/L) (Fig. 18).

Values of salinity, temperature and dissolved oxygen at 55 m (30 fath) were significantly different in autumn from those in spring. By autumn, temperatures had increased 3°C off Vancouver Island, and from 4 to 6°C off the coast of Washington. At 183 m (100 fath), the increase in temperature was about 0.6°C from spring to autumn. Below 200 m, the range of values of salinity, temperature and dissolved oxygen at a given depth was comparatively small.

In spring, a major feature of the surface geostrophic circulation was the apparent divergence of onshore flow near southern Vancouver Island (Fig. 19). Also, eddies dominated the pattern of surface flow. In autumn, the eddies were absent off the coast of Vancouver Island but present off the coast of Washington (Fig. 20). The existence of the California Undercurrent along the continental slope off Vancouver Island was shown by Ingraham (1967). The distribution of properties and water masses suggested that the flow in the California Undercurrent was greater during autumn than during spring in 1963, but this was not reflected in the net volume transport.

Dodimead and Pickard (1967) reviewed the temporal variations of water characteristics and currents for the oceanic region of the eastern Subartic Pacific and for the bordering coastal and fjord regions. In the oceanic region, upper zone waters with temperatures greater than 7°C at the top of the halocline appeared to have had their greatest extent in 1958 and 1963, and their least in 1956 and 1965, for the period 1955-66. The northward

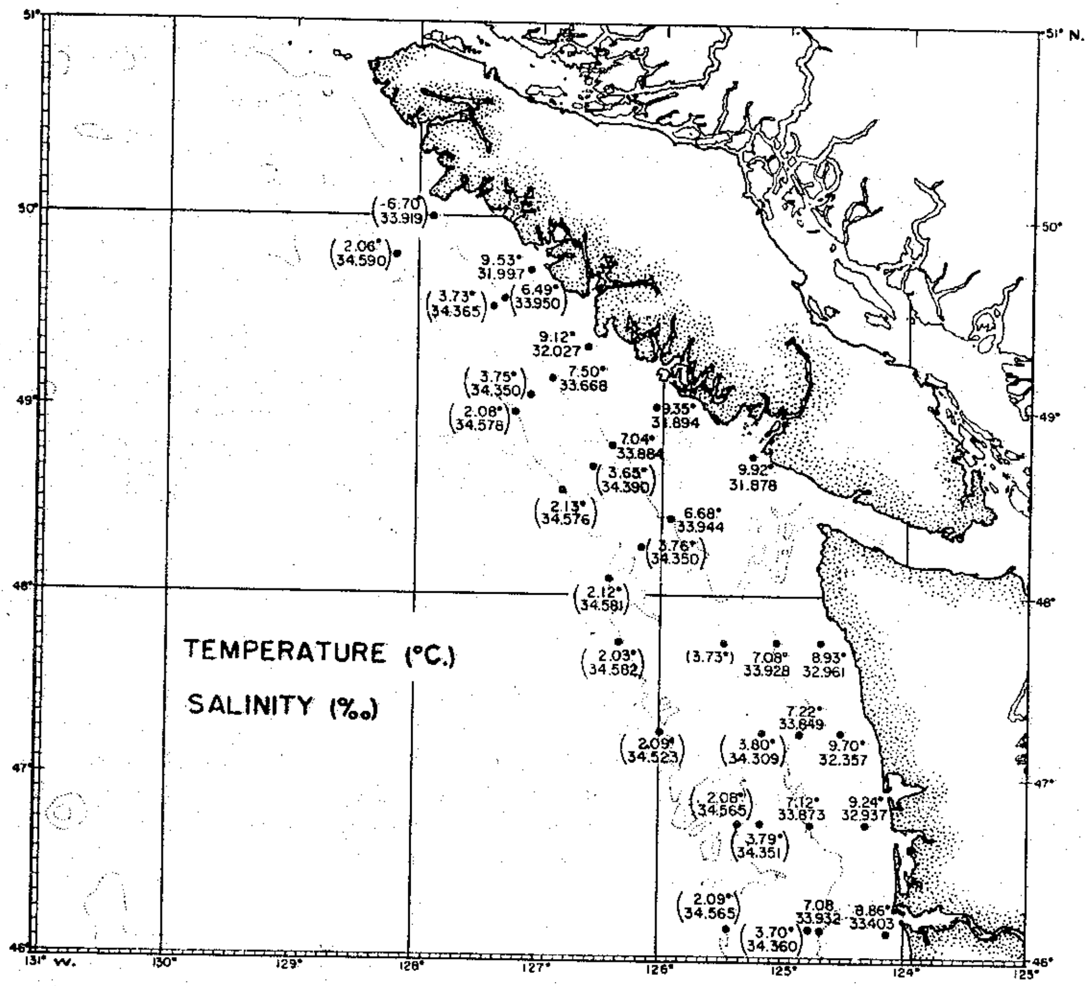

FIGURE 17. Temperature (°C.) and salinity (‰) near the bottom at 55, 183, 914, and 1,829 m. along the continental terrace, spring 1963. (The 183- and 1,829-m. depth contours are shown, and the values in parentheses are interpolated.)(from Ingraham 1967).

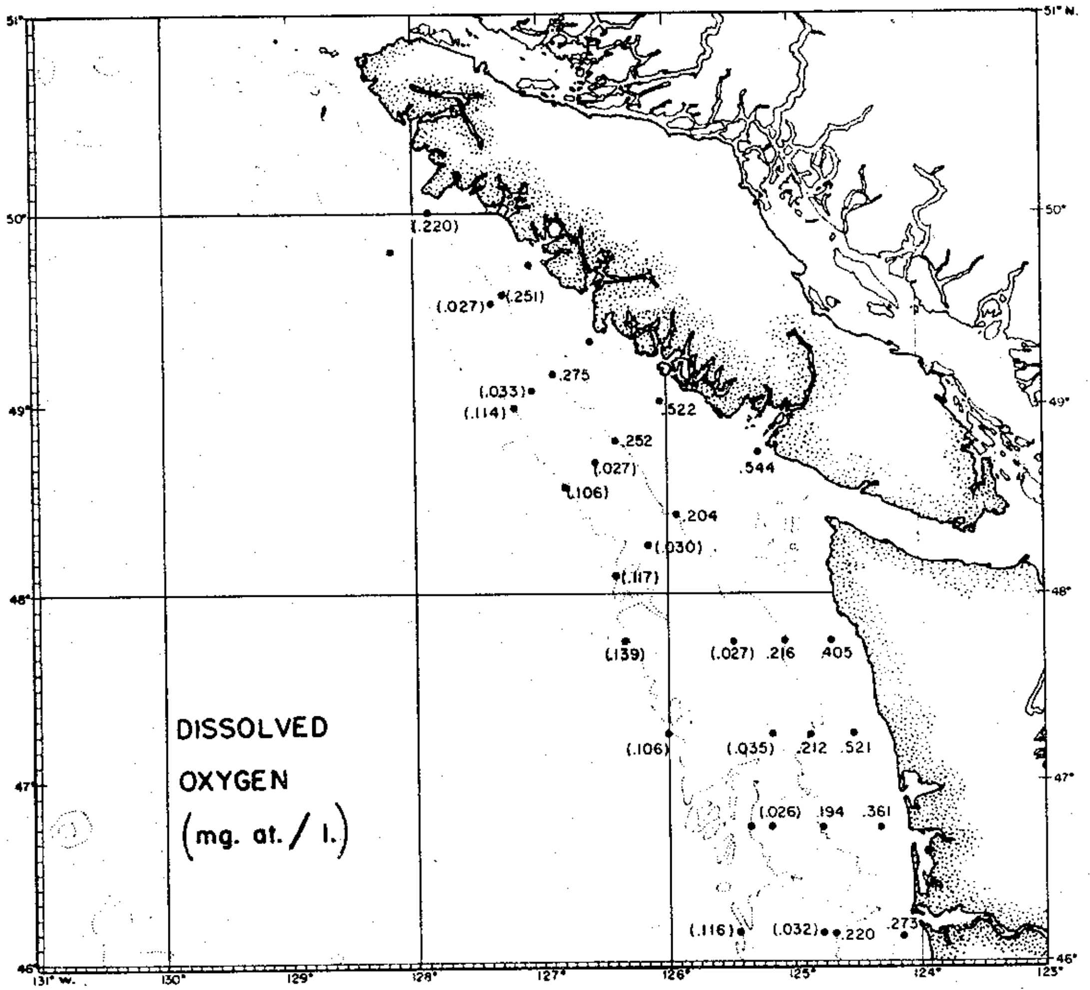

FIGURE 18. Dissolved oxygen (mg.at./l.) near the bottom at 55, 183, 914, and 1,829 m. along the continental terrace, spring 1963. (The 183- and 1,829-m. depth contours are shown, and values in parentheses are interpolated.)(from Ingraham 1967).

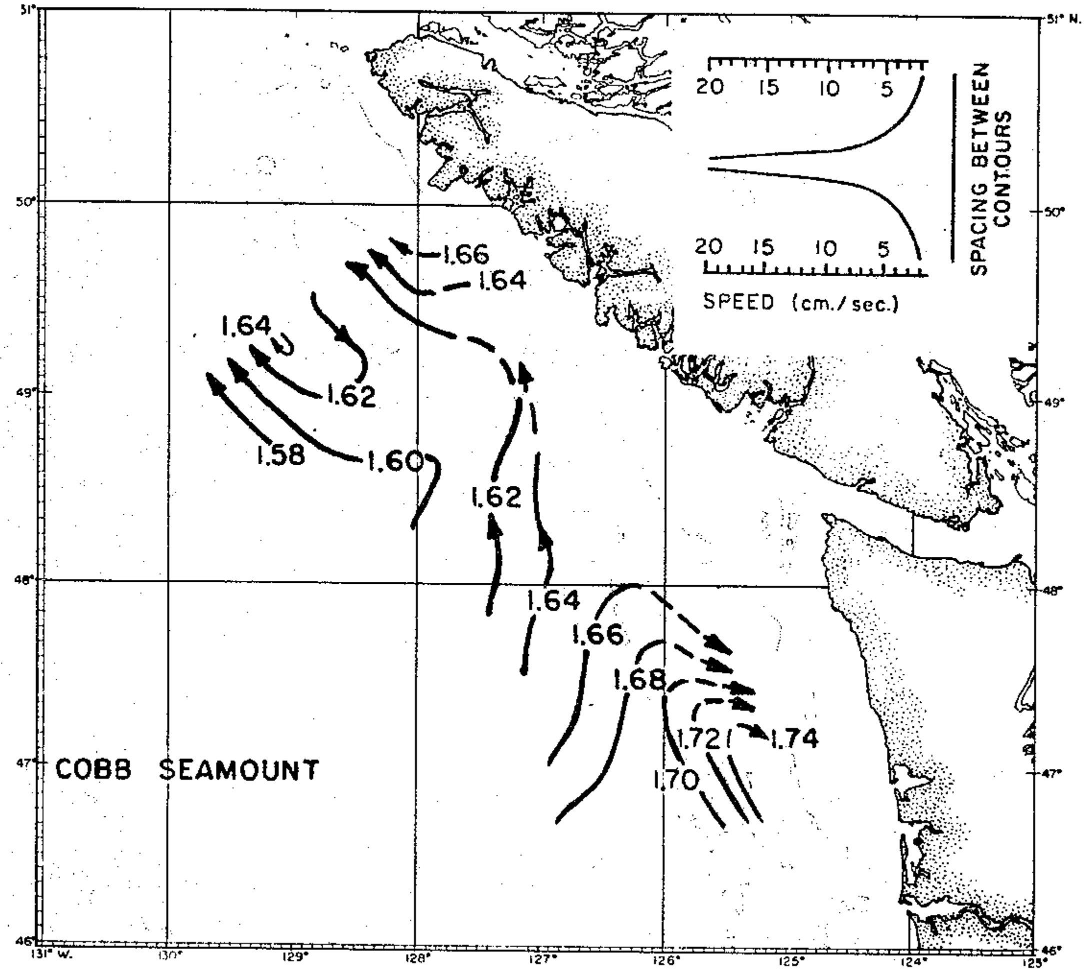

FIGURE 19. Geopotential topography, 0/1,500 m., spring 1963. (The 183- and 1,829-m. depth contours are shown.) (from Ingraham 1967).

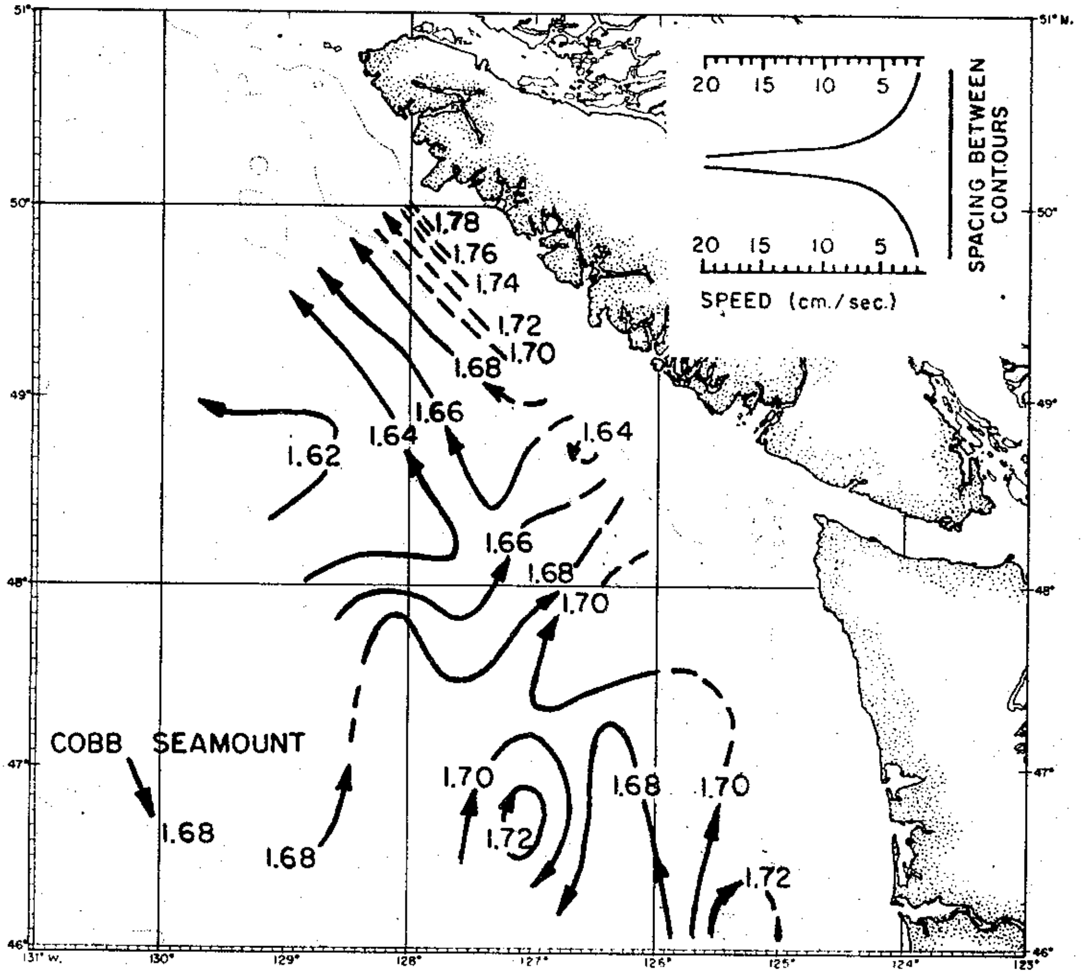

FIGURE 20. Geopotential topography, 0/1,500 db., fall 1963. (The 183- and 1,829-m. depth contours are shown.) (from Ingraham 1967).

and westward extent of water greater than 6.5°C at the bottom of the halocline ($33.8^{\circ}/_{oo}$) appeared to have been greatest in 1958, 1961, 1962 and 1966, and least in 1956 (no data for 1963 and 1964). Thomson (1972) provided an explanation for the annual variations. At the top of the halocline, the onshore Ekman transport and the relative warmth of the upper oceanic layer in winter were suggested as being responsible for these variations. At the bottom of the halocline, other processes besides the direct effort of Ekman transport were important in determing the variations at that level.

Reed and Halpern (1976) identified details of the California Undercurrent off the coasts of Washington and Vancouver Island not previously established, from data collected in September 1973. They reported that the California Undercurrent had a vertical extent in excess of 500 m and its width was highly variable, being confined quite close to the continental slope in some places and extending well offshore in others. Off Vancouver Island, the flow was augmented by a large cyclonic eddy. Considering these results and those of Ingraham (1967) and Dodimead et al. (1963), they suggested that the Undercurrent is a permanent feature off Washington and Vancouver Island.

Huyer et al. (1976) provided information on the structure of the currents over the continental shelf from continuous observations made at two locations west of Tofino (Fig. 1) from 28 November 1974 to 8 April 1975. Three current meters were moored at mid-shelf (MS), at near-surface (20-29 m), mid-depth (45-53 m) and bottom (91 m), and two at the outer edge of the shelf (OS), at near-surface (20-22 m) and bottom (180-200 m). Summaries of their results are provided in Tables 5 and 6. During the first deployment (November 28-February 11), the temperature of the near-surface was slightly higher at MS than at OS. At MS, water at mid-depth was somewhat warmer than near the surface. This indicates a positive temperature structure, as noted by Lane (1963) and Hollister (1966), a characteristic feature for those waters at this time of the year. Data from the first deployment indicate that the mean onshore flow was greatest at 20 m OS, 7.5 cm/sec (0.15 knots), and was smallest, and offshore,at 180 m OS, -3.1 cm/sec (-0.06 knots). The mean alongshore flow was poleward: smallest at 180 m OS, 2.6 cm/sec (0.11 knots), and greatest at 20 m OS, 25.2 cm/sec (0.5 knots). Data from the second deployment (February 11-April 8) showed similar results (Table 6).

In summary, the alongshore flow was usually stronger and more variable over the mid-shelf than at the outer-shelf. During winter, the flow was almost always poleward at the shallow depths. As spring approached, the flow was more frequently equatorward, and the strength of the southerly currents increased. Over the mid-shelf, the alongshore flow usually decreased with depth, and an undercurrent (opposed to the surface current) was usually not observed. Sea level fluctuations were very coherent with the near-surface current fluctuations over the mid-shelf; high sea level was associated with strong northward flow. There was a lack of coherence between wind and sea level or current fluctuations.

Further information on the distributions of surface temperature and salinity and near-bottom temperature, salinity and dissolved oxygen conditions along the continental shelf and slope from California to Vancouver Island was provided by Ingraham and Love (1978). Inshore, surface temperatures were generally 3-4°C lower than those near and seaward of the shelf area in late summer 1977 (Fig. 21). The low temperatures along Vancouver Island were

Table 5. Statistics of observations from the moored current meters, first installation. Alongshore components are directed towards 338° T at OS, and 323° T at MS, and onshore components are toward 68° T and 53° T respectively. (Meter 362 omitted due to clock malfunction). First and second modes indicate the values at which the histogram peaks occur **(from Huyer et al. 1976).**

Location	OS(48° 53.8' N, 126° 29.7' W)		MS(49° 02.1' N, 126° 14.4' W)	
Instrument Number	508	509	507	506
Nominal Depth (m)	20	180	20	45
Time, Date of First Reading	2230 UT 28 Nov. 1974	2230 UT 28 Nov. 1974	2000 UT 28 Nov. 1974	2000 UT 28 Nov. 1974
Time, Date of Last Reading	2100 UT 11 Feb. 1975	2100 UT 11 Feb. 1975	2230 UT 10 Feb. 1975	2230 UT 10 Feb. 1975
Data Interval (min.)	30	30	30	30
Number of Observations	3598	3598	3558	3558
Temperature (C):				
minimum	7.33	6.14	6.95	7.20
maximum	11.19	7.68	10.18	10.30
mean	8.86	7.16	8.74	9.04
std. dev.	0.83	0.30	0.93	0.88
Pressure (db):				
minimum	5.5, 3.9+	-	13	40
maximum	19.8, 30.8+	-	23	51
mean	7.3, 6.5+	-	16	45
std. dev.	1.5, 1.1+	-	12	1
Speed (cm/sec):				
minimum	9.6	1.5	8.9	6.4
maximum	81.3	45.5	91.0	81.3
mean	34.1	12.4	35.9	27.1
std. dev.	10.1	6.1	13.6	11.0
Direction (° T)				
first mode	335	305	320	(305)*
second mode	25	125		
Eastward Component (u) (cm/sec):				
minimum	-67.1	-40.0	-74.1	(-65.5)*
maximum	49.1	24.4	39.5	(25.8)*
mean	- 7.3	- 3.8	-14.5	(-16.3)*
std. dev.	20.3	10.2	19.5	(15.7)*
Northward Component (v) (cm/sec):				
minimum	-51.6	-20.7	-48.0	(-32.5)*
maximum	80.2	28.7	81.6	(60.8)*
mean	20.1	1.2	20.7	(10.6)*
std. dev.	19.8	8.4	21.4	(15.3)*
Onshore Component (u') (cm/sec):				
minimum	-67.6	-31.8	-44.5	(-44.4)*
maximum	56.7	23.2	45.1	(33.8)*
mean	7.5	- 3.1	0.9	(- 6.7)*
std. dev.	20.3	8.9	15.4	(13.1)*
Alongshore Component (v') (cm/sec):				
minimum	-44.9	-22.2	-43.9	(-31.0)*
maximum	73.3	37.1	89.4	(80.8)*
mean	21.4	2.6	25.2	(18.3)*
std. dev.	19.8	9.8	24.5	(17.6)*

*These values are subject to error because of a compass malfunction.

+Values are for the first 972 and last 1796 points respectively. Remainder of pressure record is of poor quality.

Table 6. Statistics of observations from the moored current meters, second installation. For orientation of onshore and alongshore components see Table 5 (from Huyer et al. 1976).

Location	OS(48 55.5' N, 126° 32.0' W)		MS(49 02.0' N, 126° 14.4' W)		
Instrument Number	508	509	1458	506	362
Nominal Depth (m)	22	200	29	53	91
Time, Date of First Reading	2300 UT 12 Feb. 1975	2300 UT 12 Feb. 1975	1900 UT 11 Feb. 1975	1900 UT 11 Feb. 1975	1900 UT 11 Feb. 1975
Time, Date of Last Reading	0200 UT 8 Apr. 1975	0200 UT 8 Apr. 1975	0100 UT 8 Apr. 1975	0100 UT 8 Apr. 1975	0100 UT 8 Apr. 1975
Data Interval (Min.)	30	30	30	30	30
Number of Observations	2599	2599	2653	2653	2653
Temperature (C):					
minimum	7.31	5.80	6.70	7.49	-
maximum	8.82	7.63	8.54	8.56	-
mean	7.91	6.85	7.75	8.04	-
std. dev.	0.23	0.33	0.22	0.19	-
Pressure (db)					
minimum	11.1	-	-	52.5	-
maximum	20.5	-	-	62.0	-
mean	12.9	-	-	59.1	-
std. dev.	1.1	-	-	0.7	-
Speed (cm/sec):					
minimum	6.6	1.5	6.4	3.4	2.0
maximum	87.2	62.3	101.4	72.7	47.0
mean	24.3	10.9	35.3	20.1	14.6
std. dev.	9.5	7.8	16.4	10.3	6.1
Direction (° T)					
first mode	335	285	335	335	275
second mode	25	165	115	135	
Eastward Component (u) (cm/sec):					
minimum	-79.1	-59.3	-81.4	-53.6	-38.4
maximum	43.7	23.3	75.8	58.4	34.8
mean	- 1.3	- 5.7	- 8.1	- 3.5	- 2.3
std. dev.	17.3	9.6	23.8	14.3	11.9
Northward Component (v) (cm/sec):					
minimum	49.6	-19.4	-63.8	-49.5	-29.0
maximum	73.4	34.4	83.2	60.1	39.8
mean	7.3	1.8	16.0	5.2	0.0
std. dev.	18.1	7.3	25.0	16.4	10.2
Onshore Component (u') (cm/sec):					
minimum	-59.7	-47.8	-48.7	-29.7	-37.7
maximum	36.4	24.4	51.0	41.2	27.4
mean	1.5	- 4.6	3.1	0.3	- 1.9
std. dev.	15.4	9.3	16.2	9.6	10.0
Alongshore Component (v') (cm/sec):					
minimum	-53.8	-19.2	-76.2	-54.6	-27.9
maximum	83.7	40.0	97.3	72.6	46.8
mean	7.2	3.8	17.7	6.3	1.4
std. dev.	19.8	7.7	30.5	19.5	12.1

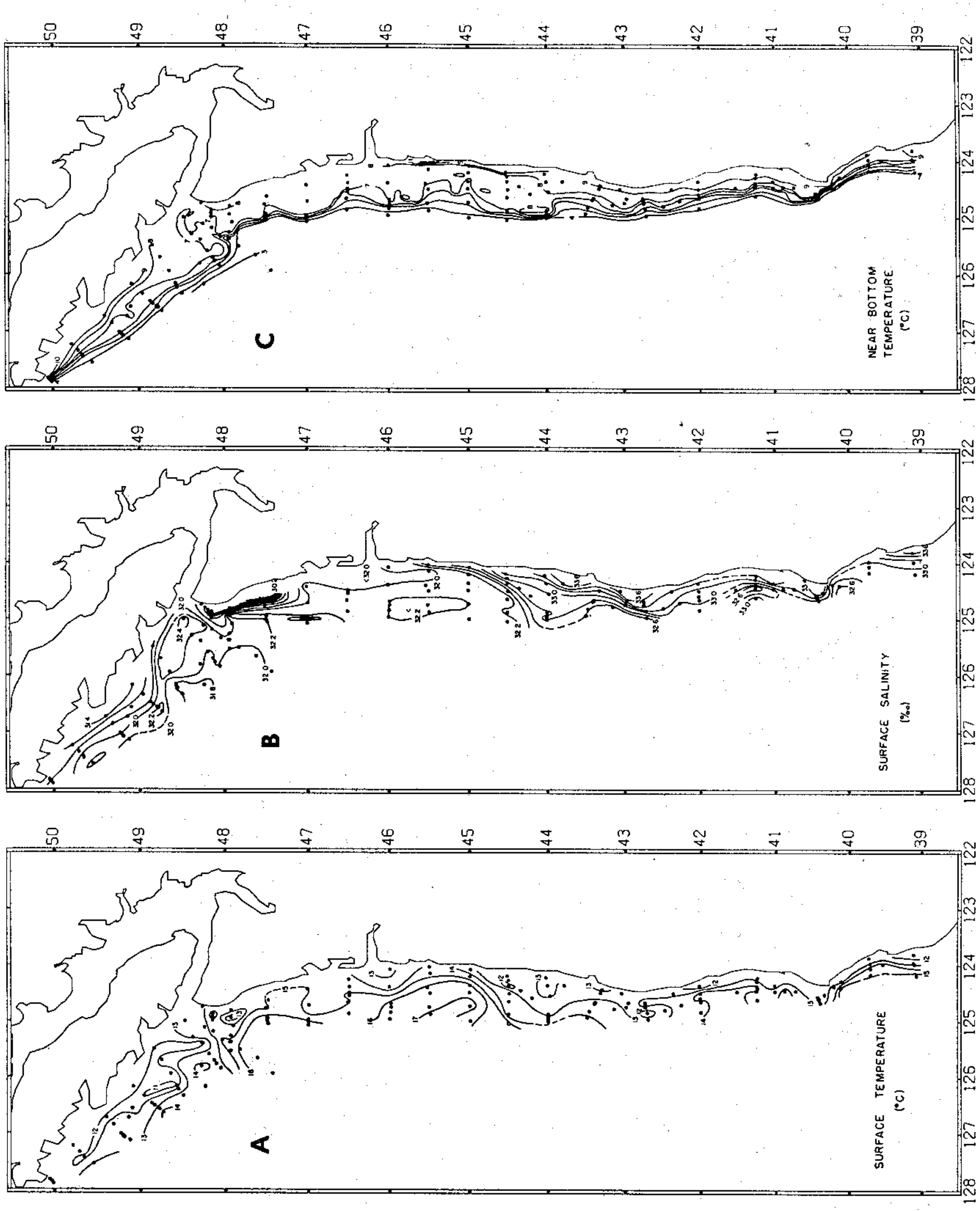

Figure 21. Track of the research vessel *Profesor Siedlecki* and stations where temperature and salinity data were obtained (from Ingraham and Love 1978).

attributed to runoff and vertical mixing in Juan de Fuca Strait since wind conditions for intense upwelling were considered unfavorable. Near-bottom temperatures were generally uniform along isobaths (Fig. 21); the inshore (50-100 m depth) temperature change along the entire coastline was only 2°C (7-9°C). Conversely, seaward temperature gradients of 0.4°C/km occurred frequently. Bottom salinities were generally similar along shelf and across shelf waters. On the other hand, marked fluctuations in dissolved oxygen occurred at depth, particularly near the bottom. Off Vancouver Island (lat. 49°40'N), values greater than 3 mL/L were present as deep as 300 m, whereas to the south (lat. 46°N and 44°30'N), values less than 2 mL/L occurred as shallow as 100 m depth (Fig. 22). Surface flow was generally southward all along the coast, except for sporadic eddies and a fairly consistent northward flow inshore along the west coast of Vancouver island. Ingraham and Love (1978) noted that this flow is fairly characteristic of summer conditions along this coast. However, the flow at 150 m (150 db relative to 500 db) was generally northward, except in the vicinity of the Columbia River where an inshore southward flow occurred. They noted that, except for the limited observations of Reed and Halpern (1976), these data were the first convincing evidence of the northward flow at depth during summer over such an extensive portion of the west coast of the United States. The flow was associated with the California Undercurrent.

This essentially completes the review of the major physical oceanographic research studies of the continental shelf and slope waters off the west coast of Vancouver Island for the purposes of this report. As noted, a major expansion in Canadian oceanographic activities in this area occurred in 1979. The Institute of Ocean Sciences, Patricia Bay, Department of Fisheries and Oceans, initiated programs that included deployments of several current meter arrays on the continental shelf and slope, coupled with periodic physical and biological surveys of these waters (e.g., Freeland and Denman 1982). Many other reports are in press or are in preparation. Other programs and research included, as examples, ships-of-opportunity (Borstad and Louttit 1980), analysis of satellite and aircraft imagery for sea surface temperature and chlorophyll structure (Tabata and Kimber 1979, Borstad and Brown ----), and extensive ichthyoplankton surveys covering the continental shelf and slope waters (Mason et al. 1981a, b, c) and the west coast troll program (Borstad and Brown 1982). With these and other programs and the continued development of more sophisticated and routine analyses, major advancements in our knowledge of the physical and biological features and processes, and the vertical structure of the currents for these waters are now forthcoming.

IV. CIRCULATION

A main feature of the large-scale oceanic surface flow off the coast of North America is the separation of the eastward-flowing Subarctic Current to form the southward-flowing California Current, and the northward-flowing Alaska Current (Fig. 23). The area of separation varies seasonally, and also markedly from year to year, and is considered to be coincident with the area of division of the wind systems (Thomson 1981). Below 300 m, the area of separation appears to be further to the south and closer to the coast than at the surface (Favorite et al. 1976). Another significant feature of the

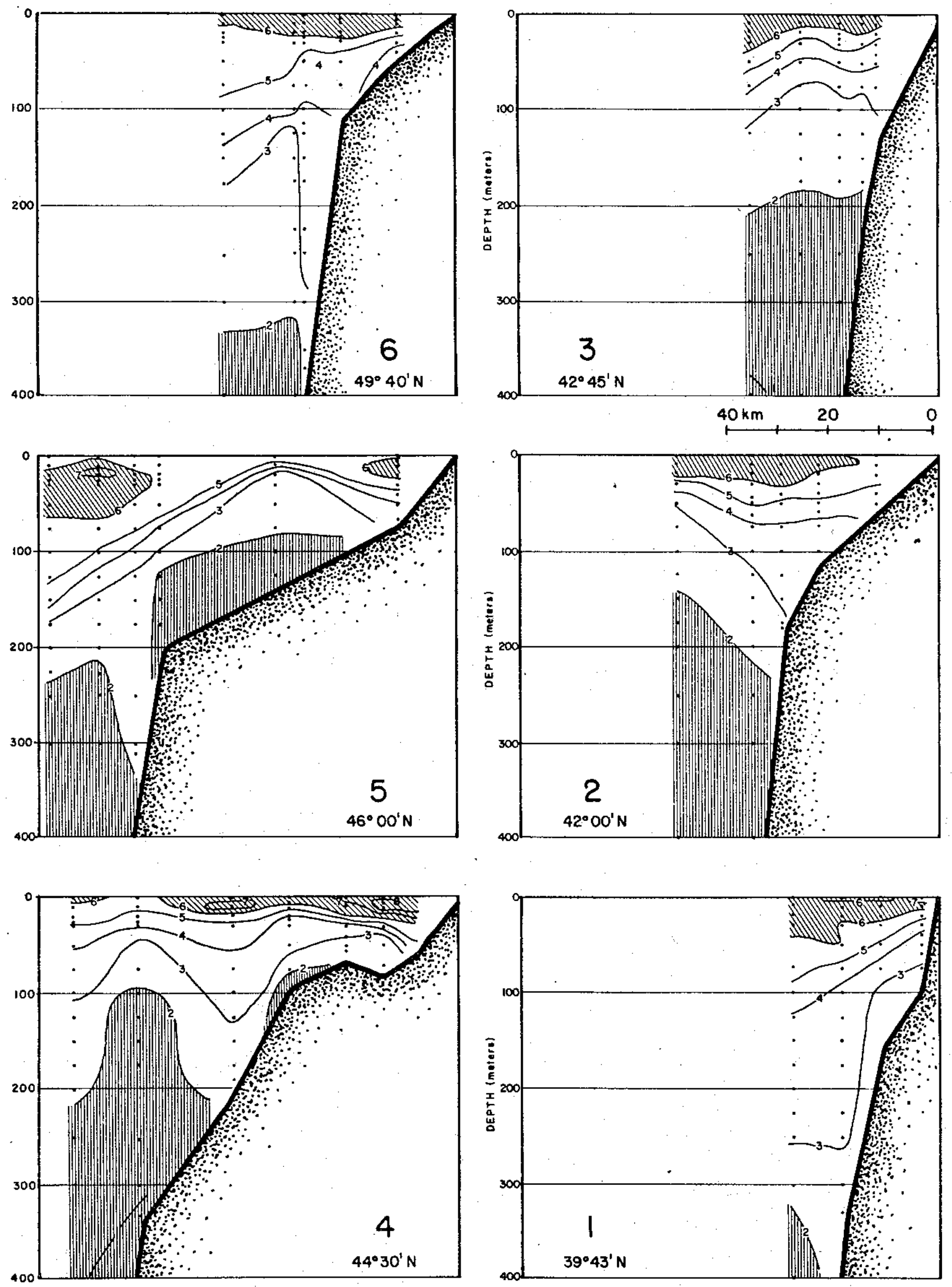

Fig. 22. Vertical distributions of dissolved oxygen (mL/L) off the west coasts of United States and Vancouver Island, summer 1977 (from Ingraham and Love 1978).

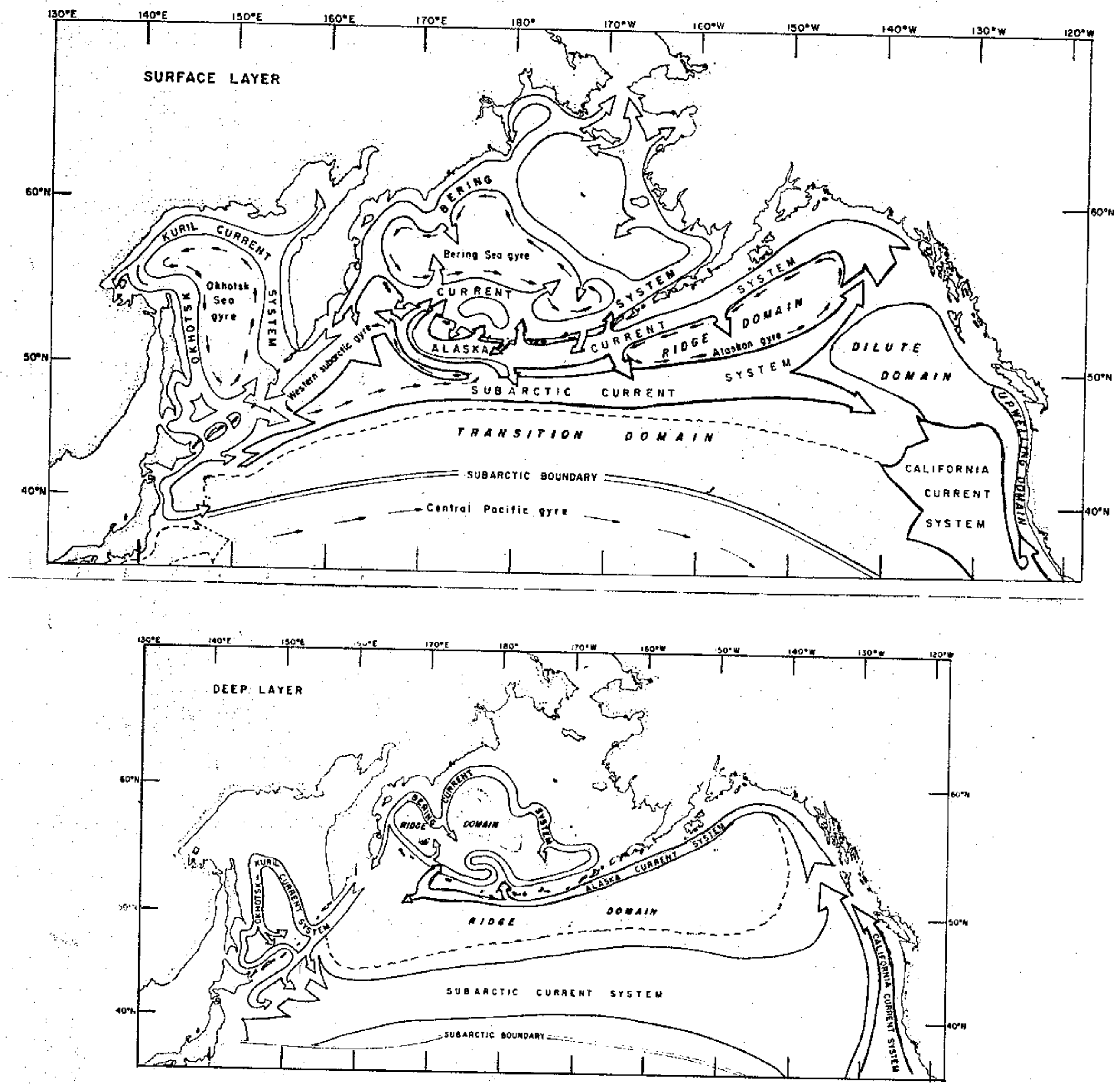

Fig. **23**. Schematic diagrams of surface and deep-water current systems in the Subarctic Pacific Region (from Favorite et al. 1976).

subsurface circulation is the near-shore northward-flowing California Undercurrent. It is sometimes referred to as the California Countercurrent, but most studies have favored the former. It is a quasi-permanent feature, with its area of influence extending generally to about 500 km offshore, and at depth between about 150-1000 m. It has been reported to exist as far south as Baja California (e.g. Reid et al. 1958, Wooster and Jones 1970) and as far north as Vancouver Island (Dodimead et al. 1963, Ingraham 1967, Favorite et al. 1976, Reid and Halpern 1976, Ingraham and Love 1978). More recently, its water mass characteristics have been identified in the deep waters of Queen Charlotte Sound and Dixon Entrance (Gardner 1982). A seasonal feature of the California Undercurrent is its strengthening, and its appearance at the surface inshore of the southward-flowing California Current from early autumn through late winter, coincident with the relaxation of the northwesterly winds. This northward winter surface flow has been referred to as the Davidson Current. There is a marked interannual variability in the California Current System (e.g. McLain and Thomas 1983). A complete review of this current system can be found in Hickey (1979).

The seasonal and interannual variability in these large-scale circulation systems result in significant changes in the surface and subsurface water characteristics of the continental shelf and slope waters off the west coast of Vancouver Island. However, their influences do not wholly dominate the oceanography of this area. It is also determined by the relative influence of the considerable and variable freshwater runoff, to the variable winds, strong tides and complex topography. As a result of these several factors, the surface (and subsurface) flow and other features are extremely variable and complex, both in time and space. Nevertheless, two basic seasonal surface flow patterns can be defined.

1. Surface Flow, Summer

In summer, a density-driven geostrophic surface current flows northward within about 35 km (20 M) of the shoreline (Fig. 24). Velocities vary considerably, ranging from 25-75 cm/sec (0.5-1.5 knots), and averaging about 50 cm/sec (1 knot) (Thomson 1981, the reprinted version of 1983). This coastal current is augmented by tidal and local wind-induced currents. Also, superimposed on these flows are tidally-controlled flows from the many sounds and bays, resulting in the formation of cloud-like masses of relatively brackish water. These clouds of estuarine water tend to dissipate enroute. However, they are continually being regenerated by additional inflows. Over the remainder of the shelf and upper continental slope, a southeasterly wind-induced surface flow usually prevails, with velocities decreasing seaward from about 50 to 25 cm/sec (1.0-0.5 knots), on average (Thompson 1981). Off the entrance to Juan de Fuca Strait, a cyclonic gyre separates the northwesterly coastal flow originating from Juan de Fuca Strait and the southeasterly offshore flow generated by the prevailing northerly winds. This upwelling center is considered to be topographically-controlled (Freeland and Denman 1982). Other surface features of the outer continental shelf and slope area are tongues, bands and cells of relatively cold and/or low-salinity water. These are attributed to extensions of features resulting from intermittent upwelling and the tidally-dominated inflows from the sounds extending seaward under favorable northerly wind conditions.

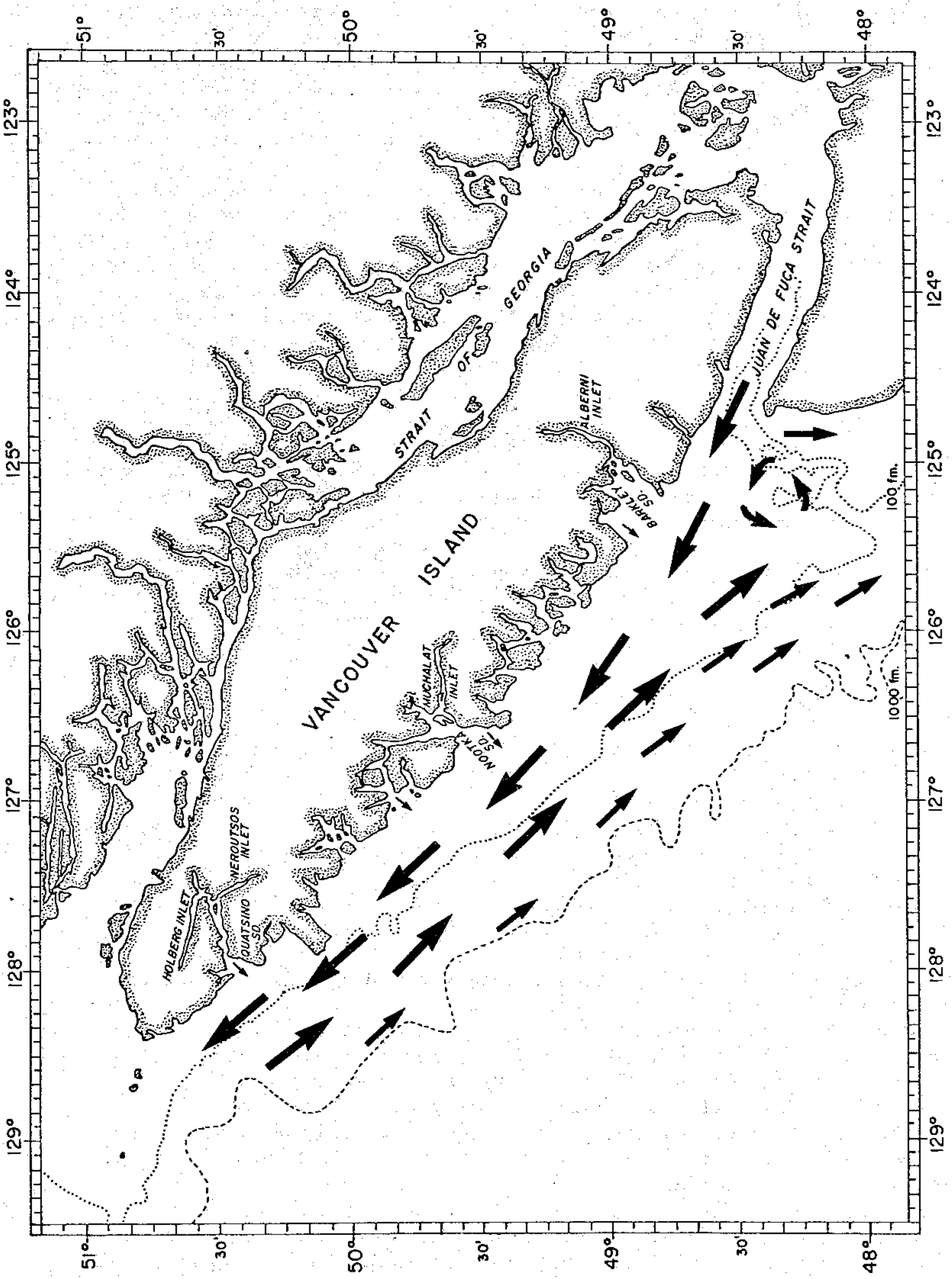

Fig. 24. Prevailing surface currents in summer off the west coast of Vancouver Island; ➡ 50 cm/sec, → 25 cm/sec (average). (Adapted from Thomson 1981).

2. Surface Flow, Winter

Throughout winter, the surface flow is generally northwesterly over the continental shelf and slope. The main feature is a relatively narrow and continuous band of low-salinity water near the coast, with velocities in excess of 75 cm/sec (1.5 knot). Its width is variable, and is determined by the magnitude of the freshwater runoff and the strength and direction of the winds but is of the order of 11-13 km (6-7 M). Over the remainder of the shelf area, velocities decrease seaward, ranging between about 50 and 25 cm/sec (1.0-0.5 knots).

3. Subsurface Flow

Below 200 m, the direction of flow is variable but a northward flow generally prevails along the continental slope during winter. This subsurface flow is considered to be a continuation of the California Undercurrent. At 200 m depth, the mean velocity is about 5 cm/sec (0.1 knots).

VII. CONVERGENT, DIVERGENT AND RELAXATION PROCESSES

In addition to these seasonal surface flow patterns that have been described, there are also two basic physical processes that not only influence the surface flow, but also other aspects of the oceanography of the continental shelf and upper slope waters. These are the convergent (downwelling) and divergent (upwelling) processes. They are dominant along most of the Pacific coast of North America, and are a result of the along-shore coastal wind conditions. The general features and conditions associated with these processes are schematically shown in Fig. 25. Winds from the south produce a northward surface drift which is deflected to the right by the earth's rotation. This in turn leads to a net onshore transport within the surface layer, resulting in an onshore accumulation of surface water and a depression of the isopycnals with a partial compensating offshore transport at depth. Resulting pressure gradients are then balanced by the establishment of a northward-flowing coastal current in the surface layer. This is a convergent or downwelling condition (Fig. 25).

The opposite condition occurs under winds from the north. The net transport is offshore, isopycnals rise near the coast, and there is an offshore transport at depth. The ensuing coastal current is southward. This is the divergent or upwelling condition (Fig. 25).

A relaxation condition exists when the winds are weak, and/or strong but variable in direction. The surface and subsurface waters adjust accordingly, but the net condition is one of level isopycnals and the lack of a wind-driven surface current (Fig. 25).

Off the west coast of Vancouver Island, deviations from the basic divergent pattern have been noted. The isopycnals do not intersect the sea surface, as occurs to the south off Oregon and California, but usually crest over the outer part of the continental shelf. This is considered to result from the fact that the divergent condition is rarely developed fully off the

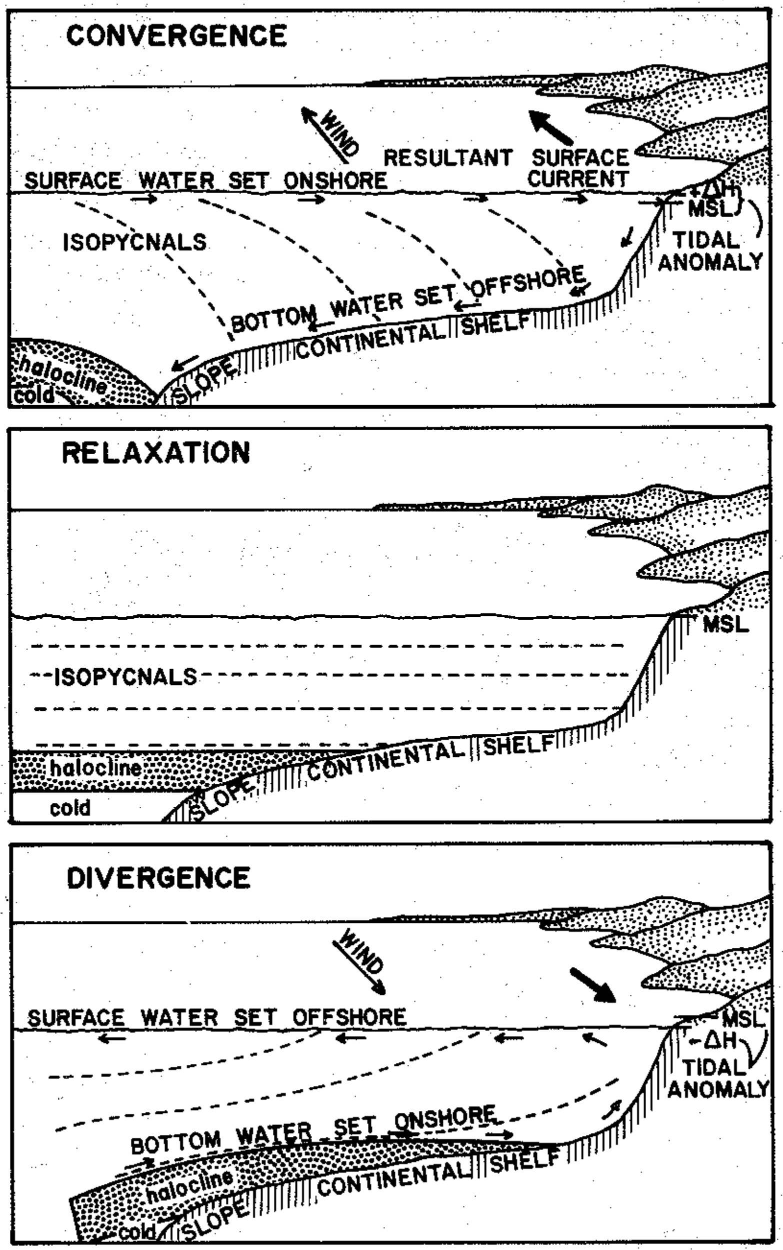

Fig. 25. Schematic of convergence, relaxation and divergence off the Pacific coast (adapted from Dodimead and Pickard 1967).

west coast of Vancouver Island, and most of the demand for replacement water near the coast is met by freshwater discharge (Lane 1963). The resulting pressure gradients result in a northward geostrophic flow near the coast, as has been noted. Over the outer continental shelf, the major contribution of replacement waters is from the underlying waters, and the wind-induced flow is typically southward.

Off the west coast of Vancouver Island, these processes are extremely variable, but nevertheless, are considered to be of major significance to the oceanography of the continental shelf and upper slope waters. Strong convergent conditions are associated with relatively high temperatures and dissolved oxygen and relatively low salinities and densities in the near-bottom waters of the continental shelf, and with strong northward surface flow over the entire continental shelf. Strong divergent conditions are associated with relatively low temperatures and dissolved oxygen, and relatively high salinity and density conditions, although the changes in the latter two parameters are relatively small. The surface flow over the outer continental shelf is southward. The seasonal and interannual variability in these processes are examined in the monthly means and anomalies of the onshore-offshore components of calculated wind-driven surface transport (Ekman transport).

VIII. EKMAN TRANSPORT

Monthly indices of the large-scale wind-induced divergence (upwelling) and convergence (downwelling) are available at selected locations along the west coast of North America. The indices are based on calculations of surface wind-driven transport (Ekman transport) normal to the coast, and are derived from monthly mean surface atmospheric pressure data (Bakun 1973). The calculation is the same as that used by Fofonoff (e.g. 1960), and continued by Wickett (e.g. 1966), except for the estimation of the pressure derivatives which differ because of the use of a different grid format. Monthly and quarterly values and anomalies for the period 1946-71 are available in Bakun (1973). Daily and weekly values for 1967-73 are also available (Bakun 1975). Subsequent data have been supplied by National Marine Fisheries Services, Monterey, CA. Other similar data are available (e.g. Fofonoff 1960, Wickett et al. 1977). Ballantyne and Wickett (1978) have also published summaries of monthly mean Ekman transport data and December-March means for selected grid points in the northeast Pacific Ocean. It is noted that the transport calculations initiated by Fofonoff and continued by Wickett were terminated in 1982.

Long-term (1948-67) mean values (Table 7) show that northward of San Francisco (lat. 38°N) the season of indicated upwelling or divergence (offshore Ekman transport - positive values) becomes restricted (Bakun 1973). Also, monthly mean values of upwelling decrease significantly from south to north. On the other hand, values of downwelling or convergence (onshore Ekman transport - negative values) generally increase between lat. 39°N and 57°N. However, there are anomalies in the latter trend, particularly between grid points 48°N, 125°W and 51°N, 131°W; long-term monthly means of onshore transport are generally greater at the former grid point. Transport values at these locations are examined as they are considered to be indicative of the convergent-divergent and relaxation conditions along the west coast of Vancouver Island.

Table 7. Monthly mean values of indices of upwelling for the 20-yr period, 1948-1967. Units are cubic meters per second per 100 m of coastline. Positive values indicate offshore transport and negative values, onshore transport (from Bakun 1973).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
60°N,149°W	−138	−86	−46	−11	0	6	6	6	−3	−26	−73	−109
60°N,146°W	−180	−103	−48	−12	−2	6	5	3	−9	−34	−94	−129
57°N,137°W	−212	−117	−51	−24	−11	0	1	−6	−29	−88	−140	−163
54°N,134°W	−97	−68	−27	−20	−10	1	3	−1	−23	−82	−98	−91
51°N,131°W	−64	−36	−12	−5	4	15	16	12	−3	−40	−58	−57
48°N,125°W	−90	−47	−21	0	18	25	34	22	4	−39	−88	−100
45°N,125°W	−94	−47	−15	9	34	48	74	50	16	−20	−73	−93
42°N,125°W	−67	−28	3	33	79	103	132	91	36	0	−42	−57
39°N,125°W	−13	9	36	69	124	168	182	139	63	20	−7	−12
36°N,122°W	11	35	80	121	203	239	198	183	94	49	12	7
33°N,119°W	19	48	120	178	282	312	231	212	137	76	22	10
30°N,119°W	56	77	116	141	199	199	143	142	129	103	65	54
27°N,116°W	71	93	119	148	202	195	114	105	110	106	74	63
24°N,113°W	51	74	93	116	143	129	48	44	49	69	52	39
21°N,107°W	18	39	97	100	87	39	3	5	−14	−15	8	8

It is noted that, for the remainder of this discussion on onshore-offshore Ekman transports, onshore transport is considered to be positive, and offshore transport negative, opposite in sign to those reported by Bakun (1973) and in subsequent listings provided by the National Marine Fisheries Service, Monterey, CA. The signs were reversed to make the data compatible with other similar data and presentations, as examples, Ballantyne and Wickett (1978) and Dodimead (1980).

Monthly mean values for 1946-82 and anomalies from the 1946-80 long-term monthly means at lat. 48°N, long. 125°W and lat. 51°N, long. 131°W are presented in Appendix tables 7 and 8, respectively. The number of standard deviations in the monthly anomalies for both grid points are presented in Appendix table 9. Generally, the long-term monthly means for the period 1946-67 (Table 7) and the newly calculated 1946-80 long-term means (Appendix tables 7 and 8) are not significantly different. Except for the October-February period, the means are within 5 units. It is also noted that during the November-February period, when transports are a maximum, an anomaly equivalent to one standard deviation reflects a substantial increase or decrease in the monthly value, from 2/3 to nearly the equivalent of the long-term monthly mean values.

Off southern Vancouver Island (48°N, 125°W), upwelling (divergence) is indicated as prevailing from May through August, and downwelling (convergence) from October through March (Table 7 and Appendix table 7). The long-term monthly means are small and negative (offshore transport) for April and September. These are considered to be periods of relaxation as transports are small and/or fluctuating between offshore and onshore. North of Vancouver Island (51°N, 131°W), onshore transport prevails from October through April, and offshore transport from June through August; the long-term monthly means are small for May (offshore) and September (onshore) (Appendix table 8). The latter months are also considered to be periods of relaxation. At these latitudes, onshore transport is considerably larger than offshore transport; maximum long-term monthly mean values are nearly 3 times the maximum values of offshore transport. Thus, these data indicate that convergence is the more intense and persistent of the two processes at these latitudes.

These data, as indices of the onshore-offshore processes, have been used with considerable success in correlating variability in year-class strengths of several fisheries with ocean variability particularly to the south from Washington to California (e.g. Bakun and Parrish 1980). Three features of these data that appear most applicable to fisheries oceanography studies off the British Columbia coast, at least at our present state of knowledge, are discussed. First, the largest transports and anomalies are associated with the October-February period. Conditions in this period, and in the following months, are considered critical to the time of spawning, survival and growth of the egg, larval and juvenile stages of many groundfish and pelagic species. Surface drift during these stages may be a dominant environmental factor.

A second feature of these data is the variability in the timing of the change from prevailing onshore transport (convergence) in October-March to relaxation, generally in April-May, to the prevailing, but usually intermittent, offshore transport (divergence) in June-August, with relaxation again in September. The timing of these sequences of events reflects the time at which the typical winter conditions of relatively warm and high-dissolved oxygen waters immediately overlying the continental shelf are replaced by the typical summer conditions of relatively cold and low-dissolved oxygen water. As noted previously, the seasonal changes in salinity and density are relatively small. Also, a change in the seasonal surface circulation pattern occurs from about mid-shelf to seaward.

The third feature is the variability in the intensity of upwelling in summer (June-August). The latter two features in these data may be significant, directly or indirectly, in the distribution, migration, growth, and year-class strengths of some groundfish, pelagic and shellfish species, and salmonids, because they reflect changes in both surface and bottom conditions, enhanced biological production, and formation of such physical features as fronts, tongues and eddies. These three features of the data are discussed in the following.

Monthly mean values for 1946-82 and anomalies from the 1946-80 long-term monthly means are presented in Fig. 26. It is again noted that onshore transport is positive and offshore transport, negative. Therefore, a positive (negative) anomaly in October through March reflects a greater (smaller) than average onshore transport, and a negative (positive) anomaly in

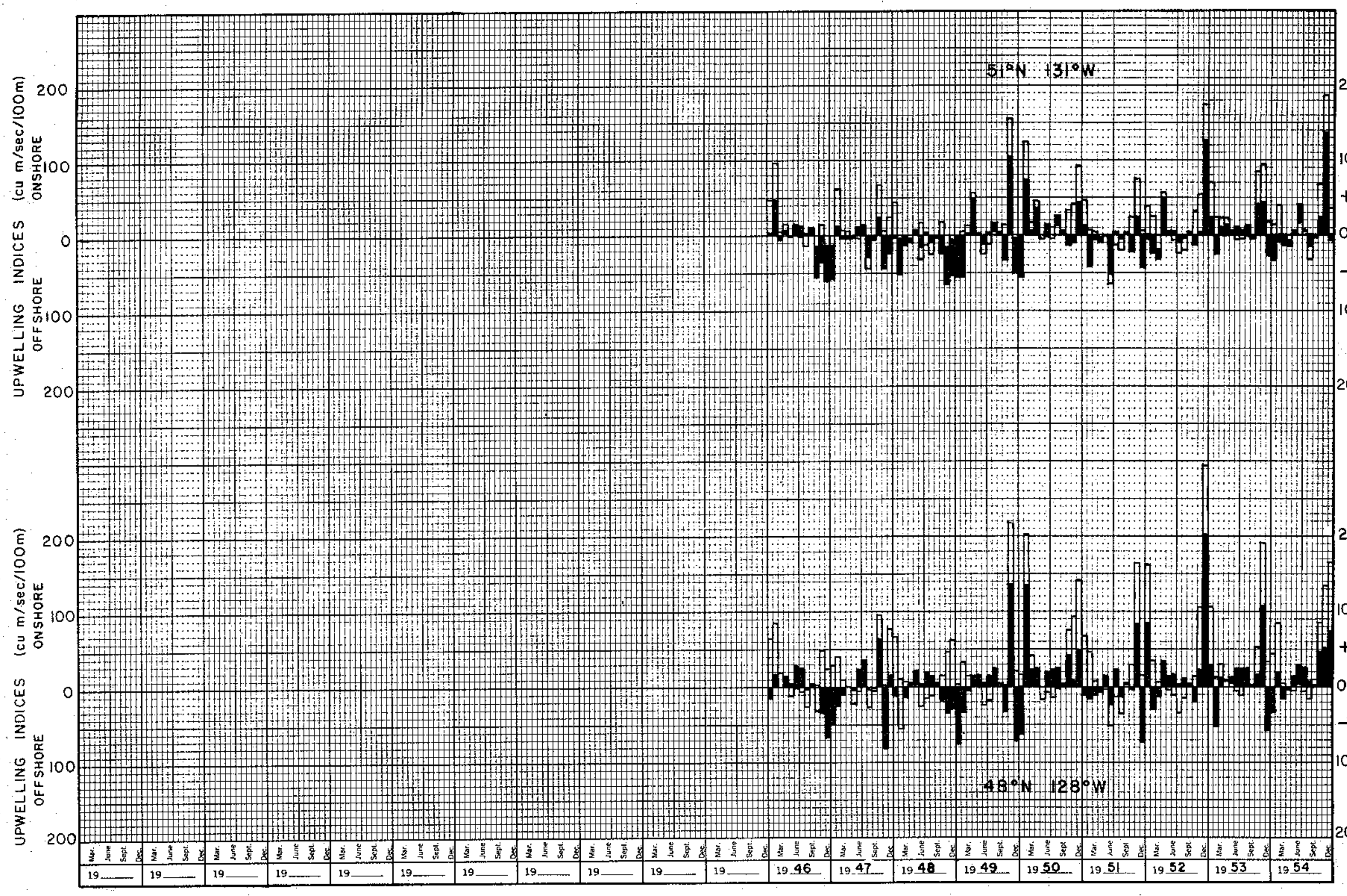

Fig. 26. Ekman transport normal to the coast (open bars) and anomalies (solid bars) at 48°N, 125°W and 51°N, 131°W, 1946-82. Values are from Bakun (1973) and printouts provided by the National Marine Fisheries Service, Monterey, CA, but the signs have been reversed. A positive anomaly for onshore transport indicates a greater than average onshore transport and a negative anomaly for offshore transport indicates a greater than average offshore transport.

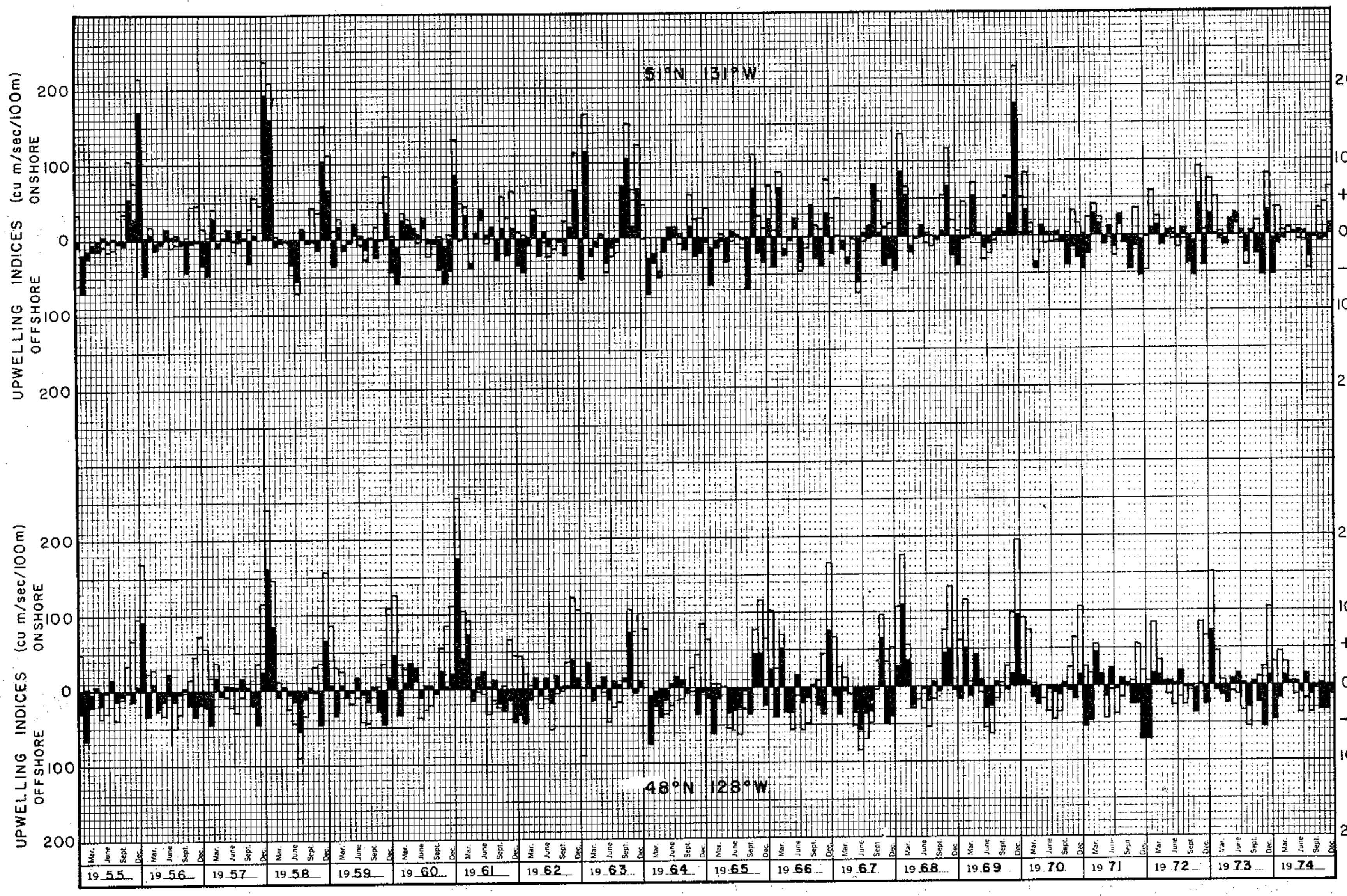

Fig. 26 (cont'd)

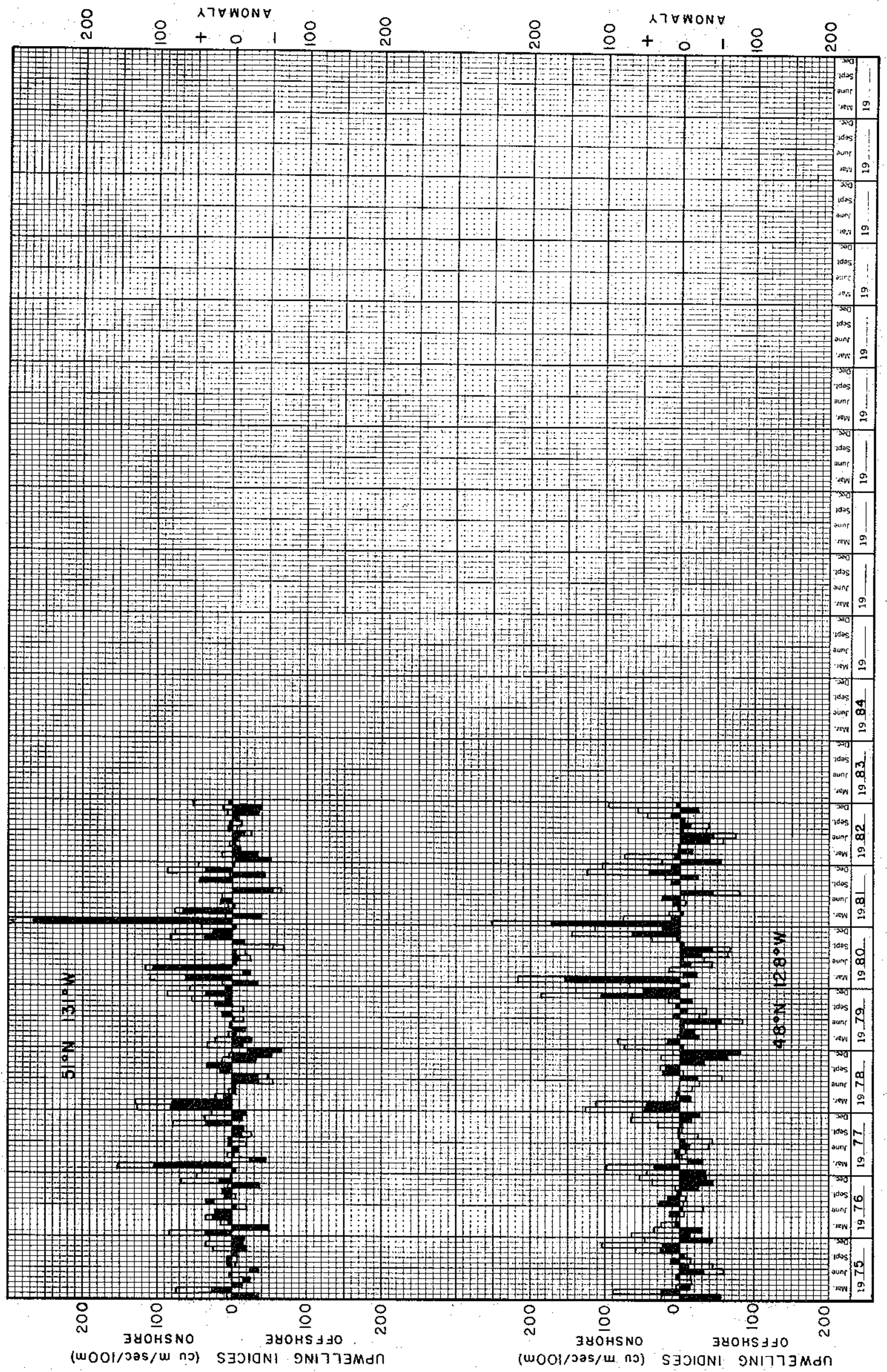

Fig. 26 (cont'd)

June through August, a greater (smaller) than-average offshore transport; similarly for the other months, depending on their signs.

Within the October-March period, monthly means of onshore transport were anomalously large to above average in 1949-50 (Nov, Feb, Mar), 1954 (Oct-Dec), 1958 (Jan, Feb), 1960-61 (Nov, Jan-Mar), 1965-66 (Oct, Nov, Mar), 1967-68 (Oct, Feb, Mar), 1978 (Jan, Feb), 1979-80 (Nov, Dec, Feb), 1980-81 (Nov, Jan). During those months of anomalously large onshore transports, an intensification in the northward flow over the continental shelf and slope is indicated. This will be accompanied by a strong advection of the relatively warm surface waters from the south, and an onshore retention of these and the low-salinity coastal waters. The upper range of winter conditions (high temperatures, low salinities, high dissolved oxygen) in the bottom waters of the continental shelf and upper slope can be expected. The anomalously warm bottom waters in Jan-Feb 1958, Jan-Feb 1978, and Jan 1981 are confirmed in the data presented in Table 4 and by Douglas and Wickett (1978) and Dodimead and Ballantyne (1984), respectively.

Anomalously small to below-average onshore transports within the October-March period prevailed in, 1946-47 (Oct-Jan); 1947-48 (Nov, Feb, Mar, but relatively large in Oct); 1948-49 (Oct-Feb); 1955 (Jan-Mar); 1959-60 (Oct, Nov, Feb); 1961-62 (Oct, Dec, Jan-Mar); 1971-72 (Oct-Jan); 1973-74 (Nov, Jan); 1974-75 (Oct, Nov, Jan, Mar); 1976-77 (except Feb); 1978-79 (Oct-Dec, Mar); and 1981-82 (Oct, Jan, Mar). The occurrence of relatively small transports during this period reflects a weak convergent condition. Cold surface conditions in a reduced northward surface flow are indicated. Bottom water conditions over the continental shelf and slope edge can be expected to be at the lower range of winter temperature conditions, or near the upper range of the cold summer conditions, e.g. Jan-Feb 1957 (Table 4).

Anomalies in the spring transition from convergence to relaxation or to divergence, and in the intensity of summer divergence (upwelling) are also indicated in the transport data. Early relaxation of convergence, or an early onset of divergence, is indicated in: 1955 (Feb) with negligible net transports in February and March, followed by an anomalous large net offshore transport (divergence) in May; 1964 (Feb) with small net offshore transports in February and March, followed by anomalously large net offshore transports in April and May; 1965 (Feb) followed by anomalously large offshore transports in May and June; 1970 (Mar) followed by an anomalously large offshore transport in April; 1977 (Mar) with a net offshore transport; and 1980 (Mar) with a small net offshore transport. An early change in the winter to summer flow pattern and bottom-water conditions is indicated for these years.

Summer months (June-August) during which anomalously strong divergence is indicated are: 1951 (June), 1958 (June, July), 1963 (June), 1965 (June, July), 1967 (June-Aug), 1969 (June, July), 1973 (Aug), 1974 (Aug), 1980 (July, Aug), 1981 (July) and 1982 (June). During these periods, a reduction in the prevailing northward near-shore coastal flow, and an increase in southward flow along the outer continental shelf and slope are indicated. The lower range of summer bottom-water conditions (low temperatures, etc) can be expected. However, strong intrusions of warm water along the continental slope as a result of a strengthening of the California Undercurrent, coupled with marked offshore surface transport, may result in bottom temperatures higher than normally expected under these conditions along the outer continental shelf and upper slope. Also, higher salinity and lower dissolved oxygen concentrations can be expected under these circumstances, as these are features of the California Undercurrent water. In summer, large offshore transports at 48°N, 125°W were generally associated with very low precipitation at Amphitrite Point, since the prevailing winds also bring fair-weather conditions; e.g. June-August 1958, June 1965, 1967 and 1969 and, to some extent, June 1970. On the other hand, very high precipitation in summer was generally associated with relatively low offshore transport; e.g. June 1963, July 1964, June 1971, July 1972, June 1973, July 1974, 1975 and 1978 and June 1981.

The transition or relaxation period from summer to winter conditions generally occurs in September, as indicated in the long-term monthly means. However, in 1946, 1949, 1966, 1971, 1972, 1974, 1976, 1978 and 1981, the relaxation process prevailed through October, as indicated by the relatively small net transports.

At the northern grid point, anomalouly large onshore transports prevailed in September 1963, 1967, and 1981. These were also periods of warm surface-layer conditions along the coast of British Columbia. These combined conditions in September appear to be suitable for the transport of Manilla clam larvae from northern Vancouver Island across Queen Charlotte Sound, with their subsequent survival, and the establishment of year-classes of the clams on those shores of Queen Charlotte Sound where surface-layer temperatures remained favorable. A year-class was established in 1963, and again in 1967 (Bourne 1982). A strong 1981 year-class should also appear, since surface temperature and onshore transport conditions appeared to be favorable.

IX. SEA LEVEL

Sea level data have also been shown to reflect several physical processes and flow conditions. The relationship of sea level data and oceanic and outer coastal circulation patterns is well documented, as examples, Reid and Mantyla (1976), Smith (1974), Huyer et al. (1976), Huyer et al. (1978) and very recently, McLain and Thomas (1983). Reid and Mantyla (1976) report that the high elevations of sea level in winter are a consequence of the circulation of the Subarctic cyclonic gyre of the North Pacific Ocean. The flow of the coastal limb of this gyre along the eastern, northern, and western boundaries are intensified in winter, and in geostrophic balance; sea level slopes upward toward the coast, thus accounting for winter rise in sea level. Smith (1974) noted alternative 1- or 2-week deviation in the coastal currents off Oregon over a 7-week period. He showed that adjusted sea levels (corrected for atmospheric pressure) fluctuated in phase with the flow on this time scale. Over the mid-shelf area off the west coast of Vancouver Island, sea level fluctuations were very coherent with the near-surface current fluctuations, high sea level was associated with strong northward flow (Huyer et al. 1976). Off the coast of Oregon, the alongshore components of wind sets up currents that are in geostrophic balance, and the pressure gradients generated by these currents force sea level up at the shore for southerly winds and downward for northerly winds (Huyer et al. 1978). McLain and Thomas (1983) reported that interannual fluctuations of alongshore currents off California can be inferred from fluctuations of sea level at coastal tide gauges. The anomalous elevations of the sea surface along the coast were associated with anomalous increases in the northward alongshore currents off California.

Sea level data may be of considerable significance in studies of the fisheries and the ocean climate off the waters off the British Columbia coast since long records of sea level are available for many locations along the Pacific coast. Monthly mean values for British Columbia stations are readily accessible through 1977 (Marine Environmental Data Services and the Canadian Hydrographic Service 1979). Recent data are regularly provided by Tide and Currents, Institute of Oceanography, Sidney, B.C. In these data, most of the tidal effects, which are relatively short-term, are averaged by calculating monthly means of the hourly tide height observations. These data then provide the nontidal oscillations in sea level but still include meteorlogical and oceanographic factors which contribute significantly to variations in sea levels. These factors include atmospheric pressure, wind, density of the water column (steric), coastal trapped waves, and alongshore components of ocean currents. The data can be corrected to eliminate a major effect of atmospheric pressure (inverted barometer effect - 1 mb change in air pressure is approximately equivalent to 1 cm change in sea level) which are then reported as adjusted sea level values.

Waldichuk (1964) has reported on many of the features of sea level for several of the British Columbia tide-gauging stations. Features discussed include the seasonal cycle, and atmospheric pressure, steric (density) and freshwater effects on daily sea level changes, and on the annual range. He noted that seasonal trends in sea level and barometric pressure were roughly inversely related; low pressure and high sea level prevail during autumn - winter, and high pressure and low sea level characterize spring and summer. Large day-to-day changes in sea level were always associated with large and rapid changes in atmospheric pressure. In the Strait of Georgia, a midsummer sea level rise coincided with the period of peak runoff from the Fraser River.

Recent studies of British Columbia sea level data include those of Crawford (1980) and Crawford et al. (1980) Thomson and Tabata (1981). Air pressure records at the coast (Tofino, B.C.) and offshore (Union Seamount, Lat. 49°35'N, Long 132°45'W) were similar, but adjusted sea levels at Tofino and bottom pressures at Union Seamount showed no similarity for the period studied (Crawford et el. 1980). This was attributed to other effects contributing to changes of sea level at Tofino, such as wind and wind-generated shelf waves. An examination of sea level at coastal stations showed that, when there is a tendency for wind and pressure to act at the same time to change sea level in the same direction, there is a tendency for an inverted barometer overshoot; individual peaks in sea level and air pressure correspond on a one-to-one basis, but are larger for sea levels. When there is an inverted barometer overshoot, oscillations of adjusted sea levels have a shape similar to recorded sea levels, but of smaller amplitude (Crawford 1980). The work of Thomson and Tabata (1981) was done to show the several new analytical techniques that could be applied in the analysis of sea level data and the information provided.

The location of Tofino is considered near enough to the open coast that the sea-level data at this location may be indicative of conditions and processes in the open continental shelf waters off the west coast of Vancouver Island. The annual cycle and monthly anomalies of sea level are discussed, and its significance to some aspects of the oceanography of the continental shelf and slope waters off the west coast of Vancouver Island are noted in the following.

The annual cycles of sea level (Fig. 27) and monthly anomalies of unadjusted (1940-82) and adjusted sea level (1946-81) at Tofino B.C. are presented (Fig. 28). Listings of unadjusted and adjusted monthly means and anomalies, and long-term monthly means and standard deviations are given in Appendix tables 10 and 11, as provided by the National Marine Fisheries Service, Monterey, CA. The numbers of standard deviations in the monthly anomalies are provided in Appendix table 12.

The greatest variability, as indicated by the standard deviations (Fig. 27), and the largest anomalies occur most frequently during mid-autumn through early spring (October-March) (Fig. 28), very similar to those features of Ekman transport. A good coherence appears to exist between monthly anomalies of sea level and Ekman transport, particularly during the October-March period; anomalously low (high) sea levels were generally associated with anomalously small (large) onshore transport during this period. In some cases, changes in sea level anomalies appeared to lag changes in transport anomalies.

During summer (June-August), anomalously low (high) sea levels were, to a fair degree, associated with anomalously large (small) offshore transports. In several cases, steric effects, primarily associated with temperature, were obvious in the sea level anomalies, and in a few cases dominated. Steric effects appear to be particularly significant in 1958 and 1967. In summer 1958, monthly mean sea levels were generally anomalously high; contarily, offshore Ekman transport was much above average. In summer 1967, offshore transports were persistently anomalously large and sea levels anomalies were small, from positive to negative. These were periods of anomalously warm (1958) and average to above-average (1967) surface temperatures in the coastal (see following section) and the offshore waters. The warm surface conditions in the summer of 1958 were also associated with a marked intrusion of warm water at depth (now associated with the California Undercurrent) (Tully et al. 1960). A warm-water subsurface intrusion did not appear to be as marked in 1967 as in 1958 (Favorite et al. 1976).

These examples may be of considerable significance in that it may be possible to identify anomalous intrusions of the California Undercurrent off the British Columbia coast in summer in sea level and transport data, if they deviate markedly from their expected summer relationship, i.e. large offshore transport and anomalously low sea level, and considering surface layer effects.

Early shifts from convergence to relaxation or divergence in 1955 (Feb), 1964 (Feb), 1965 (Feb), 1970 (Mar), 1977 (Mar), 1980 (Mar), as indicated in the transport data, were associated with a change in the sign of the sea level anomalies from those of the previous months; from positive anomalies to large negative anomalies.

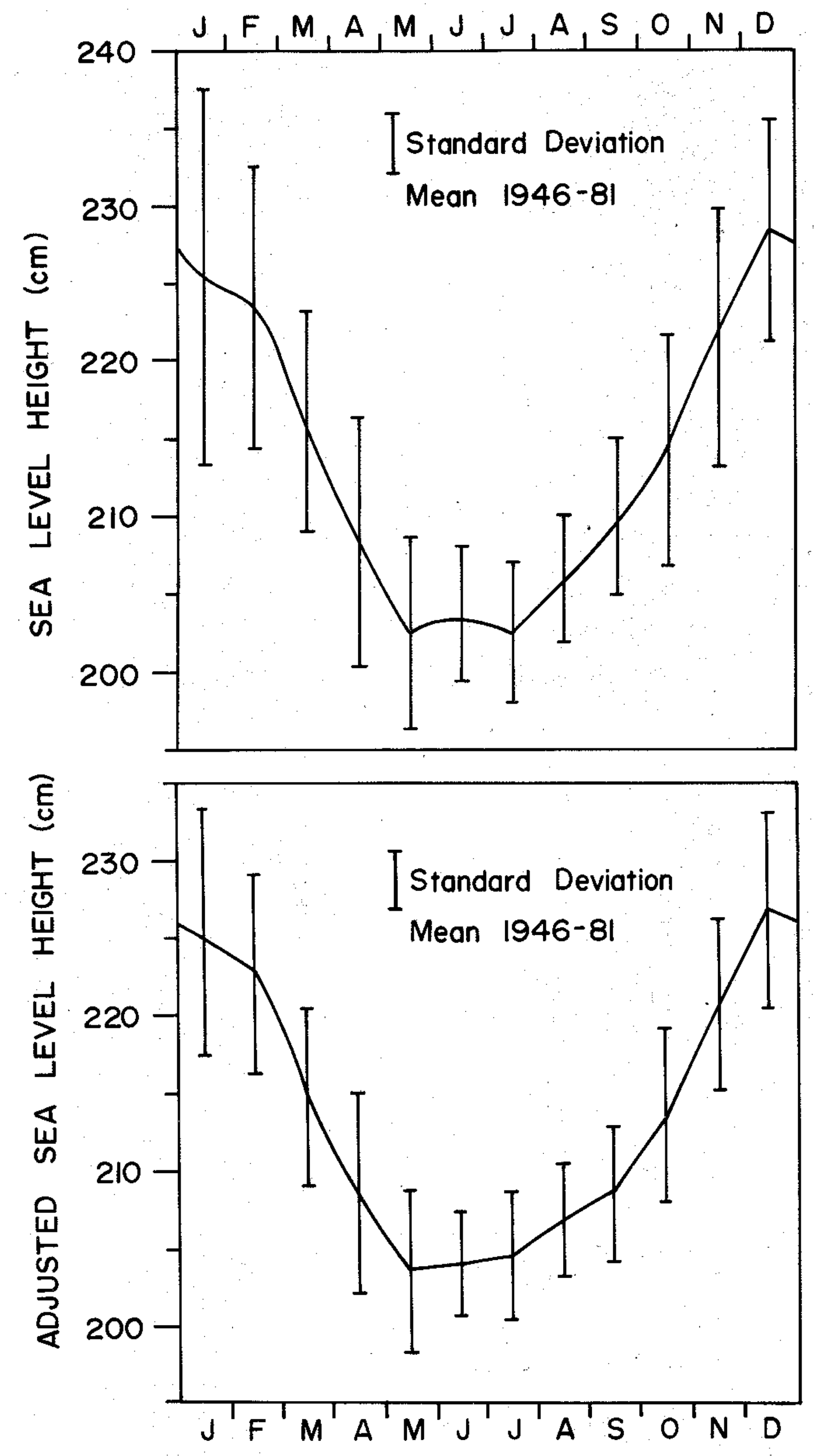

Fig. 27. Annual cycle of sea level at Tofino, B.C.

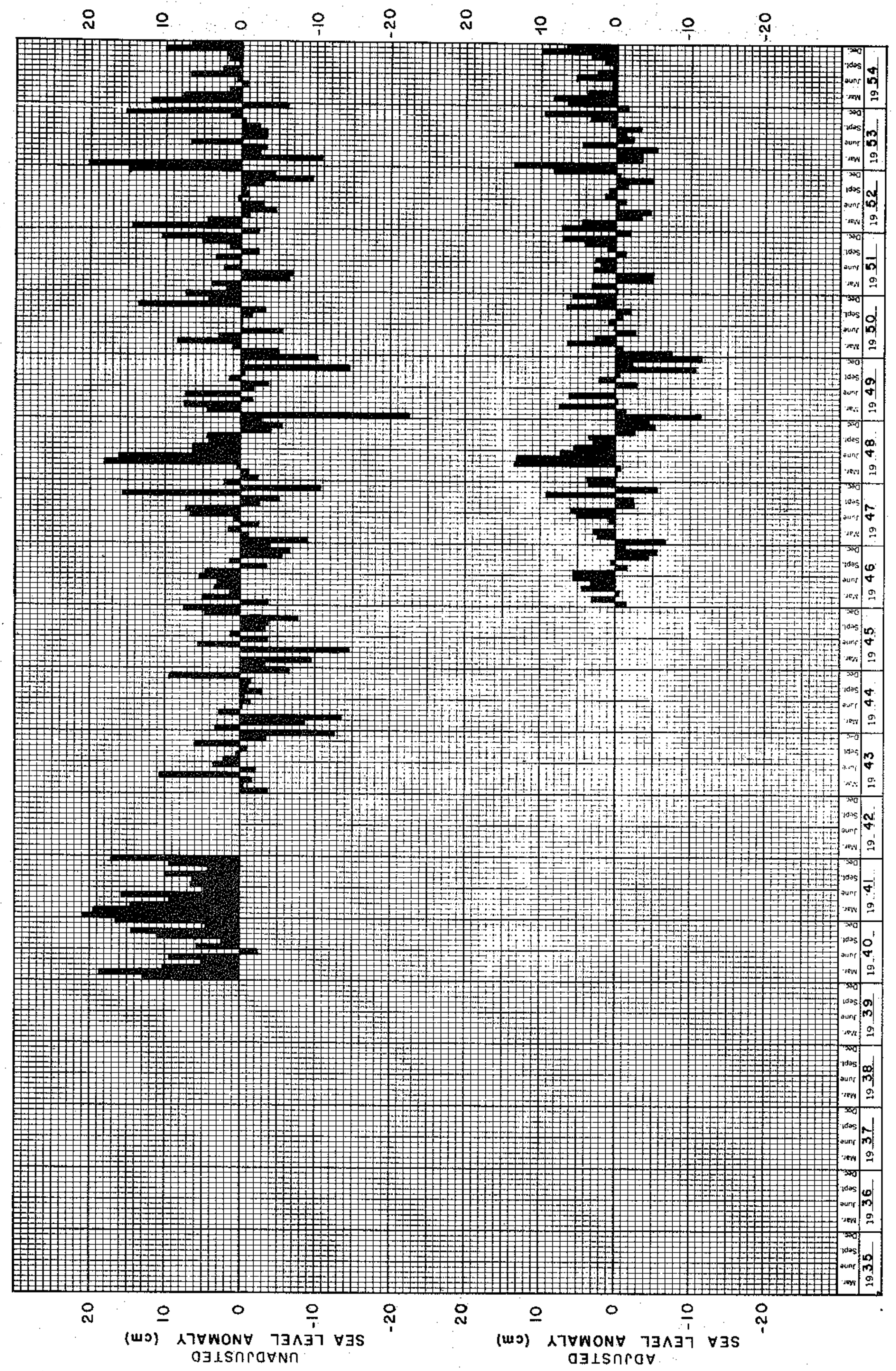

Fig. 28. Sea level anomalies (cm) at Tofino, B.C.

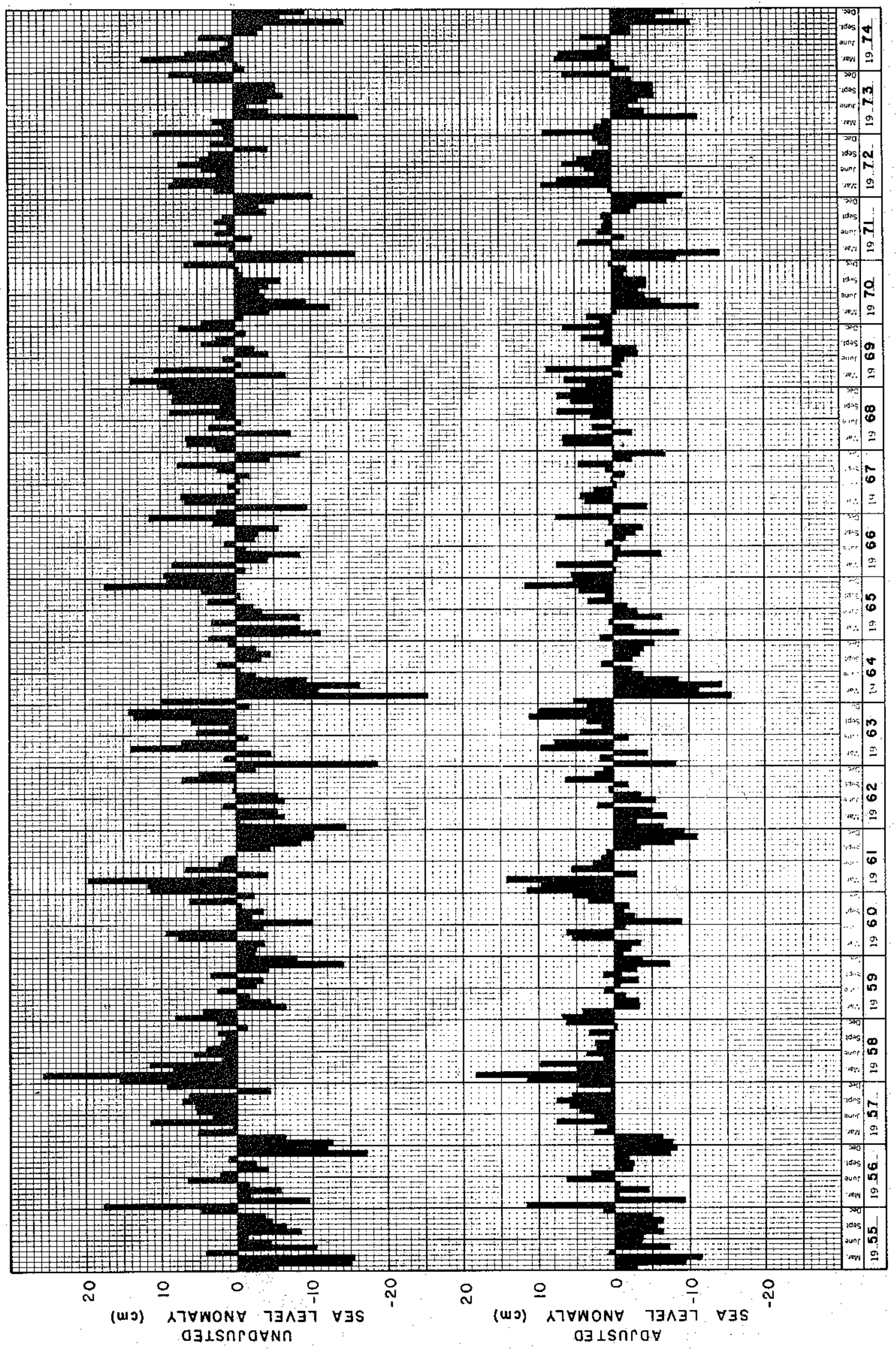

Fig. 28. (cont'd)

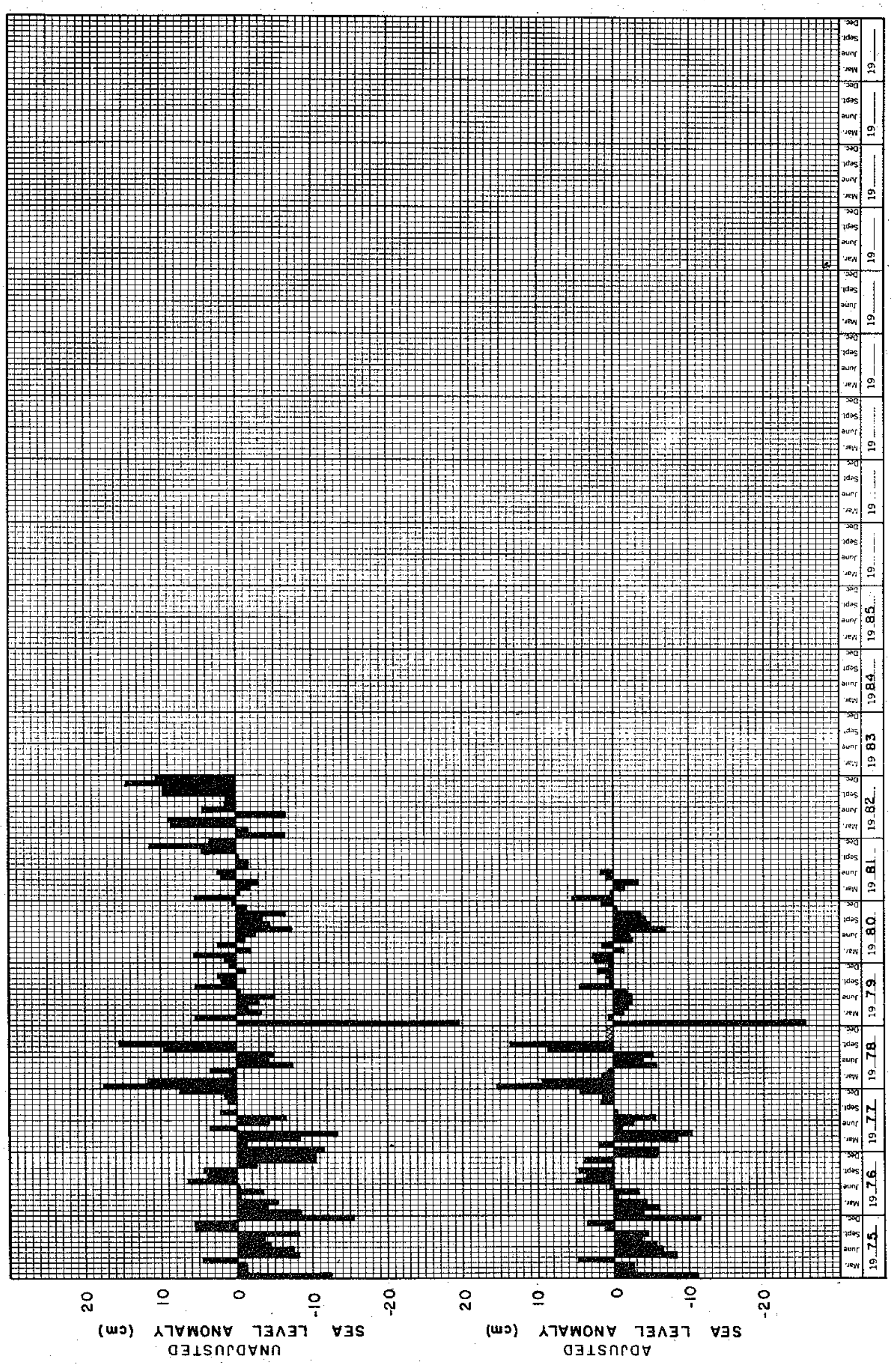

Fig. 28. (cont'd)

X. SEA SURFACE CONDITIONS AT COASTAL LIGHTSTATIONS

The long-term records of daily sea surface temperature and salinity available for many of the British Columbia coastal lightstations have been particularly useful in identifying annual cycles, long-term trends and variability in the ocean climate, at least for the coastal surface waters off the British Columbia coast. During late winter-early spring period, they also reflect near-bottom water conditions on the continental shelf, since these waters are governed by local surface cooling and mixing, advection, and the convergent process.

Listings of monthly and annual means (°C) and anomalies, and long-term monthly and annual means and standard deviations at Amphitrite Point and Kains Island are provided in Appendix tables 13 and 14, respectively. The number of standard deviations in the anomalies are listed in Appendix table 15.

1. Annual Sea Surface Temperature Cycle

The annual sea surface temperature cycles at Amphitrite Point and Kains Island are similar and show the characteristic features of the surface temperature régime for these waters; a maximum in August and a minimum in February (Fig. 29). The minimum and maximum monthly mean values, and hence annual range, are similar for each station; 7.7-13.1°C (45.9-55.6°F) at Amphitrite Point and 7.5-13.1°C (45.5-55.6°F) at Kains Island, indicating these stations have generally like exposures, and the waters in their vicinity are subject to similar heating, cooling, mixing and advective processes. The standard deviations vary from 0.6 to 1.0°C (1.1-1.8°F); the greatest variability occurs in November through February.

2. Annual Sea Surface Temperature Anomalies

Deviations (anomalies) of yearly averages from the long-term annual mean temperature show trends and anomalies similar to those observed at the northern stations and described by Dodimead (1980). The annual anomalies indicate a heating trend during the 1930's peaking in 1941 (Fig. 30). From 1941 to 1950, a cooling trend occurred, followed by warming to 1963, and cooling thereafter to 1972. The current warming trend is considered to be close to peaking, followed by a general cooling trend commencing about 1984. This is based on the premise that a 10-12 year cycle occurs in these and other sea surface temperature data. Recently, Mysak et al. (1982) reported coherent signals in these data corresponding to periods of 11, 5-6, and 3 and 2.3 years.

Extremely high annual mean sea surface temperatures (large positive anomalies) are indicated for 1940, 1941, 1958, 1963, and 1967, and for 4 consecutive years, 1978-81 (Fig. 30). Although temperature conditions were anomalously warm throughout most of 1958, the average to cool conditions during the latter part of the year reduced the magnitude of the annual anomaly below those of other years, in some cases. Very low annual mean surface temperatures are indicated for 1950, 1955, 1956, and for 3 consecutive years, 1970-72.

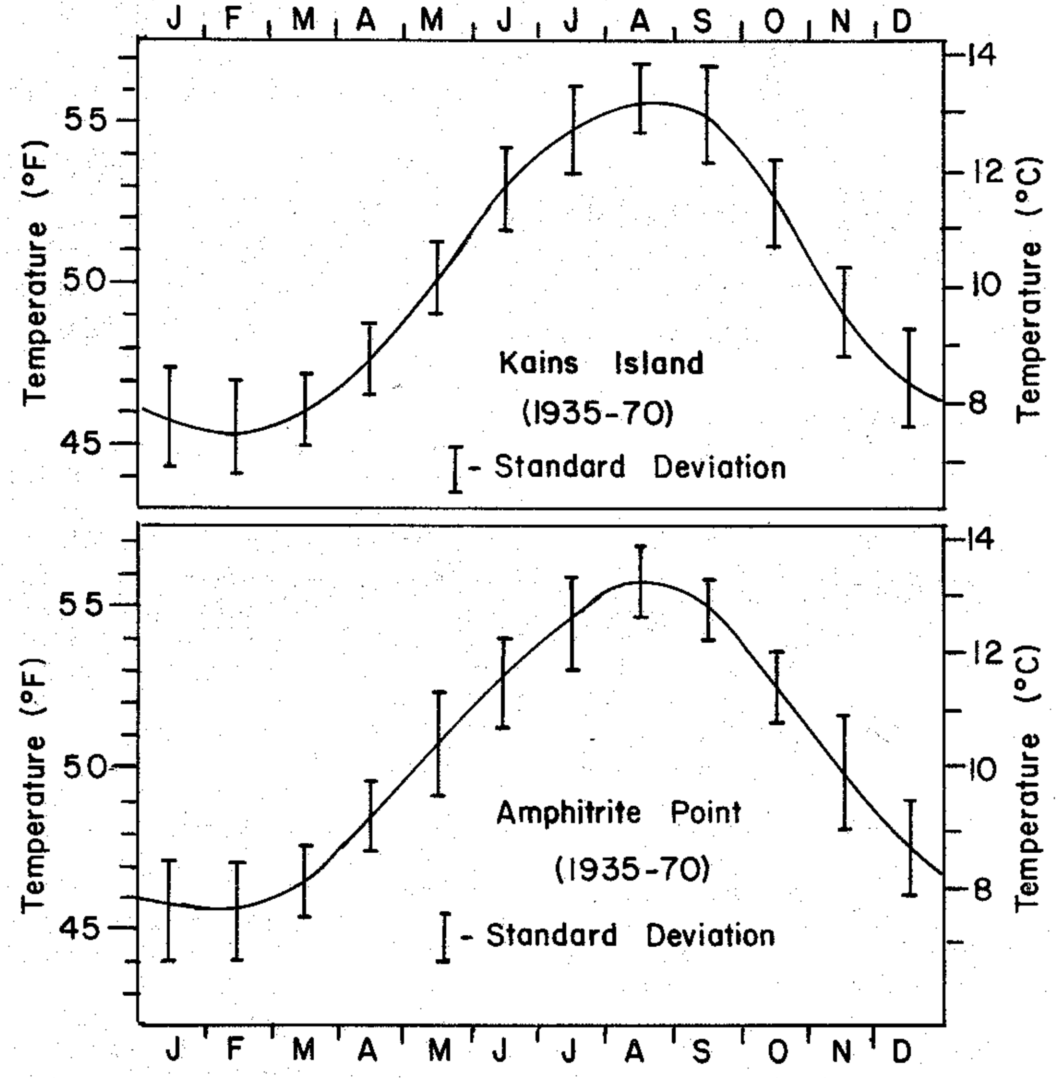

Fig. 29. Annual sea surface temperature cycle at Amphitrite Point and Kains Island, Vancouver Island.

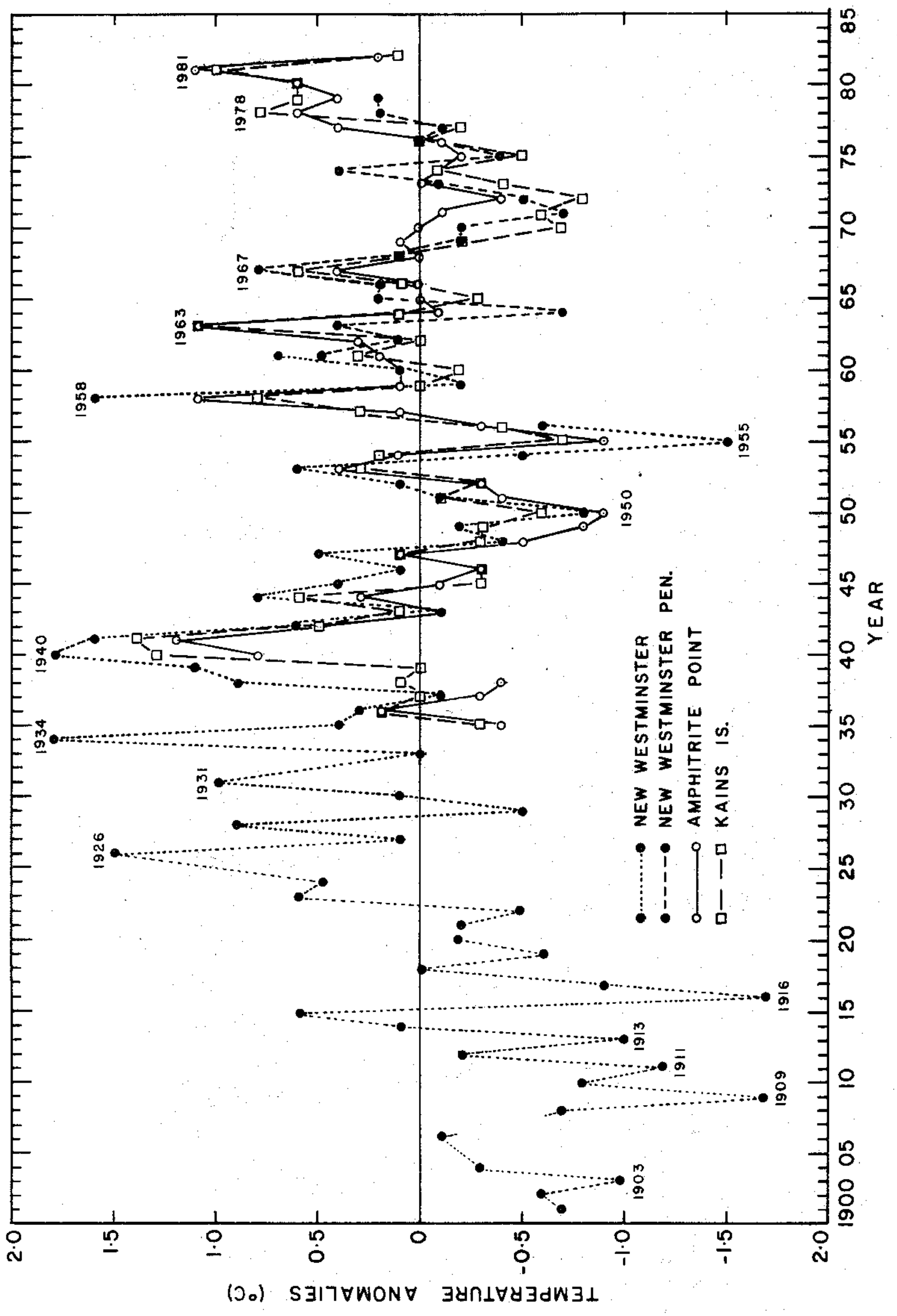

Fig. 30. Annual sea surface temperature anomalies at Amphitrite Point and Kains Island, 1935-82, and annual air temperature anomalies at New Westminster, B.C. 1901-80.

Trends and large anomalies in annual mean sea surface temperatures prior to 1935 may be of significance to some fisheries studies. These can be identified in annual mean air temperatures. Powell (1965) has reported on air temperature (and precipitation) trends in British Columbia for the period 1890-1960. Five-year running annual means indicate an upward trend which began within the 1910-18 period and continued until 1940-42. A rapid decrease followed from the early 1940's to 1950, continuing at some stations until 1955. An upward trend followed. The latter trends generally coincide with the sea surface temperature trends. Since a long record of air temperatures was readily available for New Westminister, these data were used. In Figure 30, it is apparent that trends and large annual anomalies in air temperature at New Westminister and sea surface temperature at Amphitrite Point and Kains Island are generally closely related. Therefore, prior to 1935, high sea surface temperature conditions are indicated for 1926, 1931 and 1934; and low temperatures for 1903, 1909, 1911, 1913 and 1916. A sea surface warming trend from 1909 to 1940-41 is also indicated.

Although the discussions of the time-series data in this report are limited to data to the end of 1982, it is noted that anomalously warm sea surface conditions prevailed in 1983, at least to October, associated with the 1982-83 El Nino event. It appears that the 1983 annual anomaly will be about 1.4°C at Amphitrite Point and Kains Island, and will likely be the peak of the recent warming trend.

3. Monthly Sea Surface Temperature Anomalies

Monthly sea surface temperature anomalies at Amphitrite Point and Kains Island are also similar to those reported recently for the northern stations (Dodimead 1980). From 1936 through early 1945, large positive anomalies (warm surface conditions) were dominant in the monthly means (Fig. 31). Warm surface conditions prevailed in summer 1936, generally throughout 1940, 1941, and 1942, and in winter 1944-45. This warm period was followed by a lengthy period from mid-1945 through early 1957 during which there was a dominance of large negative anomalies (cold surface conditions). During this period, the largest anomalies generally occurred during mid-autumn-early spring (October-March); conditions during this period were anomalously cold in 1946-47, 1948-49, 1955-56, and 1956-57. During the 1945-57 period, temperatures in summer were also generally low, except in 1947, when temperatures were relatively high. From mid-1957 through 1967, there was a dominance of anomalously warm surface conditions; mid-1957 through summer 1958, winter 1960-61 and continuing through summer, late 1962 and continuing through early 1964, and during the latter half of 1967. From 1968 through to mid-1976, conditions were generally cold; large negative anomalies occurred in January-March 1969, May 1970 through May 1971, the latter part of 1971 through May 1972, the latter part of 1972, with occasional large negative anomalies from 1973 to mid-1976. During the 1977-81 period, warm conditions prevailed, except in November-February 1978-79, when temperatures were anomalously low. Except for the May-August period, the anomalies in 1981 were generally as large or larger than those observed in 1958.

Years in which there were marked similarities in the degree and persistence of positive and negative monthly sea surface temperature anomalies were, 1940, 1941, 1958, 1963, 1980, and 1981 (warm); 1949, 1950, 1955, 1956, 1970, and 1972 (cold).

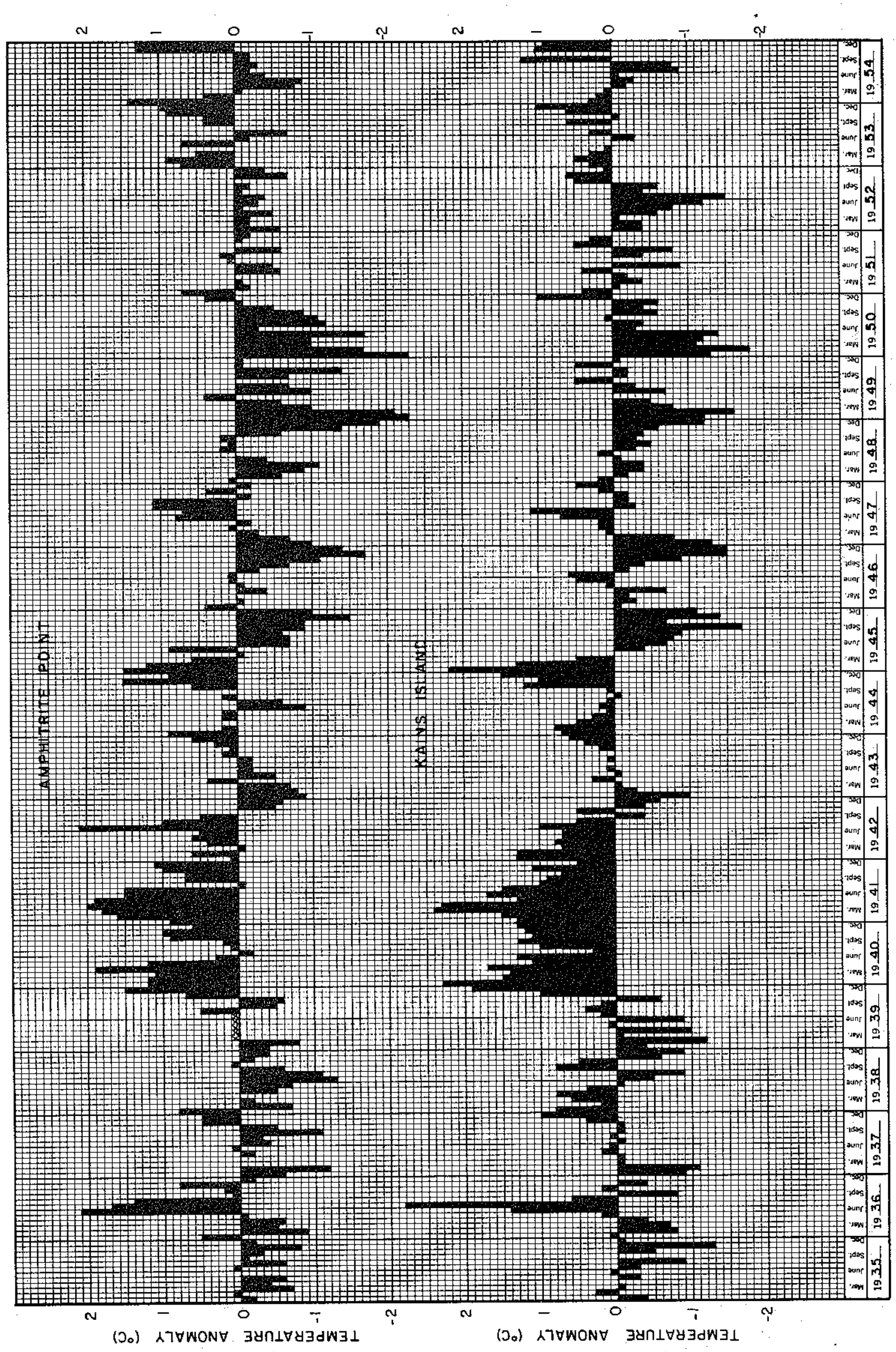

Fig. 31. Temperature anomalies (°C) at Amphitrite Point and Kains Island, Vancouver Island.

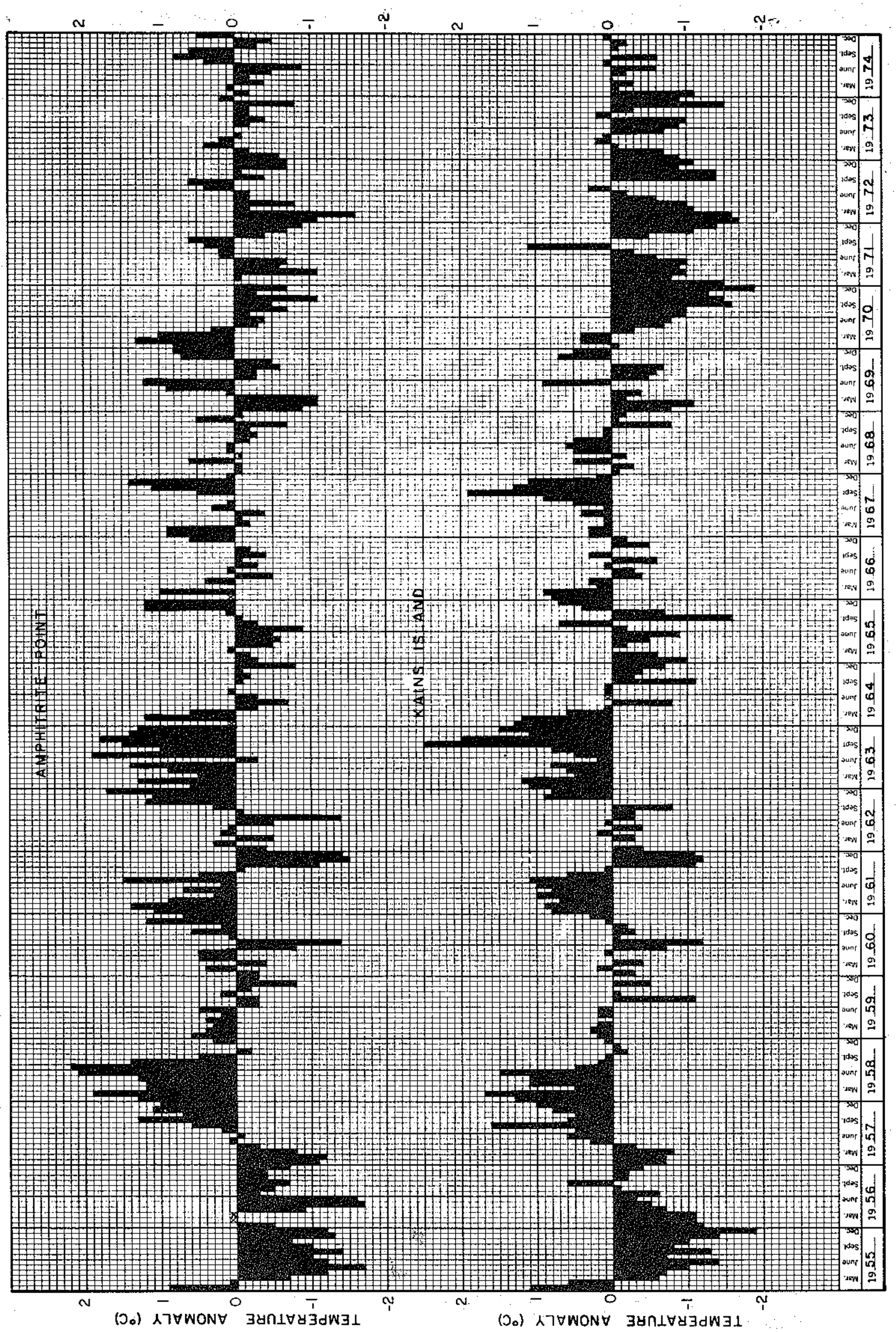

Fig. 31. (cont'd)

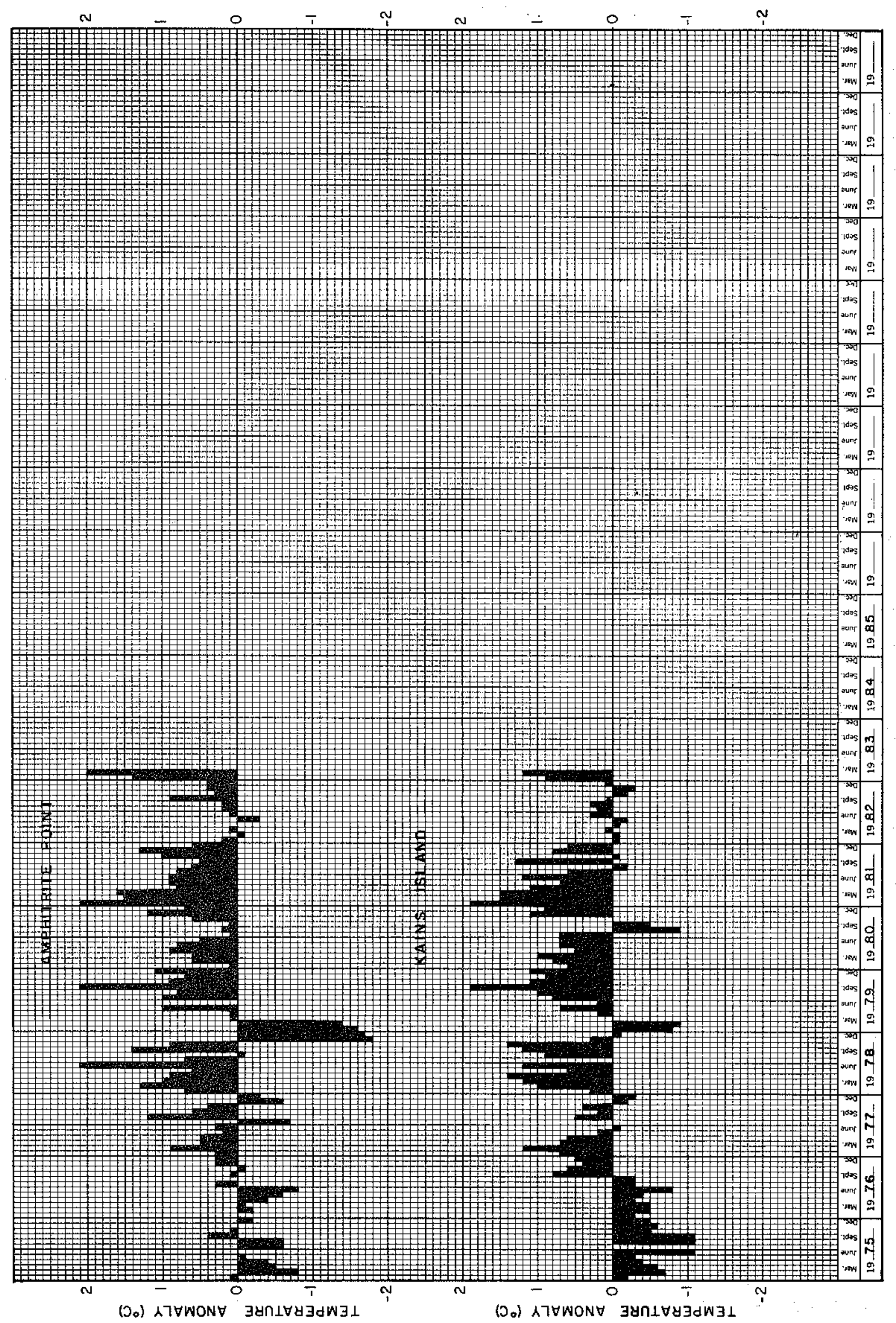

Fig. 31. (cont'd)

Generally, the October-March periods of comparatively high sea surface temperatures at the light stations were associated with high sea levels at Tofino, B. C. and large onshore transports at the grid points reported on. The anomalously warm October-March period in 1981-82 was associated with large onshore transports, but sea levels were generally not anomalously high. During the mid-autumn through early-spring periods of anomalously low sea surface temperatures, onshore transports were generally small and sea levels low.

The association of warm surface conditions, large onshore transports and high sea levels, and of cold surface conditions, small onshore transport and low sea level in mid-autumn-early spring was also noted in the lighthouse data for the Queen Charlotte Sound-Hecate Strait-Dixon Entrance Region, sea level at Prince Rupert, B. C. and transport at 51°N, 131°W (Dodimead 1980).

4. Annual Surface Salinity Cycle

The annual surface salinity cycles for Amphitrite Point and Kains Island each show a maximum in August and a minimum in December (Fig. 32); the annual cycle of precipition has a maximum in December and a minimum in July, and of runoff, a maximum in December and a minimum in August. The summer maximum in salinity is attributed to upwelling and to low precipitation during midsummer (Pickard and McLeod 1953). The winter minimum is attributed to local precipitation and runoff which are a maximum at this time of year. Also, there is a predominant onshore retention of the low-salinity, near-shore waters at this time of the year. Throughout the year, surface salinities are greater at Kains Island, with the largest differences in the long-term monthly means occurring in July-September (0.8-1.0°/oo). The greatest variability generally occurs in October-March, paralleling that of precipitation, runoff, transport and sea level.

5. Annual Surface Salinity Anomalies

The annual surface salinity anomalies indicate a decreasing trend of about 0.5°/oo /41 yr from 1935 to at least 1977 (Fig. 33), continuing the decline of 0.4°/oo/35 yr from 1935-71 reported by Webster and Farmer (1976). Beyond 1977, the variability is too large to identify any trend. Similar trends are also evident at the northern stations (Webster and Farmer, 1976, Dodimead 1980). Barber (pers. comm.) has noted a decreasing trend in the October monthly means at Kains Island.

Relatively large positive annual anomalies (high annual mean salinity) occurred at both locations in 1936, 1938, 1943-45, 1951, 1955, 1970, and 1979. The latter two years were also low-precipitation years. However, in 1958 annual precipition was very low, but the annual salinity was only slightly below average. Relatively large negative annual anomalies (low annual mean salinity) occurred in 1950, 1967-69, 1971, 1980-81. Annual precipitation was high only in 1967 and 1968. Webster and Farmer (1976) reported that annual mean precipitation and salinity seemed to be little correlated at Amphitrite Point and Kains Island.

6. Monthly Surface Salinity Anomalies

Similar trends and anomalies in the monthly mean values occur at

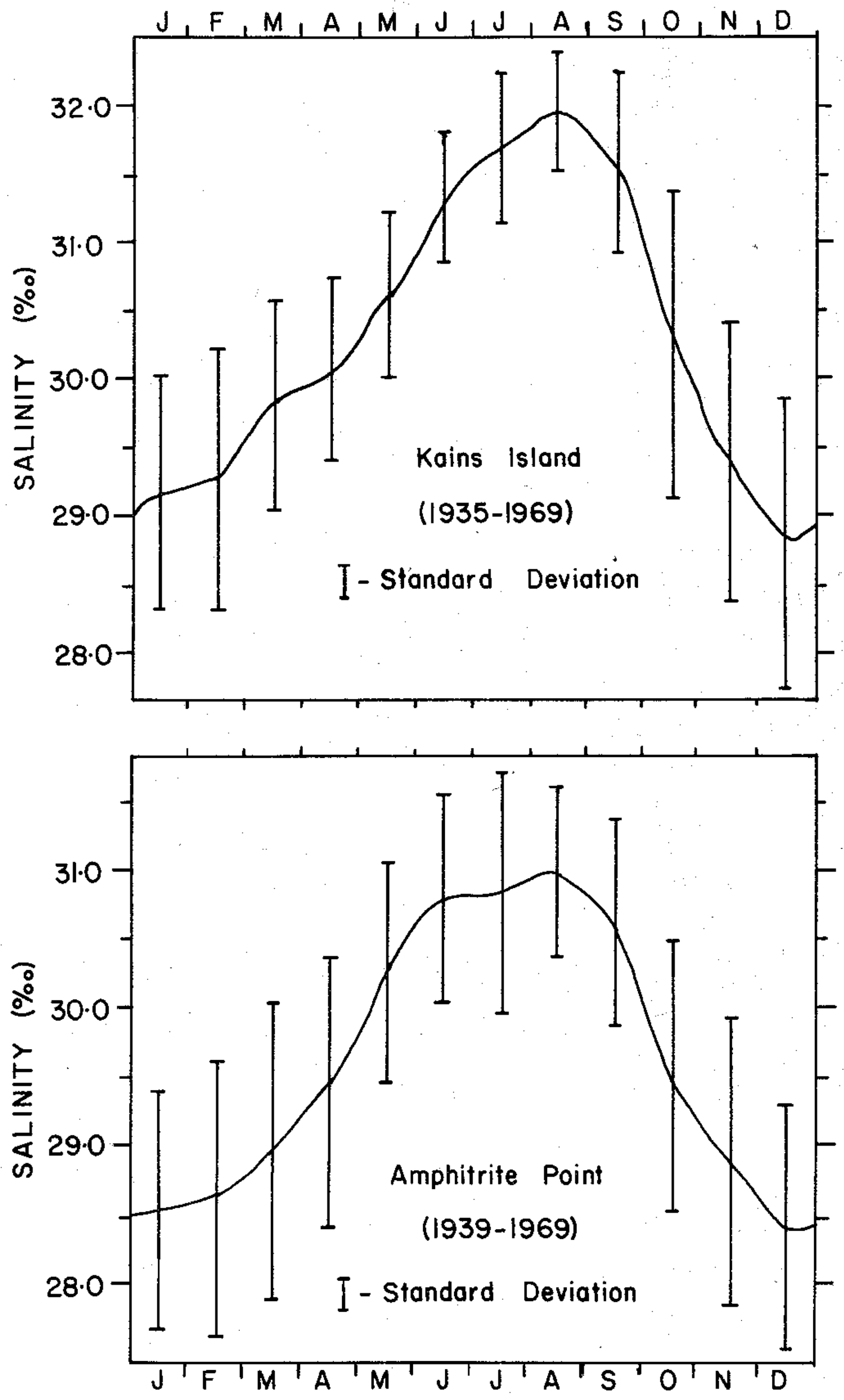

Fig. 32. Annual surface salinity (°/oo) cycle at Amphitrite Point and Kains Island, Vancouver Island.

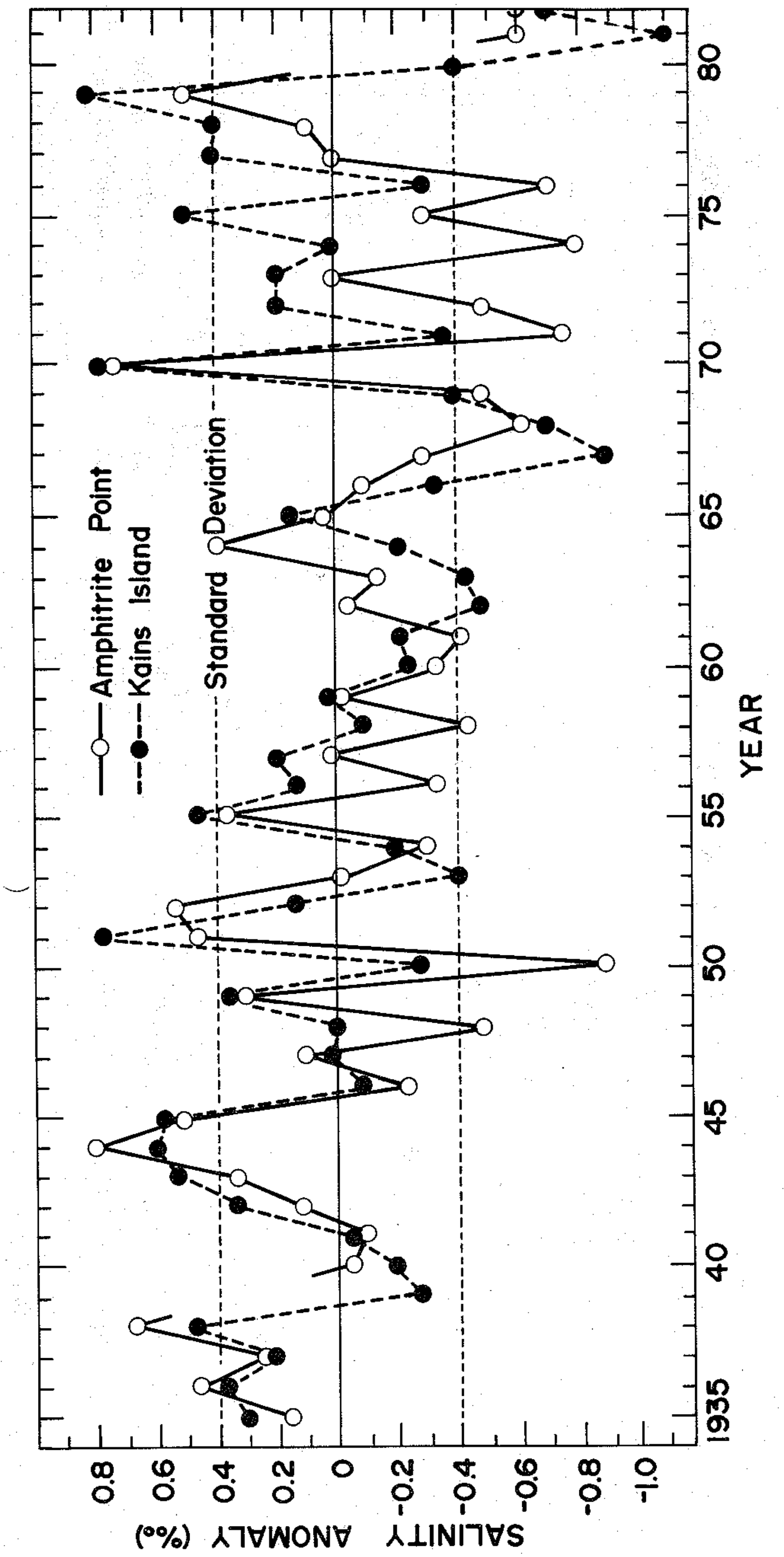

Fig. 33. Annual surface salinity (‰) anomalies at Amphitrite Point and Kains Island, 1935-81.

Amphitrite Point and Kains Island (Fig. 34), indicating that the surface waters in their vicinity are relatively influenced by the same factors, namely, precipitation or runoff, mixing and upwelling.

From 1934 through 1945, there was a dominance of high-salinity surface water, with occasional periods of 1-2 months duration of anomalously low-salinity conditions. During 1946-69, there was a dominance of relatively low-salinity conditions. Notable exceptions occurred: high-salinity conditions prevailed in March through December 1951, in March-May 1955, in June-July 1958, and in June-September 1965. The latter two periods, at least, were periods of generally anomalously low precipitation (Appendix table 3) coupled with relatively large offshore transports (Appendix table 9). The summer period in 1951 was also a period of large offshore transport; however, precipitation data for this period are lacking. From 1970 through 1979, anomalously high-salinity conditions generally prevailed. Again, there were notable exceptions; low-salinity conditions occurred in March-May 1972 and 1974, May-September 1976. These conditions were associated with generally above-average precipitation during or preceding these periods, i.e., March-April 1972 and March-August 1976, respectively. In the latter period of summer, offshore transports were average (June) to anomalously low (July-August). During 1980-81, surface salinities were anomalously low, particularly through 1981. The first half of 1980 was marked by average to below-average precipitation, and the latter half by below-average to significantly above-average precipitation. In 1981, precipitation was generally above average, except in January-March. The transport data during these years (1980-81) were generally favorable for confining low-salinity water relatively near to the coast.

Although precipitation and surface salinity appear to be little correlated for the data presented, it would appear from this cursory examination that high precipitation and large onshore transport were generally associated with low surface salinity conditions at the lightstations. These anomalous conditions indicate the presence of a narrow band of low-salinity water adjacent to the coast, within which the northward surface flow is a maximum.

The two most contrasting years appear to be 1951 (high salinity) and 1981 (low salinity). During the latter period, anomalously high surface temperatures also prevailed; in 1951, surface temperatures were variable, but not significantly different from average.

XI. VERTICAL DISTRIBUTIONS OF TEMPERATURE, SALINITY, DENSITY, AND DISSOLVED OXYGEN, 1957-1962 AND MARCH 1969

In this section, vertical distributions of temperature, salinity, density (as defined by sigma-t) and dissolved oxygen to a maximum depth of 500 m are presented in sections seaward of Amphitrite Point, Estevan Point and Cape Cook for the period 1957-62. A cruise chart identifying stations precedes each series of sections. A listing of the reports in which these data are published is provided in Data Sources, 1957-62. Lane (1962, 1963) used these data to describe features of the vertical distributions of

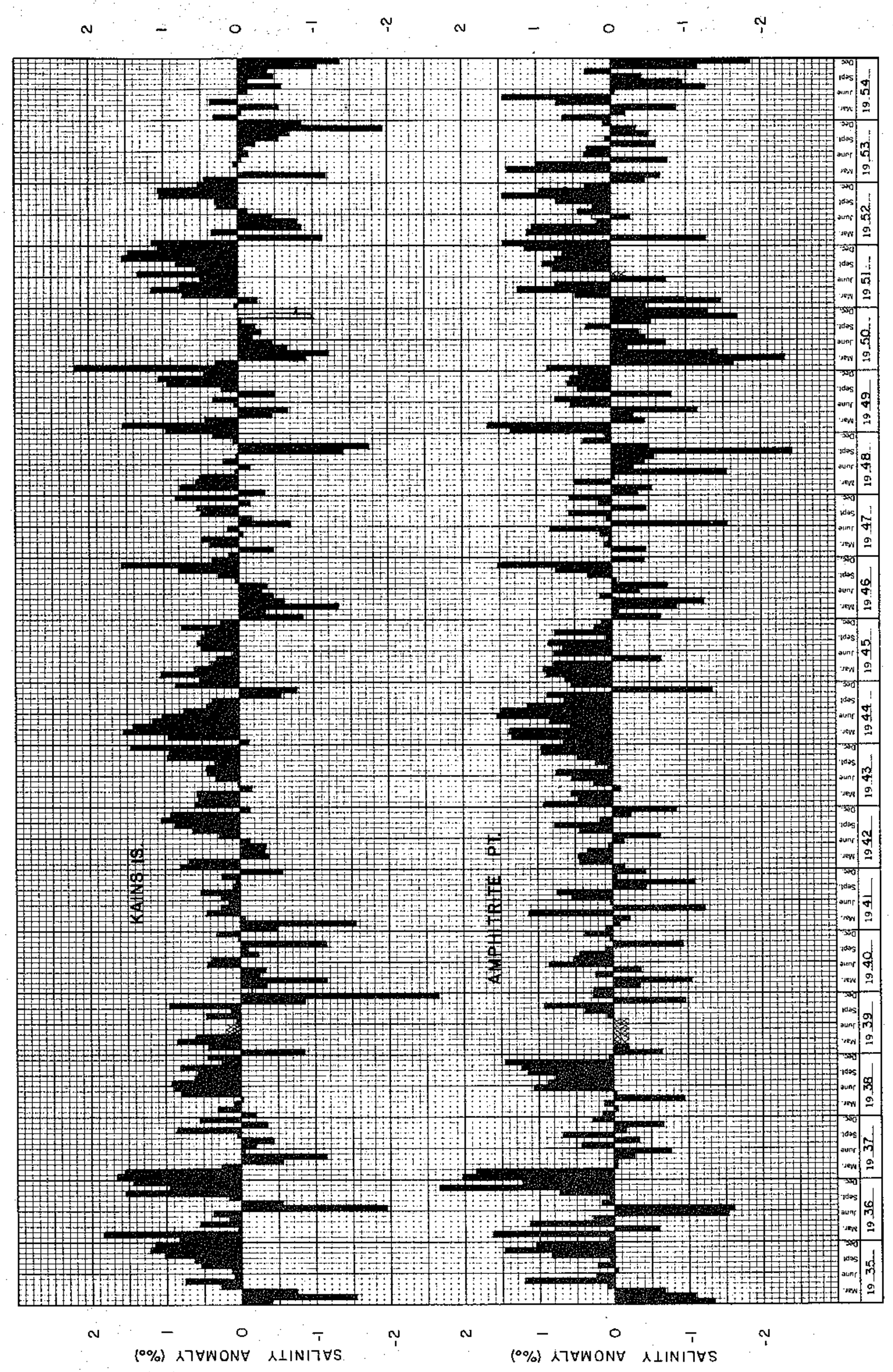

Fig. 34. Monthly surface salinity anomalies at Amphitrite Point and Kains Island, Vancouver Island.

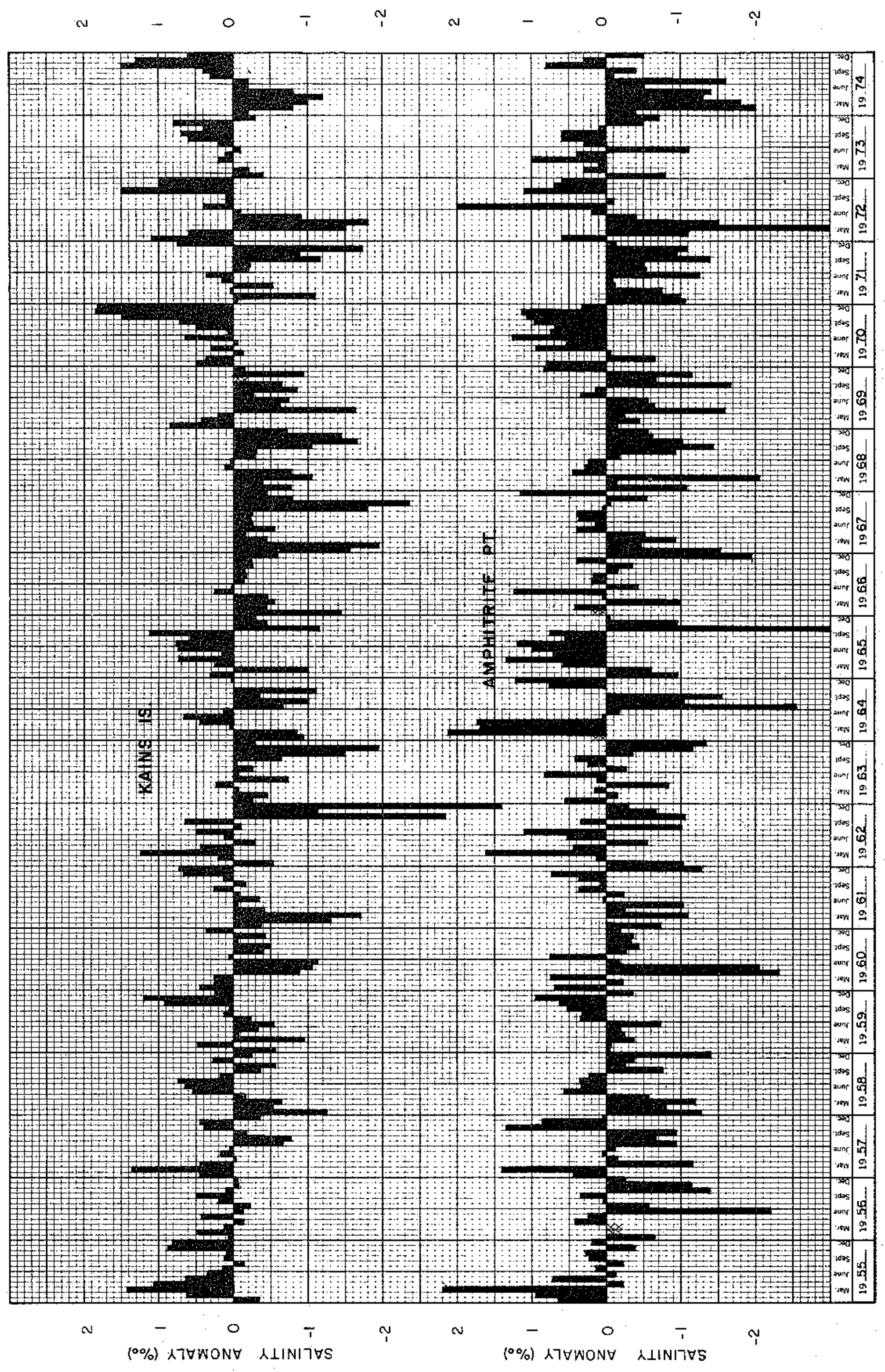

Fig. 34. (cont'd)

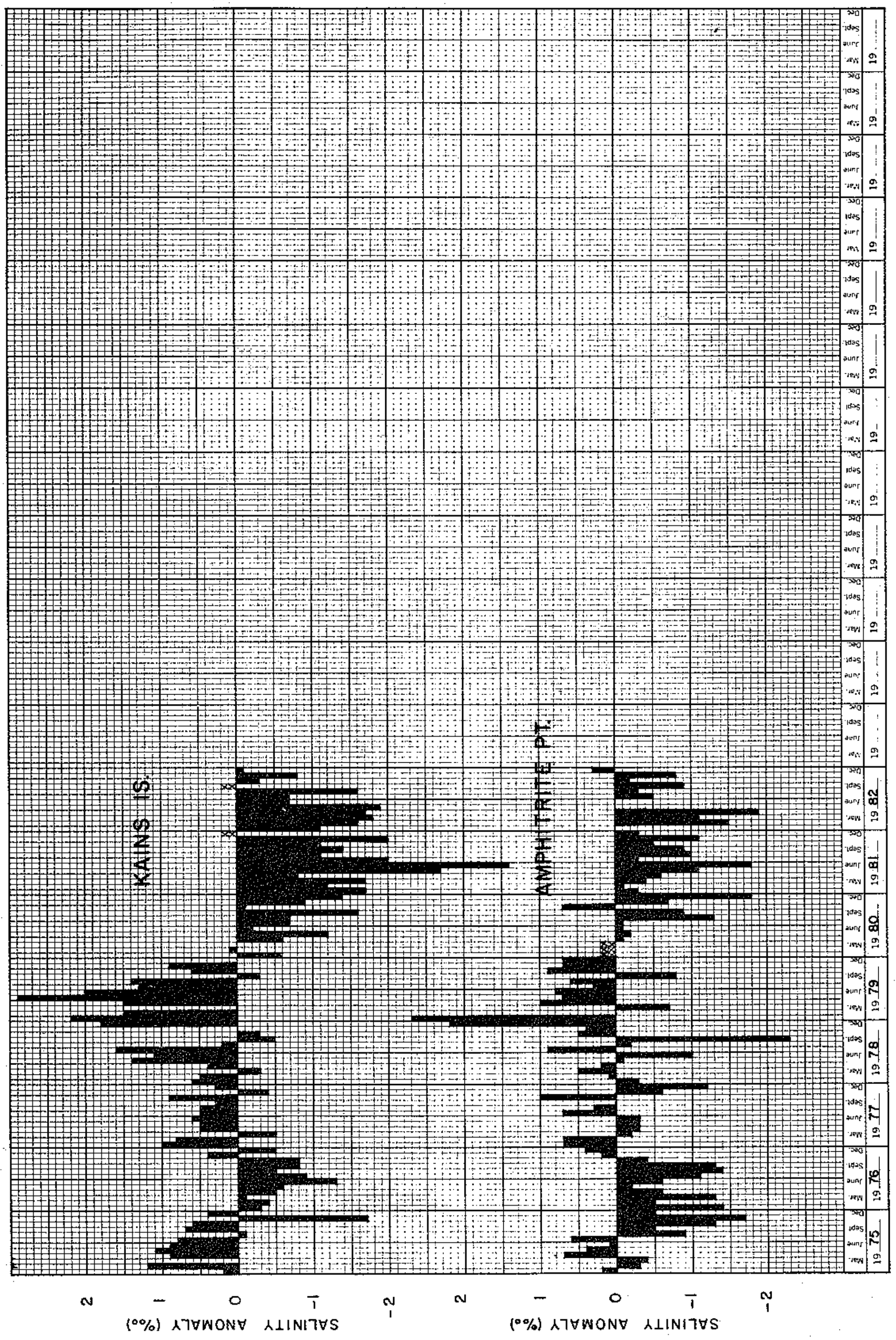

Fig. 34 (cont'd)

temperature, salinity and density and the seasonal variability in the vertical structures of temperature and salinity seaward of Vancouver Island. However, not all sections, nor were all 4 parameters presented. For each of the 3 geographical sections (seaward of Amphitrite Point, Estevan Point and Cape Cook), a standard depth profile was constructed along a mean transect (two mean transects for Amphitrite Point). Because of the deviation in station positions from the mean transect, the bottom depths at stations (generally those located near the edge of the continental shelf) did not always agree with those reported in the data records, or with the maximum sampling depth. A small shift in the position was usually made to make the depth correct. Vertical distributions along 3 closely-spaced transects occupied in early March 1969 are also presented. The latter data have not been published.

A summary of bottom-water conditions at 50, 100, 150, 200 and 500 m depth for each of the sections is provided in Table 7a-d. The bottom values were obtained by extrapolation of the isolines shoreward to intersect the bottom profile. Seven-day equally-weighted mean temperatures at 45 m depth (near-bottom) at Swiftsure for 1955-60 (Hollister 1966) are presented in Figure 35 as a comparison to the 50 m bottom-water temperatures in the sections seaward of Amphitrite Point.

A brief description of surface and other features is provided. The prevailing conditions for the month prior to the surveys, as reflected in the monthly means of sea surface temperature and salinity at the lightstations, Ekman transport and sea level, are also noted. The transport and sea level data, together with the surface temperature data, are considered to indicate the relative strengths of the seasonal convergent-divergent processes in the serial data presented. Shorter time periods for the time-series date would be preferable. Nevertheless, an attempt has been made to classify the vertical sections seaward of Amphitrite Point as to the strength of convergence or divergence they reflect. It is suggested that in the absence of such data, it may be feasible to grossly estimate seasonal surface and subsurface conditons in the continental shelf waters by comparing the sections presented in the following, and the prevailing conditions indicated in the time-series data.

The vertical sections (Fig. 36-92) are presented in chronological order on p. 97-252 following Acknowledgments.

1. Oceanographic Conditions during 1957

In mid-May 1957, sea surface temperatures ranged from 10.8 to 12.2°C, with the warmest waters overlying the outer continental shelf; surface salinities and densities typically increased seaward, 30.5-32.5°/°° and 23.2 -24.9, respectively; and dissolved oxygen typically decreased seaward, 9.0-6.6 mL/L, within 80 km (43 M) of Amphitrite Point (Fig. 37a-d). Bottom temperatures, between 50 and 200 m depth, ranged from 7.9 at 50 m to 6.7°C at 200 m depth; salinities, 32.3-33.0°/°°; densities, 25.2-26.6; and dissolved oxygen, 4.7-2.1 mL/L (Table 7a-d). The mid-month 7-day mean was about 8.3°C at 45 m at Swiftsure (Fig. 35) and 7.9°C at 50 m off Amphitrite Point (Table 7a). At Swiftsure, the 7-day equally-weighted means at 45 m depth varied between about 8.0 and 8.6°C during May, with maximum temperatures at the beginning of the 3rd week (Fig. 35). The monthly mean for May was 8.4°C (Table 4).

Table 7a. Temperatures (°C) at bottom depths of 50-500 m. (These are extrapolated values from the sections.)

	Bottom depth (m)					Bottom depth (m)				
	50	100	150	200	500	50	100	150	200	200
	Amphitrite Point Section					Cape Cook Section				
May 12-14/57	7.9	7.5	7.1	6.7	4.9	9.2	7.4	7.4	7.0	4.9
July 12	8.5	7.5	7.2	6.8	5.3	-	-	-	-	-
Oct 1-2	-	-	-	-	-	11.0	7.7	7.4	7.2	5.2
Nov 25-28	11.0	8.3	7.9	7.6	5.0	11.0	7.8	7.5	7.3	5.1
Dec 5/58	9.8	8.0	7.7	7.4	-	-	-	-	-	-
Apr 8-9/59	8.8	8.9	8.1	7.5	5.2	8.4	8.1	7.9	7.2	5.0
Jun 14-18	9.0	7.4	7.0	6.6	5.1	10.9	8.0	6.6	6.3	4.6
Nov 26	8.8	7.4	7.2	6.9	5.1	-	-	-	-	-
Nov 27	9.4	7.4	7.1	6.8	4.9	8.5	8.1	7.5	7.2	5.1
						Estevan Point Section				
May 6-10/60	8.7	8.3	7.4	6.7	4.9	8.0	7.8	7.2	6.6	-
Jun 8-9	9.3	7.6	7.0	6.3	4.8	-	-	-	-	-
Jun 14-16	8.7	7.8	6.7	6.2	-	8.0	6.7	6.6	6.3	-
Oct 9	9.0	6.9	6.9	6.6	5.3	-	-	-	-	-
Dec 1-2	10.0	9.5	7.6	7.3	5.3	9.5	9.2	7.5	7.0	-
						Cape Cook Section				
Feb 26-27/61	9.4	9.8	8.3	7.3	5.1	-	-	-	-	-
Mar 27-28	8.9	9.5	7.9	7.5	5.1	-	-	-	-	-
Apr 11	-	-	-	-	-	8.5	7.7	6.3	6.0	4.7
Jul 25-27	8.9	7.0	6.4	5.9	5.1	7.5	6.7	6.1	5.9	5.0
Oct 26-28	9.3	7.9	6.8	6.5	5.0	8.8	8.1	7.5	7.1	4.8
Nov 2	9.1	7.9	7.1	-	-	-	-	-	-	-
Jan 25/62	8.4	7.9	7.0	6.4	5.0	-	-	-	-	-
Jan 30-31	7.9	7.9	7.1	6.8	5.2	7.9	7.9	7.1	6.9	5.1
Mar 27	7.6	7.6	7.7	7.3	5.2	-	-	-	-	-
Mar 6-10	7.5	8.3	8.2	7.6	5.0					
Max temp	11.0	9.8	8.3	7.6	5.3					
Min temp	7.5	6.9	6.4	5.9	4.8					
ΔT	3.5	2.9	1.9	1.7	0.5					

Table 7b. Salinities (°/₀₀) at bottom depths of 50-500 m. (These are extropolated values from the sections.)

	Bottom depth (m)					Bottom depth (m)				
	50	100	150	200	500	50	100	150	200	200
	Amphitrite Point Section					Cape Cook Section				
May 12-14/57	32.3	33.2	33.7	33.9	34.1	31.8	32.8	33.8	33.9	34.1
July 12	32.5	33.1	33.7	33.85	34.05	-	-	-	-	-
Oct 1-2	-	-	-	-	-	32.1	33.2	33.7	33.85	34.1
Nov 25-28	32.3	33.3	33.7	33.9	-	32.1	33.2	33.7	33.85	34.1
Dec 5/58	32.7	33.5	33.85	33.9	-	-	-	-	-	-
Apr 8-9/59	32.0	32.7	33.7	33.9	34.1	32.0	32.5	33.2	33.8	34.1
Jun 14-18	32.0	33.5	33.8	33.85	34.1	32.4	33.1	33.7	33.85	34.1
Nov 26	32.2	33.7	33.85	33.9	34.1	-	-	-	-	-
Nov 27	32.2	33.6	33.85	33.9	34.1	32.2	32.9	33.6	33.85	34.1
						Estevan Point Section				
May 6-10/60	31.5	33.0	33.7	33.9	34.1	32.2	33.2	33.85	33.9	
Jun 8-9	32.1	33.7	33.9	33.95	34.15	-	-	-	-	-
Jun 14-16	31.5	33.6	33.85	33.95		33.0	33.9	33.95	33.95	34.1
Oct 9	32.4	33.8	33.9	33.95	34.05	-	-	-	-	-
Dec 1-2	31.4	33.0	33.6	33.8	34.05	32.2	33.0	33.65	33.9	-
						Cape Cook Section				
Feb 26-27/61	32.0	32.5	33.7	33.9	34.05	-	-	-	-	-
Mar 27-28	31.1	32.6	33.7	33.85	34.1	-	-	-	-	-
Apr 11						32.0	33.7	33.9	33.95	34.1
Jul 25-27	32.5	33.4	33.95	34.0	34.1	33.3	33.9	33.9	33.95	-
Oct 26-28	32.4	33.7	33.9	33.95	34.1	32.8	33.3	33.7	33.95	34.2
Nov 2	32.7	33.6	33.9	-	-					
Jan 25/62	32.3	33.5	33.9	33.95	34.1					
Jan 30-31	32.1	33.5	33.85	33.9	34.1					
Mar 27	32.0	33.2	33.85	33.9	-					
Mar 6-10	31.5	32.9	33.7	33.9	34.1					
Max sal	32.7	33.8	33.95	34.0	34.15					
Min sal	31.1	32.5	33.6	33.8	34.05					
ΔS	1.6	1.3	0.35	0.2	0.1					

Table 7c. Density (σ_t)at bottom depths of 50-500 m. (These values were extrapolated from the sections.)

	Bottom depth (m)					Bottom depth (m)				
	50	100	150	200	500	50	100	150	200	200
	Amphitrite Point Section					Cape Cook Section				
May 12-14/57	25.1	26.0	26.45	26.6	27.0	24.8	26.1	26.45	26.55	26.95
July 12	25.3	25.9	26.4	26.55	26.95	-	-	-	-	-
Oct 1-2	-	-	-	-	-	24.5	25.9	26.2	26.5	27.0
Nov 25-28	24.6	25.9	26.3	26.45	27.0	24.4	25.9	26.4	26.5	26.9
Dec 5/58	25.0	26.2	26.45	26.5	-	-	-	-	-	-
Apr 8-9/59	24.8	25.4	26.3	26.5	26.95	24.7	25.3	25.9	26.35	27.0
Jun 14-18	24.8	26.2	26.5	26.65	26.95	24.8	25.8	26.5	26.65	27.0
Nov 26	25.1	26.4	26.5	26.6	27.0	-	-	-	-	-
Nov 27	25.0	26.3	26.5	26.6	26.95	25.0	25.5	26.3	26.5	27.0
						Estevan Point Section				
May 6-10/60	24.7	25.6	26.4	26.65	27.0	25.0	25.7	25.55	26.65	-
Jun 8-9	24.8	26.3	26.6	26.7	27.0	-	-	-	-	-
Jun 14-16	24.5	26.0	26.6	26.7	-	25.8	26.6	26.7	-	-
Oct 9	25.1	26.55	26.65	26.7	26.9	-	-	-	-	-
Dec 1-2	24.1	25.3	26.3	26.4	26.9	25.0	25.6	20.3	26.5	-
						Cape Cook Section				
Feb 26-27/61	24.6	25.1	26.3	26.5	26.9	-	-	-	-	-
Mar 27-28	24.1	25.2	26.25	26.5	26.9	-	-	-	-	-
Apr 11						24.9	26.4	26.65	26.7	27.1
Jul 25-27	25.3	26.2	26.7	26.8	26.95	25.8	26.65	26.8	26.85	-
Oct 26-28	25.0	26.4	26.65	26.7	27.0	25.6	25.9	26.3	26.6	27.1
Nov 2	25.3	26.2	26.6	-	-	-	-	-	-	-
Jan 25/62	25.1	26.0	26.55	26.65	26.95	-	-	-	-	-
Jan 30-31	25.1	26.2	26.5	26.6	26.9	24.9	25.6	26.4	26.6	27.0
Mar 27	25.1	25.9	26.4	26.5	26.95	-	-	-	-	-
Mar 6-10	24.4	25.6	26.3	26.5	27.0					
Max σ_T	25.3	26.55	26.7	26.8	27.0					
Min σ_T	24.1	25.1	26.3	26.45	26.9					
$\Delta\sigma_T$	1.2	1.45	0.4	0.35	0.1					

Table 7d. Dissolved oxygen (mL/L) at bottom depths of 50-500 m. (These are extrapolated values from the sections.)

	Bottom depth (m)					Bottom depth (m)				
	50	100	150	200	500	50	100	150	200	200
	Amphitrite Point Section					Cape Cook Section				
May 12-14/57	4.7	3.3	2.4	2.2	<1.0	6.3	4.0	2.5	2.0	<1.0
July 12	3.2	2.8	2.7	2.5	>1.0	-	-	-	-	-
Oct 1-2	-	-	-	-	-	4.6	3.8	3.2	2.7	1.0
Nov 25-28	-	-	-	-	-	5.7	4.0	2.4	2.3	>1.0
Dec 5/58	5.0	3.1	2.4	2.2	-	-	-	-	-	-
Apr 8-9/59	6.2	5.5	3.1	2.8	>1.0	6.8	6.7	4.9	3.8	>1.0
Jun 14-18	4.8	2.6	2.4	2.4	<1.0	6.5	5.0	3.6	2.9	<1.0
Nov 26	6.1	2.5	2.3	2.2	<1.0	-	-	-	-	-
Nov 27	6.1	2.8	2.7	2.4	<0.5	6.1	4.5	2.9	2.4	1.0
						Estevan Point Section				
May 6-10/60	-	1.4	1.4	1.4	>1.0					
Jun 8-9	-	-	-	-	-					
Jun 14-16	5.6	3.5	2.4	2.1	>1.0					
Oct 9	-	-	-	-	-					
Dec 1-2	5.7	4.5	2.8	2.3	>1.0					
						Cape Cook Section				
Feb 26-27/61	-	-	-	-	-					
Mar 27-28	6.0	6.4	3.4	2.8	1.4	-	-	-	-	-
Apr 11	-	-	-	-	-	5.1	3.0	1.9	1.7	<1.0
Jul 25-27	3.5	2.4	2.2	1.8	<1.0	4.0	2.8	2.3	2.0	<1.0
Oct 26-28	4.3	2.8	1.8	1.5	<1.0	3.9	3.3	3.1	2.4	<1.0
Nov 2	4.8	3.4	-	-	-					
Jan 25/62	5.9	4.0	2.5	2.3	<1.0					
Jan 30-31	-	-	-	-	-					
Mar 27	-	-	-	-	-					
Mar 6-10	6.7	5.0	3.3	2.8	1.2					
Max O_2	6.7	6.4	3.4	2.8	-					
Min O_2	3.2	1.4	1.4	1.4	-					
ΔO_2	3.5	5.0	2.0	1.4	-					

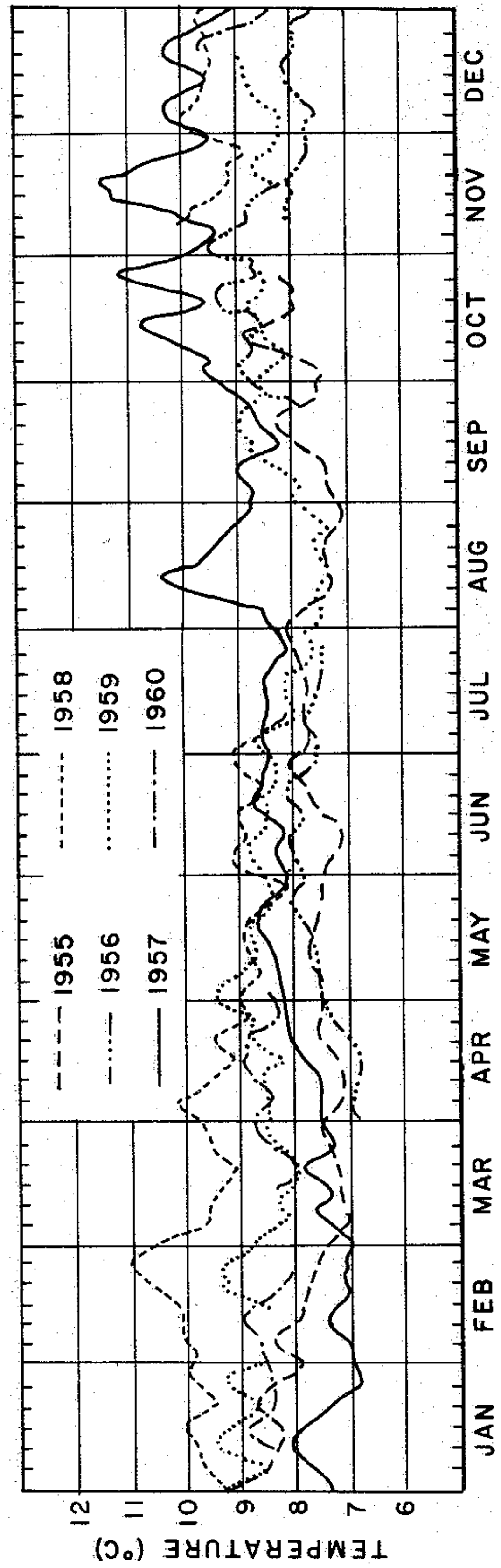

Fig. 35. Seven-day equally-weighted average temperatures (°C) at 45 m depth at Swiftsure lightship station, 1955-60 (adapted from Hollister 1966).

Within 60 km (32 M) of Cape Cook during mid-May 1957, surface temperatures were about 10.8°C, slightly lower than temperatures within 60 km of Amphitrite Point; surface salinities and densities were generally similar, 30.6- 32.2°/oo and 23.4 - 24.5, respectively; dissolved oxygen was lower, 7.09 mL/L (Fig. 38a-d). Bottom-water conditions were generally similar to those seaward of Amphitrite Point, except at 50 m (Table 7a-d). The higher bottom temperatures and dissolved oxygen, and lower salinity and density at 50 m off Cape Cook was associated with a thickening of the surface-mixed layer. This may be attributed to greater tidal mixing. An increase in the surface flow is also indicated.

A feature common to both sections is a cell of relatively warm water between 100 and 200 m depth, coincident with the depth of the oceanic halocline (Fig. 37a,b; 38a,b). At depth, little flow is indicated in either section.

These features and conditions were preceded by average monthly sea surface temperature and salinity (April-May) at the lightstations, relatively small, but average, offshore Ekman transport (April-May) and average (April) to anomalously high sea level (May). These data are considered to indicate a predominant relaxation condition seaward of Amphitrite Point. This state is also indicated by the level distribution of the isopycnals in Figures 37c.

By about mid-July 1957, heating resulted in an increase in surface temperatures of about 4°C, ranging from 13.3 to 14.6°C, with the warmest waters overlying the outer continental shelf, typical of summer conditions; surface salinities were generally greater, except offshore, at 30.9-31.9°/oo; densities were similar, at 23.2-23.8; and dissolved oxygen was lower, at 6.5 mL/L than observed in mid-May seaward of Amphitrite Point (Fig. 40a-d). Bottom conditions were generally similar to those observed in mid-May, except at 50 m depth, where a temperature increase of 0.5°C and a salinity decrease of 0.7°/oo occurred seaward of Amphitrite Point (Table 7a-d). The bottom-water temperature at 50 m was 8.5°C, within 0.1°C of the 7-day mean at 45 m depth at Swiftsure (Fig. 35), and is considered to be anomalously high. The seven-day mean at 45 m ranged from about 8.2 to 8.7°C during July (Fig. 35) and the monthly mean was 8.4°C at Swiftsure.

Conditions in mid-July were associated with average monthly mean surface temperatures (June-July), average (June) to anomalously low (July) salinities at the lightstations, slightly below-average offshore transport (June-July), and average (June) to anomalously high (July) sea level. Although the monthly mean values of Ekman transport (June-July) indicate divergence, it appears that the indicated increase in offshore transport was not sufficient to materially alter bottom conditions at depths of 100-200 m from those observed in mid-May. Conditions at 50 m generally followed the surface trends, as noted by Hollister (1966). A weak divergent condition is indicated.

By the beginning of October 1957, surface temperatures were about 14°C; salinities, 31.6-32.0°/oo; densities, 23.6-23.9; and dissolved oxygen, 5.8 mL/L, seaward of Cape Cook (Fig. 42a-d). Bottom conditions were generally similar to those observed in mid-May, except at 50 m, where temperatures were relatively high in October (Table 7a-d), as would be expected following summer heating coupled with mixing. The downward slope of the isopycnals at all depths (Fig. 41c) indicates a northward flow near the coast which was greater than in May seaward of Cape Cook.

By the end of November 1957, surface temperatures were relatively constant, 11.0-11.9°C; surface salinities, 31.4-32.4°/oo; densities, 23.9-24.7, off Amphitrite Point (Fig. 44a-c). The bottom temperature at 50 m (11.0°C) was higher than the 45 m 7-day temperature (9.6°C) at Swiftsure. There was a wide range in the 7-day means during this month, between 9.5 and about 11.5°C, with maximum temperatures about mid-month (Fig. 35). The monthly mean temperature at 45 m depth was 10.3°C (Table 4).

Within 45 km of Cape Cook, surface temperatures were 10.4-10.0°C, lower than observed within 45 km of Amphitrite Point; however, salinities and densities were similar, 31.6-32.2°/oo and 24.2-24.8, respectively; dissolved oxygen, about 6.0 mL/L (Fig. 45a-d). The marked downward slope of the isopycnals in the surface layer and in the subsurface layer (200-500 m) indicates a significant northward flow at these levels seaward of Cape Cook.

A significant increase in bottom temperatures occurred from mid-July to late November, although other conditions were generally similar, off Amphitrite Point (Table 7a-d). Part of the increase in temperature may be attributed to a change in the onshore-offshore processes, from a weak divergent condition in July to a relaxation or weak convergent condition in November. However, it may be partly due to an increase in the northward flow of the California Undercurrent, as was observed in November 1957 through January 1958.

These conditions were preceded (November) by anomalously warm and saline surface conditions at the lightstations, below-average onshore transport and average sea level. A weak convergent or relaxation condition is indicated seaward of Amphitrite Point.

2. Oceanographic Conditions during 1958

A marked increase in onshore transport occurred from December 1957 through February 1958 (Fig. 26). Sea levels were also anomalously high in this period (Fig. 28). Sea surface and bottom temperatures were likely anomalously high over the entire continental shelf and slope, as indicated by the anomalously high sea surface temperatures at the lightstations (Fig. 31) and the high surface and bottom temperatures at Swiftsure Bank (Table 4). Also, a strengthening of the subsurface intrusion of warm water along the continental slope was observed (Tully et al. 1960). A strong convergent condition is indicated.

For the remainder of 1958, anomalous oceanographic and meteorological conditions peaked about August, followed by a gradual decrease to near-average conditions towards the end of the year. Surface temperatures were anomalously high to October; offshore transport was anomalously large in July-August; and sea levels were anomalously high during June-July, and remained relatively high through October. A marked divergent condition in summer is indicated.

In early December 1958, surface temperatures were relatively constant, at 9.6°C; salinities ranged from 30.4 to 32.2°/oo; densities, 23.6-25.0; and dissolved oxygen was uniform at 6.5 mL/L, seaward of Amphitrite Point (Fig. 47a-d). Bottom conditions were generally similar to those observed in late November 1957, except at 50 m (Table 7a-d). The bottom temperature was 9.8°C at 50 m, about the same as the 7-day mean at 45 m (9.6°C) at Swiftsure (Fig. 35). The seven-day mean varied markedly during November, between about 9.3 and 11.3°C (Fig. 35); the monthly mean was 9.8°C at Swiftsure (Table 4).

These conditions were preceded (November) by average surface temperature and slightly below-average salinity at the lightstations, below-average onshore transport and average sea level (similar to conditions observed in November 1957). A relaxation to weak convergent condition is indicated.

3. Oceanographic Conditions during 1959

In early April 1959, surface temperatures were relatively constant, about 9.4°C; salinities ranged from 28.6 to 31.2°/oo; densities, 22.8-24.1; and dissolved oxygen was at about 8.0 mL/L, seaward of Amphitrite Point (Fig. 49a-d). The bottom temperature at 50 m off Amphitrite Point was about 0.3°C higher than the 7-day running mean (8.5°C) at 45 m at Swiftsure in early April (Fig. 35). The 7-day mean temperatures at 45 m varied between 8.2 and 9.4°C, with a monthly mean of 8.7°C for April at Swiftsure.

Off Cape Cook, surface temperatures were also about 9.4°C; salinities and densities were relatively high at 30.4-32.5°/oo and 23.4 - 25.2, respectively; and dissolved oxygen ranged from 8.0 to 7.2 mL/L (Fig. 50a-d).

Bottom waters were generally markedly different along these sections during this period; seaward of Cape Cook, temperatures were lower, salinities and densities generally lower, and dissolved oxygen higher, than those seaward of Amphitrite Point (Table 7a-d). These differences are attributed to a marked thickening of the surface-mixed layer within 15 km off Cape Cook (Fig. 50). This marked thickening of the surface-mixed layer may be associated with an acceleration in the northward flow. This feature was not evident off Amphitrite Point.

These conditions were preceded (March) by average sea surface temperatures and below-average surface salinities at the lightstations, near-average, but small, onshore transport, and below-average sea level. A relaxation condition is indicated seaward of Amphitrite Point.

By mid-June 1959, surface temperatures were about 12.8°C; salinities ranged from, 30.8 to 31.8°/oo; densities, 23.4 - 24.0; and dissolved oxygen, 8.2 - 6.5 mL/L off Amphitrite Point (Fig. 52a-d). The bottom temperature at 50 m off Amphitrite Point (Table 7a) was 0.3°C higher than mid-month 7-day mean at Swiftsure (Fig. 35). The June monthly mean temperature at 45 m was 8.6°C at Swiftsure (Table 4).

Off Cape Cook, similar surface conditions generally prevailed (Fig. 53a-d). Bottom conditions, however, were generally dissimilar; seaward of Amphitrite Point, temperatures at 50 and 100 m appeared to be lower, but at 150 and 200 m they were higher, than those off Cape Cook (Table 7a). However, salinities and densities were generally similar, and dissolved oxygen lower off Amphitrite Point than off Cape Cook (Fig. 7b-d). There was a slight deepening of the surface-layer isolines off Cape Cook.

It is not possible to define the conditions that prevailed prior to this period in the monthly data, since the mean values for May and June 1959 are considerably different. The monthly mean sea surface temperature for May was above average, but anomalously low for June; surface salinity was anomalously low for May, but near-average for June; transport was offshore and average for May and offshore and below-average for June; sea level was slightly below average for May and slightly above average for June. Nevertheless, a relaxation condition is indicated in the vertical distribution of density seaward of Amphitrite Point (Fig. 52c).

In late November 1959, the vertical distributions for consecutive days generally show similar features seaward of Amphitrite Point. Surface temperatures ranged from 10 to 9°C, with lowest temperatures at the outer edge of the continental shelf; salinities, 31-32.4°/oo; densities, 24-25.0; and dissolved oxygen, about 6.5 mL/L (Fig. 55a-d, 56a-d).

Seaward of Cape Cook, surface temperatures were 9-10.4°C, with the warmest waters to seaward; salinities, 32.0-32.4°/oo; densities, 25.0; and dissolved oxygen, about 6.5 mL/L (Fig. 57a-d), generally similar to surface conditions seaward of Amphitrite Point.

Bottom temperatures off Cape Cook were higher than off Amphitrite Point; salinities, densities and dissolved oxygen were generally similar, except at 100 m (Table 7a-d). The higher temperatures are again attributed to the thickening of the surface-mixed layer off Cape Cook; other properties were only slightly affected, but the changes were as would be expected. An increase in the surface-layer flow is indicated seaward of Cape Cook.

These conditions were associated with below-average surface temperatures, above-average surface salinities at the lightstations, below-average onshore transport, and anomalously low sea level during November. A weak convergent to relaxation condition is indicated.

4. Oceanographic Conditions during 1960

In early May 1960, sea surface temperatures decreased seaward, ranging from 12.0 to 10.0°C; salinities ranged from 29.0 to 32.4°/oo and densities, 22.0-25.0, seaward of Amphitrite Point (Fig. 59a-d).

Off Estevan Point, surface temperatures were constant at about 10°C; salinities ranged from 30.4 to 32.3°/oo, and densities, 23.2 - 24.9 (Fig. 60a-c). Seaward of Amphitrite Point, bottom temperatures at 50 and 100 m were higher than those seaward of Estevan point; salinities and densities were generally similar (Table 7a-c). Observations at Swiftsure were terminated in early May.

These conditions were associated with above-average sea surface temperature (April) and below-average surface salinity at the lightstations, large onshore transport, and relatively high sea level. Similar conditions also prevailed in May. A weak convergent condition is indicated.

In early June 1960, surface temperatures decreased seaward, ranging from 12.4 to 11.9°C; salinities, 28.4 - 29.6°/oo with the lowest salinity water overlying the continental shelf; densities, 22.0 - 22.5; and dissolved oxygen was uniform at about 7.0 mL/L, seaward of Amphitrite Point (Fig. 62a-d). By mid-June, surface temperatures were 12.6-12.8°C; salinities 30.4-31.0°/oo; densities, 22.8 - 23.2; and dissolved oxygen, about 7.0 mL/L (Fig. 63a-d).

Off Estevan Point in mid-June, surface temperatures were 12.2-11.6°C; salinities, 31-31.5°/oo, densities, 23.4 - 24.0 (Fig. 64a-c).

Bottom-water conditions at 100-200 m remained similar from early to mid-June off Amphitrite Point (Table 7a-d). However, at 50 m, a temperature decrease (0.6°C) and a salinity decrease (0.6°/oo) were indicated from early June to mid-June.

Conditions in early June were preceded by near-average (May) sea surface temperature and average surface salinities at the lightstations, and anomalously large onshore transport and above-average sea level. A weak convergent condition is indicated in early June.

In early October 1960, surface temperatures ranged from 11.0 to 13.0°C, with the warmest waters to seaward; salinities, 31.2-32.2°/oo; densities, 24.0-24.8, seaward of Amphitrite Point (Fig. 66a-c). Bottom temperatures were lower (0.9°C) at 100 m, but slightly higher (0.4°C) at 200 m than in mid-June. However, bottom salinities were generally similar, except at 50 m.

Monthly mean (September) sea surface temperature was above average, surface salinity, below average at the lightstations, offshore transport, near average and sea level, slightly below average. A weak divergent condition is indicated.

At the beginning of December 1960, surface temperatures were 9.8-10.2°C; surface salinities, 31.0-32.4°/oo, densities, 23.8 - 24.9; and dissolved oxygen, about 6.0 mL/L, off Amphitrite Point (Fig. 68a-d).

Off Estevan Point, surface temperatures and dissolved oxygen were similar, but near-shore salinities and densities were higher (by 1°/oo and 0.8, respectively) (Fig. 69a-d).

Bottom temperatures were markedly higher, salinities and densities generally lower than observed in early October (Table 7a-c), indicating a fuller development of the convergent process.

Prevailing conditions during November 1960 were: above-average surface temperatures, and near-average surface salinities, average onshore transport, and slightly above-average sea level. A moderate convergent condition is indicated.

5. Oceanographic Conditions during 1961

At the end of February 1961, surface temperatures ranged from

9.0 to 9.7°C, with the warmest waters occurring over the outer shelf; salinities, 27.0-32.6°/oo; densities, 21.0 - 25.2, seaward of Amphitrite Point (Fig. 71a-c). The most significant changes from early December to late February in bottom-water conditions occurred in temperature, at 50 m a decrease of 0.6°C, and an increase of 0.3 and 0.7°C at 100 and 150 m, respectively (Table 7a).

These conditions were associated with above-average surface temperature (February), average salinity at the lightstations, above-average onshore transport and anomalously high sea level. A strong convergent condition is indicated.

By the end of March 1961, surface temperatures decreased seaward, ranging from 9.6 to 9.0°C; salinities, 29.0-32.6°/oo; densities, 22.4-25.4; and dissolved oxygen, about 6.5 mL/L, seaward of Amphitrite Point (Fig. 73a-d). Bottom temperatures were slightly lower, except at 200 m, bottom salinities similar, except at 50 m, and densities similar to those observed in late February (Table 7a-c).

These conditions were associated with anomalously high surface temperature (March) and below-average salinity at the lightstations, anomalously large onshore transport and anomalously high sea level. They indicate a markedly developed convergent condition.

By about mid-April 1961 off Cape Cook, surface temperatures ranged from 8.5 to 9.0°C; salinity, 30.9-31.2°/oo; density, 24.0; and dissolved oxygen, 6.4-7.1 mL/L (Fig. 75a-d). Bottom temperatures at 100-200 m were markedly lower than off Amphitrite Point in late March (Table 7a). Similarly, salinities and densities were generally higher, particularly at 50-100 m (Table 7b,c). A southward flow at depth over the outer continental shelf and upper slope is indicated by the upward slope of the isopycnals (Fig. 75c).

Above-average sea surface temperature (March-April), significantly below-average (March) and above average (April) surface salinities prevailed at the lightstations. A marked reversal in transport occurred, from anomalously large onshore transport (March) to small offshore transport (April). Sea level was anomalously high for March, but average for April. A divergent condition is indicated.

In late June 1961, surface temperatures ranged from 16 to 13°C; salinities, 31-32°/oo; densities, 23.0 - 24.0; and dissolved oxygen, 8.0-9.0 mL/L, with a surface high at mid-shelf, off Amphitrite Point (Fig. 77a-d).

Off Cape Cook, surface temperatures ranged from 9.6 to 10.6°C, with the warmest waters to seaward; salinities, 32.4 - 32.2°/oo, with the lowest salinities also to seaward; densities 25 - 24.6; and dissolved oxygen about 6.0-8.2 mL/L (Fig. 78a-d). A decrease in bottom temperatures occurred from mid-April to the end of July off Cape Cook (Table 7a). Bottom temperatures off Cape Cook were similar to those off Amphitrite Point, except at 50 m.

These conditions were associated with anomalously high sea surface temperature (July), average surface salinity at the lightstations, average offshore transport and average sea level. A weak divergent condition is indicated.

In late October 1961, surface temperatures increased seaward, ranging from 9.0 to 10.4°C; salinities, 31.2 - 32.4°/oo; densities, 24.2-24.8; and dissolved oxygen 6.0-6.5 mL/L, seaward of Amphitrite Point (Fig. 80a-d, 81a-d).

Off Cape Cook, surface temperatures ranged from 9.1 to 11.6°C; salinities, about 32.3°/oo; densities, 25.0 - 24.6; and dissolved oxygen, about 6.3 mL/L (Fig. 82a-d). Bottom temperatures were higher than observed in July (Table 7e). Salinity and density changes were small, and not entirely consistent with the temperature changes.

These conditions were associated with below-average sea surface temperature (October) near-average surface salinity at the lightstations, low onshore transport and anomalously low sea level. A weak convergent to relaxation condition is indicated.

6. Oceanographic Conditions during 1962

Near and at the end of January 1962, surface temperatures generally ranged from 7.0 to 7.8°C; surface salinities, 30.0-32.4°/oo; densities, 23.4-25.2; and dissolved oxygen 7.0-6.8 mL/L, off Amphitrite Point (Fig. 84a-d, 86a-d).

Off Cape Cook, surface temperatures ranged from 7.8 to 8.0°C; salinities, 31.6-32.2°/oo; densities, 24.6 - 25.2 (Fig. 87a-d).

Bottom temperatures were generally similar along each of the sections, and were also similar to those observed in late October and early November 1961, except at 50 m (Table 7a).

These conditions were associated with below-average temperature and salinity (January) at the lightstations, an anomalously small onshore transport and anomalously low sea level. The conditions described above reflect a weak convergent condition.

Near the end of March 1962, surface temperatures ranged from 7.4 to 7.8°C; salinities, 31.4-32.2°/oo; and densities, 24.6 - 25.2, seaward of Amphitrite Point (Fig. 89a-c). Bottom temperatures decreased slightly at 50 and 100 m, and increased at 150 and 200 m from late January to late March (Table 7a). The decrease at 50 and 100 m can be attributed to surface cooling and mixing and a relaxation of the convergent state. The increase at 150 and 200 m is attributed to the onshore movement of a cell of warm water.

These conditions were associated with below-average sea surface temperature (March), anomalously high surface salinity at the lightstations, below-average onshore transport and anomalously low sea level. These indicate a very weak convergent or relaxation state.

7. Oceanographic Conditions, March 6-10, 1969

In early March 1969, surface temperatures generally ranged from 7.2 to 8.0°C; surface salinities, 29.5-32.6°/oo; densities, 23.0 - 25.4; dissolved oxygen, 8.0-6.5 mL/L (Fig. 91-94). Bottom temperatures at 150 and 200 m were at their upper limit, but at, or near, their lower limit at 50 and 100 m. A large cell of warm water was present off the outer continental shelf and slope.

These conditions were associated (February) with anomalously low sea surface temperature and below-average salinity at the lightstations. Above-average onshore transport and anomalously high sea level prevailed, indicating a well-developed convergent state.

XII. HORIZONTAL DISTRIBUTIONS OF TEMPERATURE AND SALINITY AT 200 AND 500 METERS DEPTH

Horizontal distributions of temperature and salinity at depths of 200 and 500 m are presented to show the spatial variability that can be expected along the continental slope off the coast of British Columbia.

Temperature distributions at 200 m depth indicate both a seasonal and spatial variability along the upper continental slope. Temperatures appeared to be about 0.6°C lower in early autumn (Fig. 95, 96) than in early spring (Fig. 97). Ingraham (1967) reported an increase in temperature of 0.6°C at 183 m depth from late spring to late autumn off southern Vancouver Island. Both sets of data are consistent with the seasonal patterns of temperature associated with convergence and divergence. The data presented here were taken in periods generally associated with weak convergence (early spring) and weak divergence (early autumn). On the other hand, the data presented by Ingraham were taken during periods generally associated with weak divergence (late spring) and weak to moderately strong convergence (late autumn). In early autumn, temperatures ranged from about 6.8°C off southern Vancouver Island, to about 6.2°C off Queen Charlotte Sound, to about 6°C off the northern Queen Charlotte Islands, a range of 0.8°C over a distance of about 425 km (230 M). In early spring, temperatures ranged from about 7.4°C off southern Vancouver Island to 6.8°C off northern Queen Charlotte Sound, similar to the autumn range of 0.6°C for this area. In the deep waters of Queen Charlotte Sound, a seasonal variation of about 1.0°C is indicated in these data.

Salinity distributions at 200 m depth show little spatial variation along the upper continental slope, ranging from less than 33.95°/oo off southern Vancouver Island to about 33.85°/oo off the northern Queen Charlotte Islands (Fig. 98, 99 and 100). Salinities appeared to be slightly lower (~0.5°/°°) in early spring (Fig. 100) than in autumn (Fig. 98 and 99) along the upper contintental slope off the west coast of Vancouver Island, consistent with the seasonal change in temperature at 200 m depth.

At 500 m depth, temperatures ranged from about 5.2°C off southern Vancouver Island to about 4.4°C off northern Queen Charlotte Islands (Fig. 101, 102, and 103), a range of 0.8°C, similar to that at 200 m depth.

The salinity distributions at 500 m depth indicate little spatial variation along the continental slope, ranging from about 34.15°/°° in the south to 34.05°/°° in the north (Fig. 104, 105 and 106).

XIII. HIGHLIGHTS OF OCEANOGRAPHIC CONDITIONS

Annual sea surface and air temperature anomalies indicate several long-term heating and cooling trends in the coastal waters; warming (1909-41), cooling (1941-50), warming (1950-63), cooling (1963-72), warming (1972-83). A cooling trend in the annual sea surface temperatures is expected to occur the next 10-12 years. Since 1935, annual sea surface temperatures were very high for 1940, 1941, 1958, 1963, 1967 and for 4 consecutive years, 1978-81; and very low for 1950, 1955, 1956, and for 3 consecutive years, 1970-72.

Annual surface salinity anomalies indicate a decreasing trend from 1935 through to at least 1977, about 0.5°/°°/41 yr.

Monthly anomalies of sea level, Ekman transport normal to the coast and sea surface temperature at the lightstations indicate periods of maximum and minimum convergence, and their associated conditions. The winters of 1940-42, 1958, 1961, 1978 and 1981 were periods of anomalously warm surface and bottom waters and maximum northward flow over the continental shelf.

Early changes from a prevailing convergent condition to a relaxation or prevailing divergent condition are indicated in the monthly anomalies of calculated transport and sea level, in 1955 (Feb), 1964 (Feb), 1965 (Feb), 1970 (Mar), 1977 (Mar) and 1980 (Mar).

A temperature decrease of 0.6°C, and a salinity increase of 0.5°/°° at 200 m depth along the edge of the continental shelf can be expected from early spring to early autumn.

There appeared to be little seasonal variation at 500 m along the continental slope; temperatures were about 5.2°C, and salinities, 34.15°/°° off southern Vancouver Island.

ACKNOWLEDGMENTS

The authors wishes to thank Dr. M. Waldichuk for reviewing this report and for his invaluable comments, and Dr. R. E. Thomson for his comments on the section dealing with circulation.

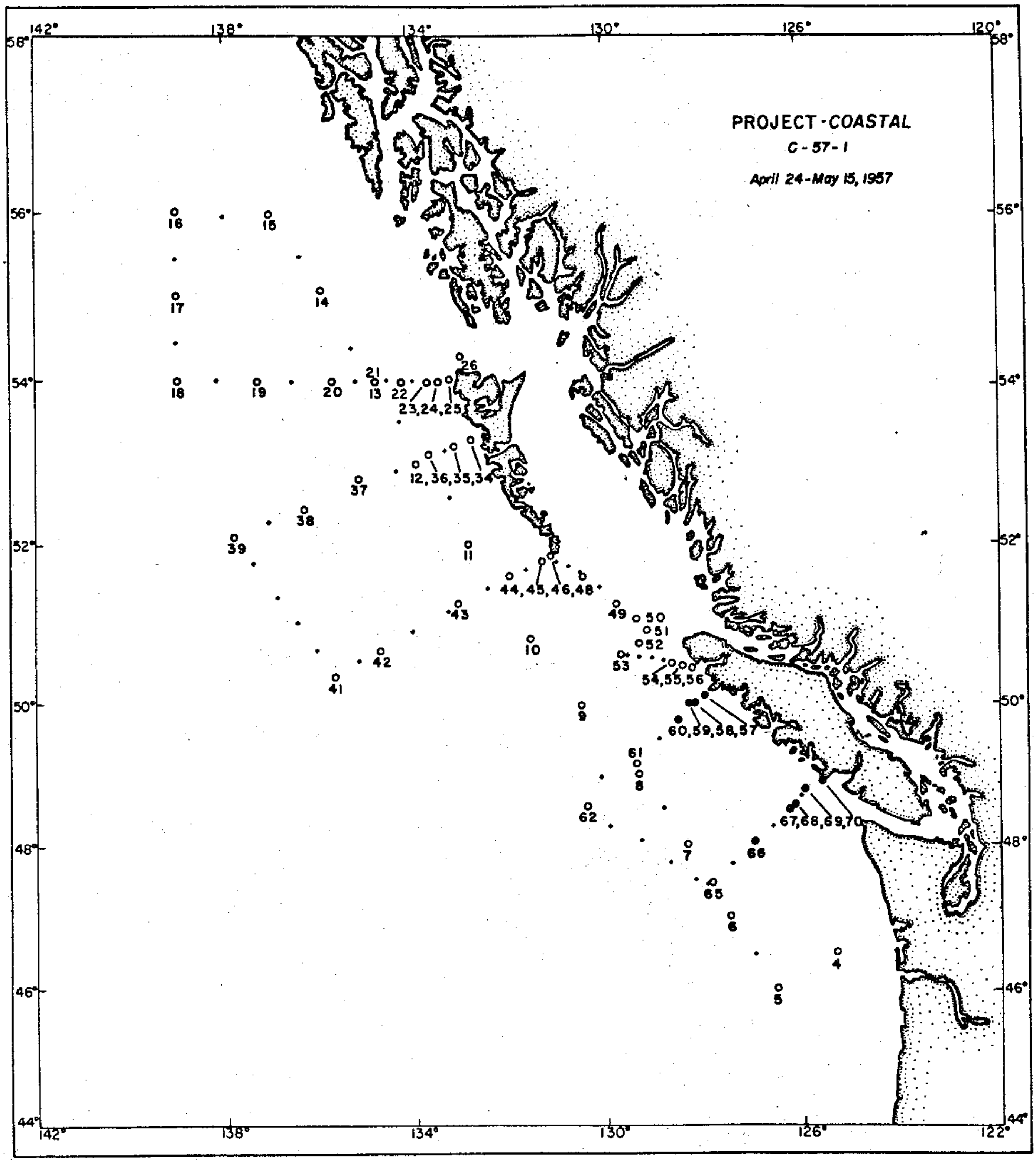

Fig. 36. Coastal project, April 24-May 15, 1957. Large solid circles indicate stations used in the sections.

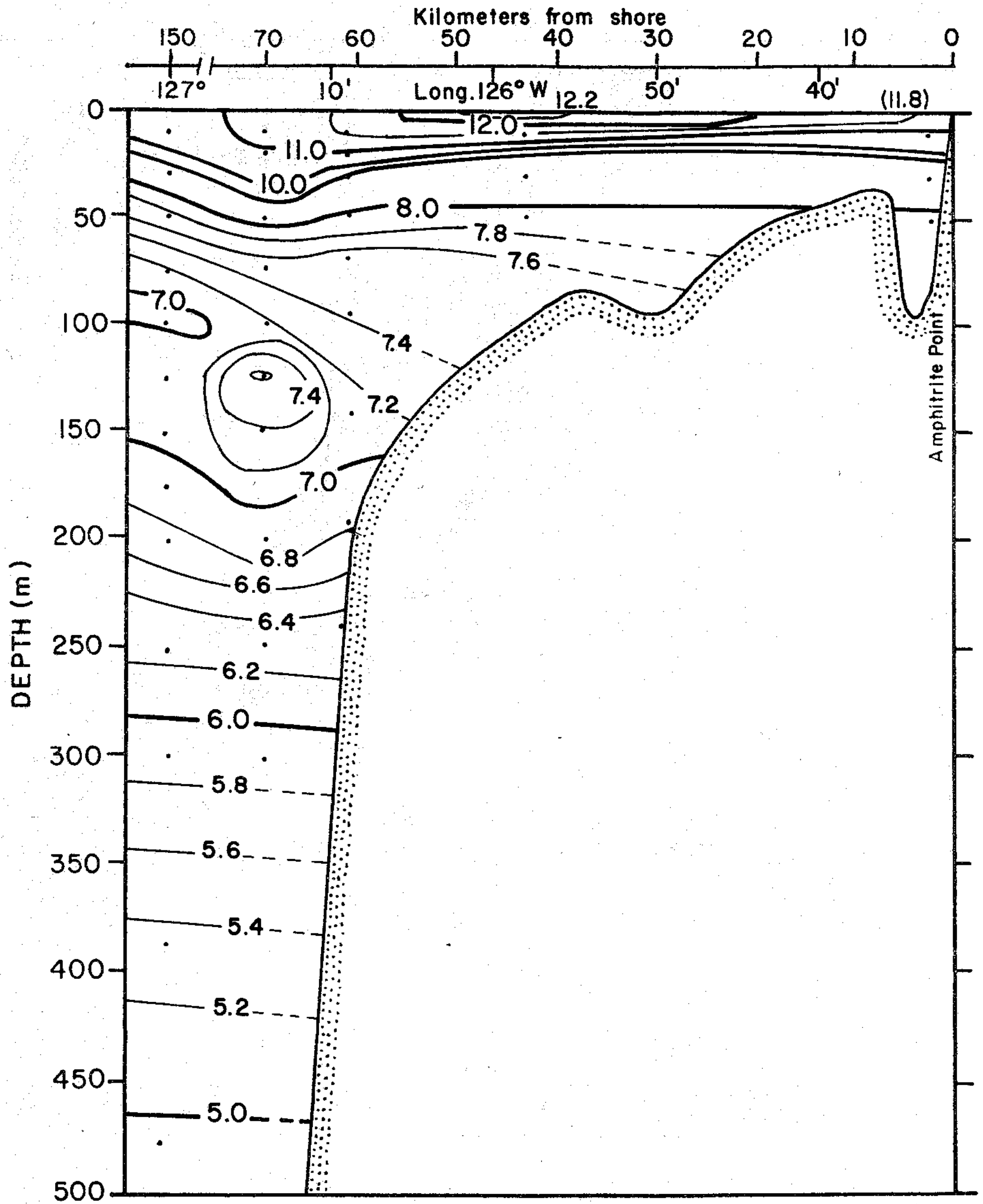

Fig. 37a. Temperature (°C) seaward of Amphitrite Point, May 14, 1957.

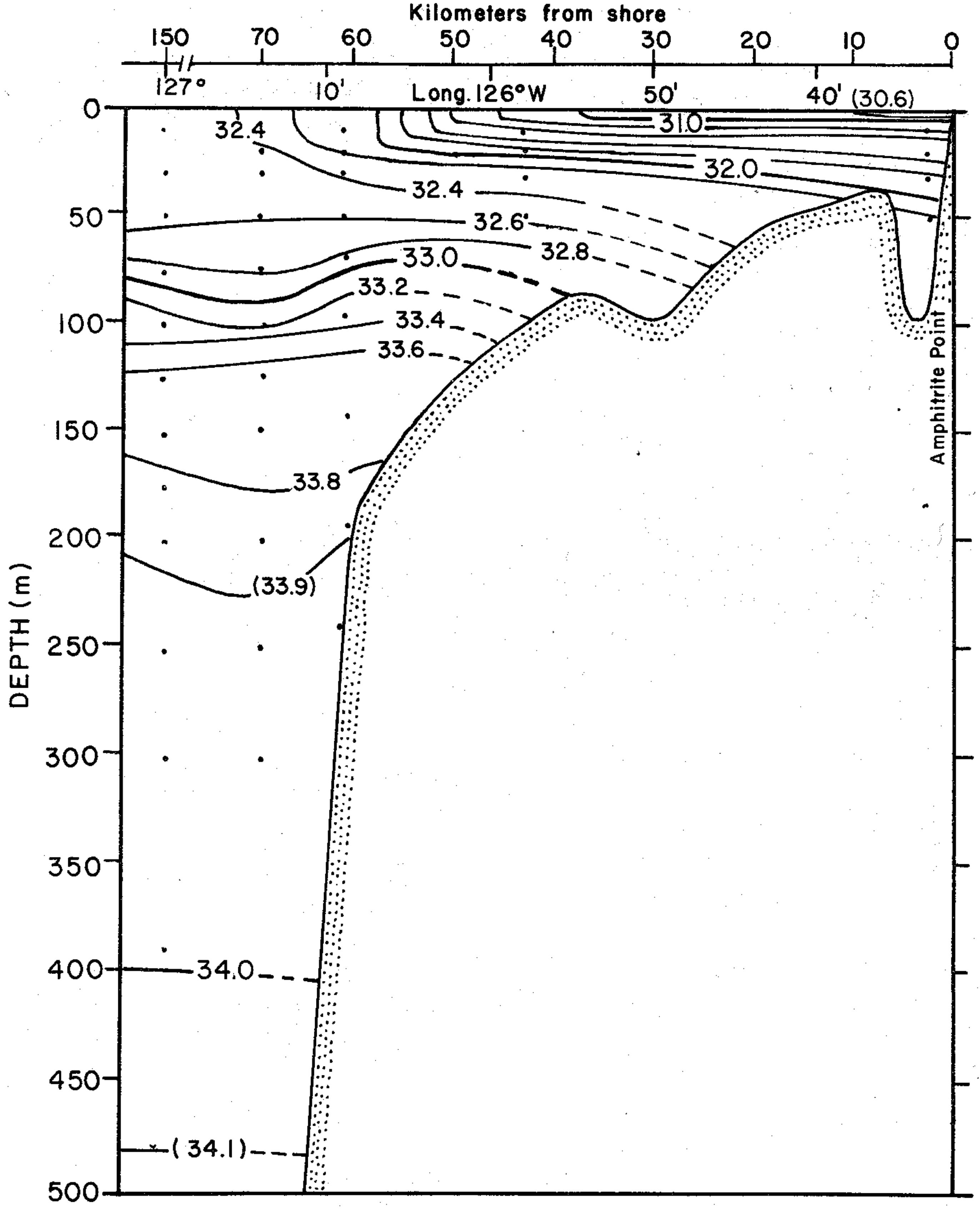

Fig. 37b. Salinity (°/oo) seaward of Amphitrite Point, May 14, 1957.

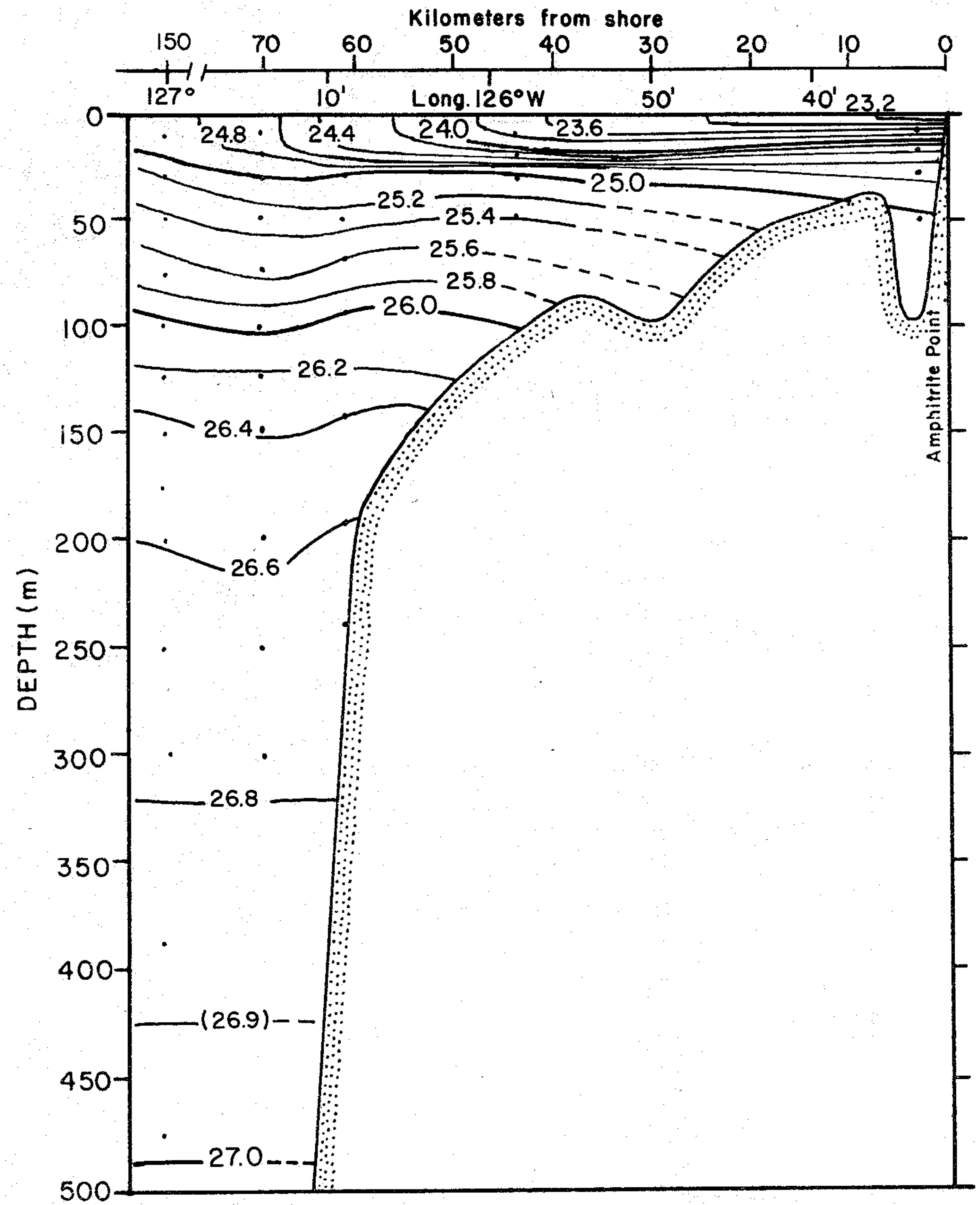

Fig. 37c. Density (σ_t) seaward of Amphitrite Point, May 14, 1957.

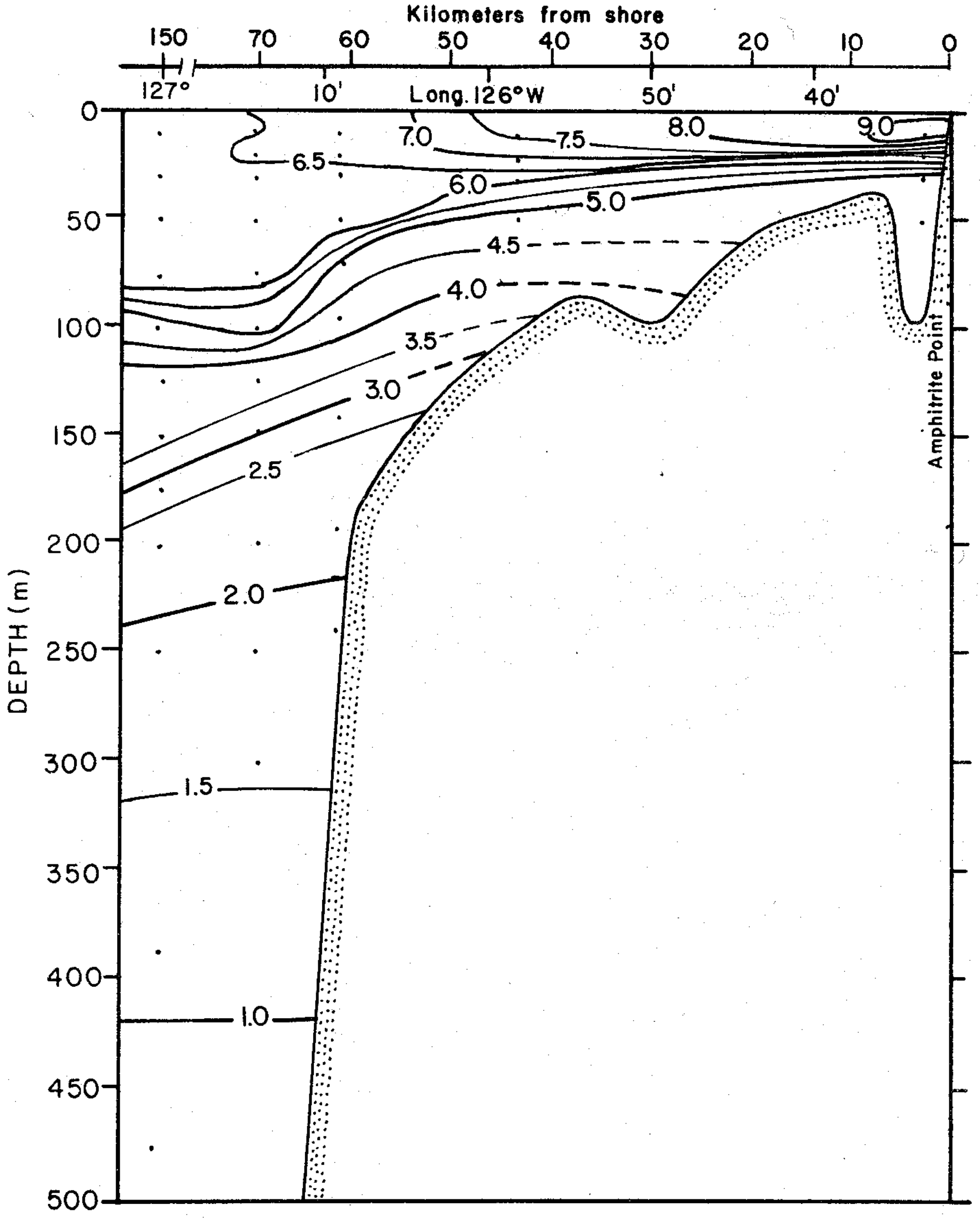

Fig. 37d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, May 14, 1957.

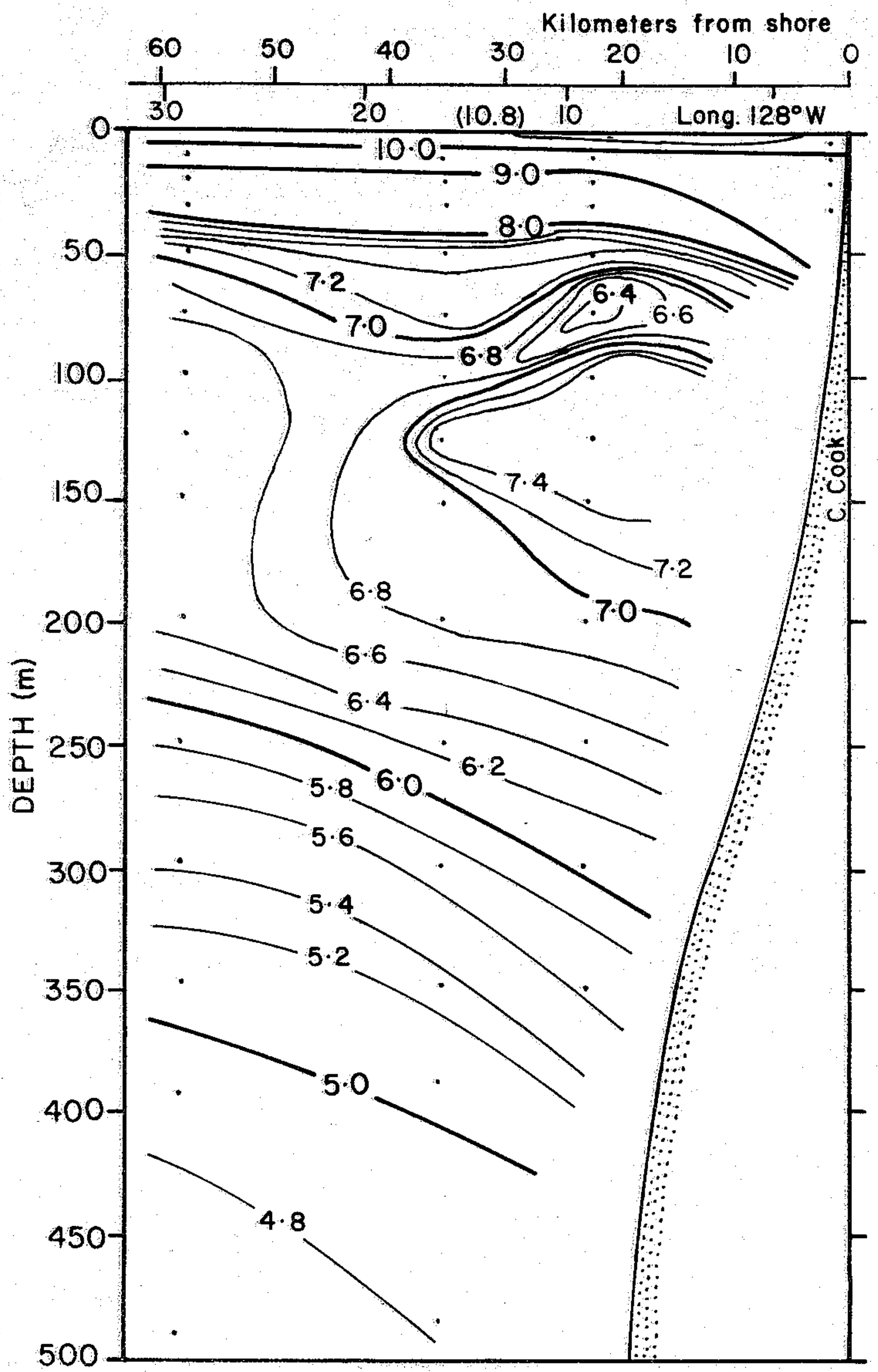

Fig. 38a. Temperature (°C) seaward of Cape Cook, May 12, 1957.

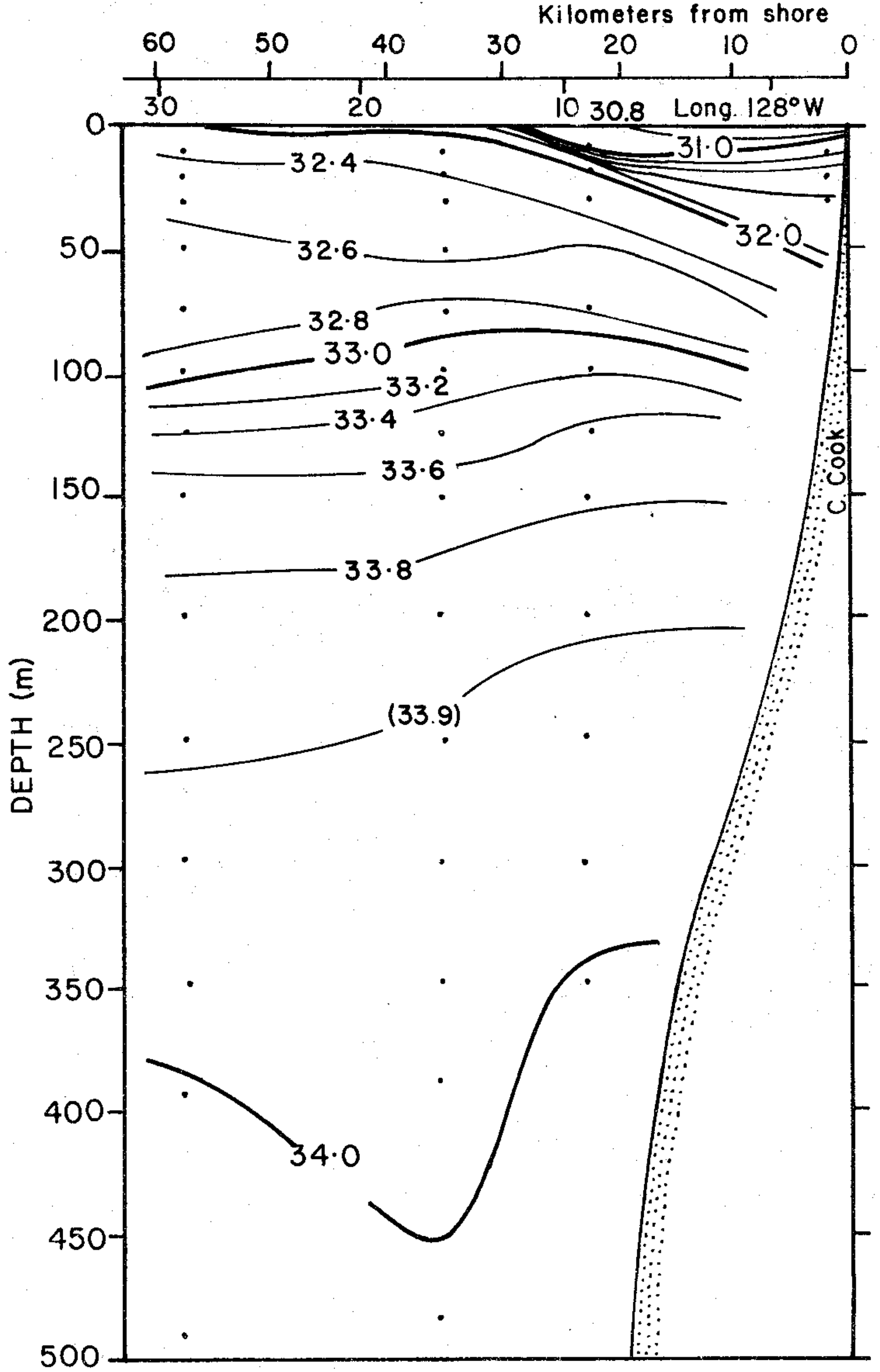

Fig. 38b. Salinity (°/oo) seaward of Cape Cook, May 12, 1957.

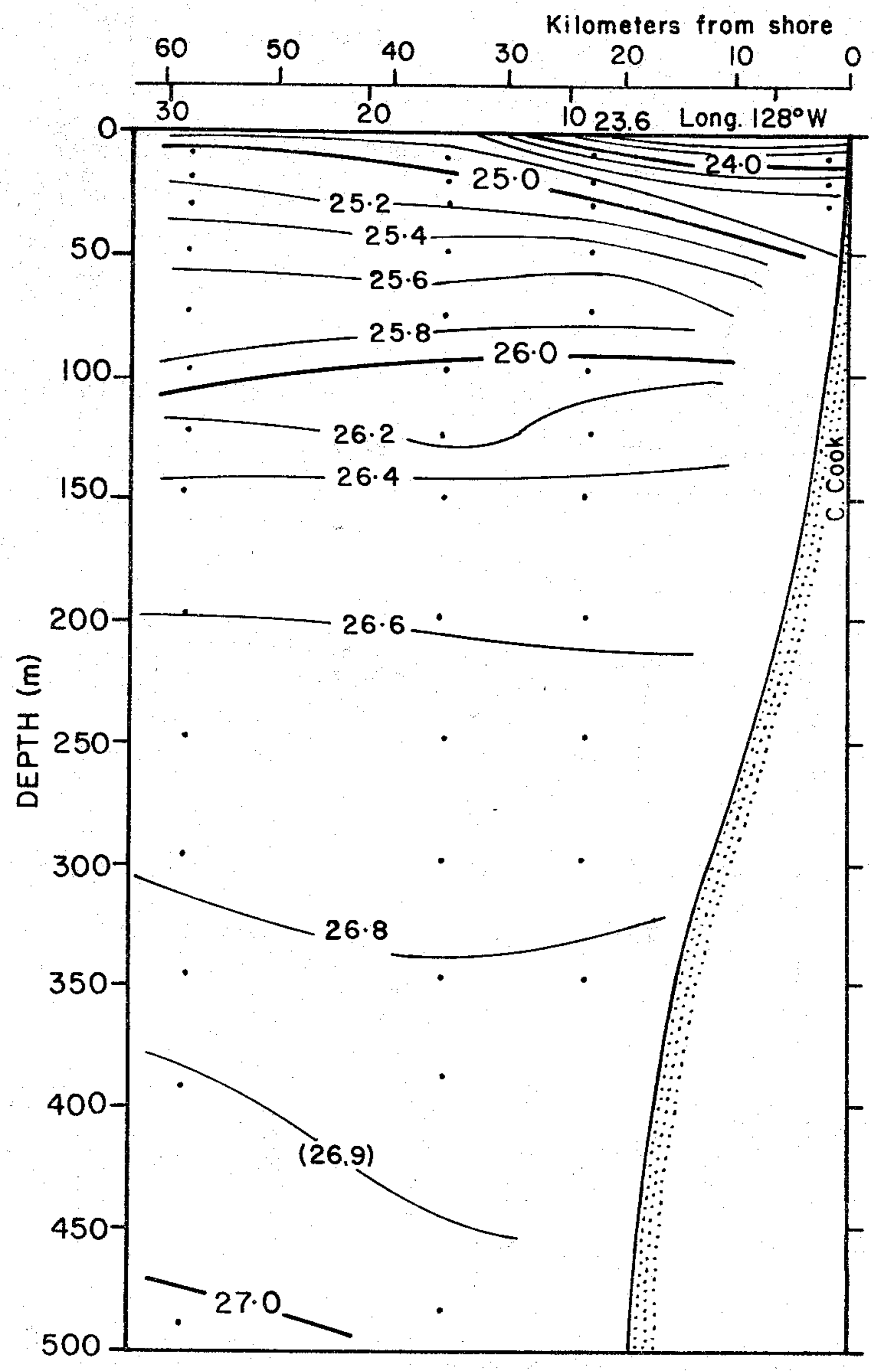

Fig. 38c. Density (σ_t) seaward of Cape Cook, May 12, 1957.

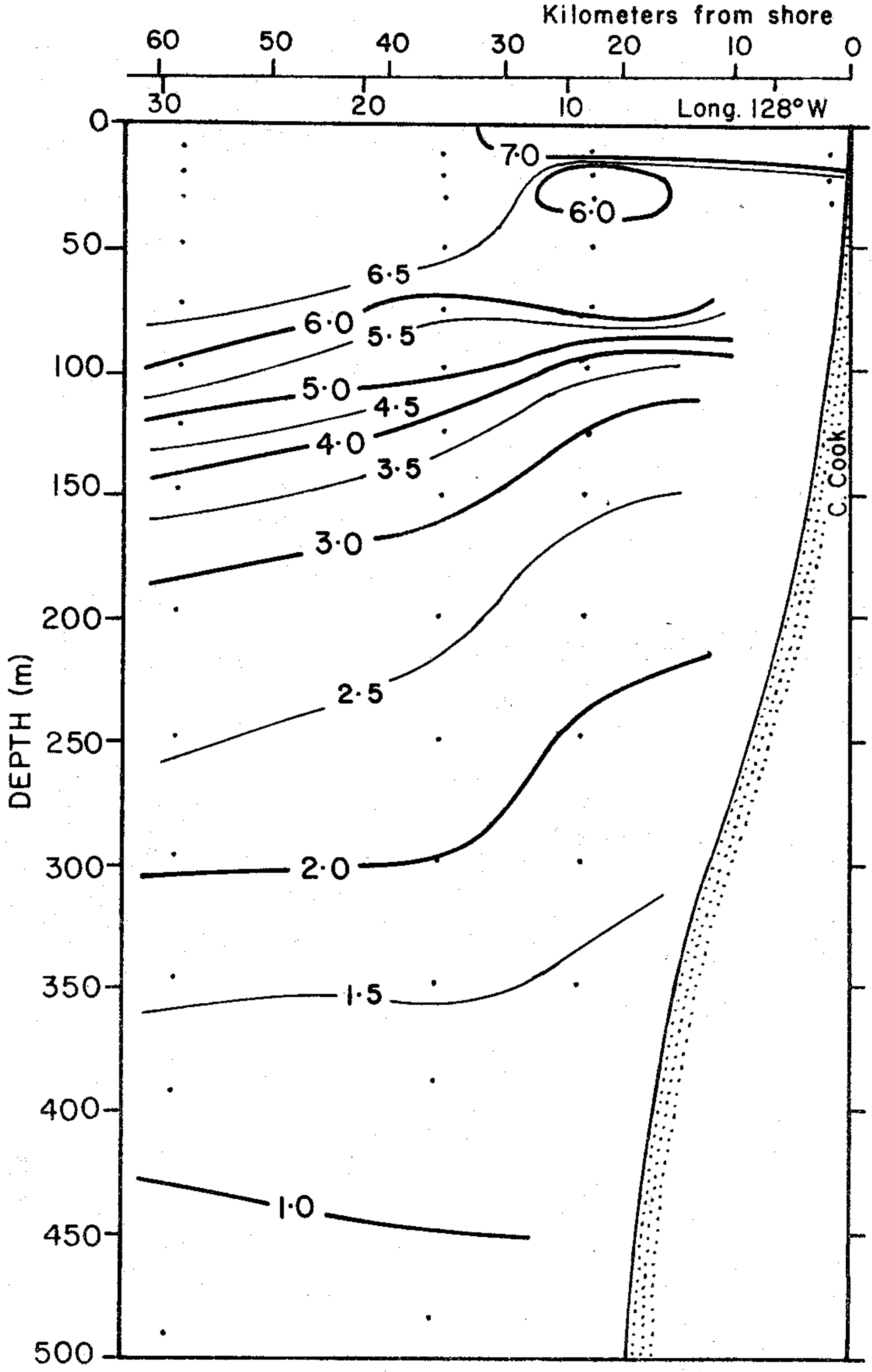

Fig. 38d. Dissolved oxygen (mL/L) seaward of Cape Cook, May 12, 1957.

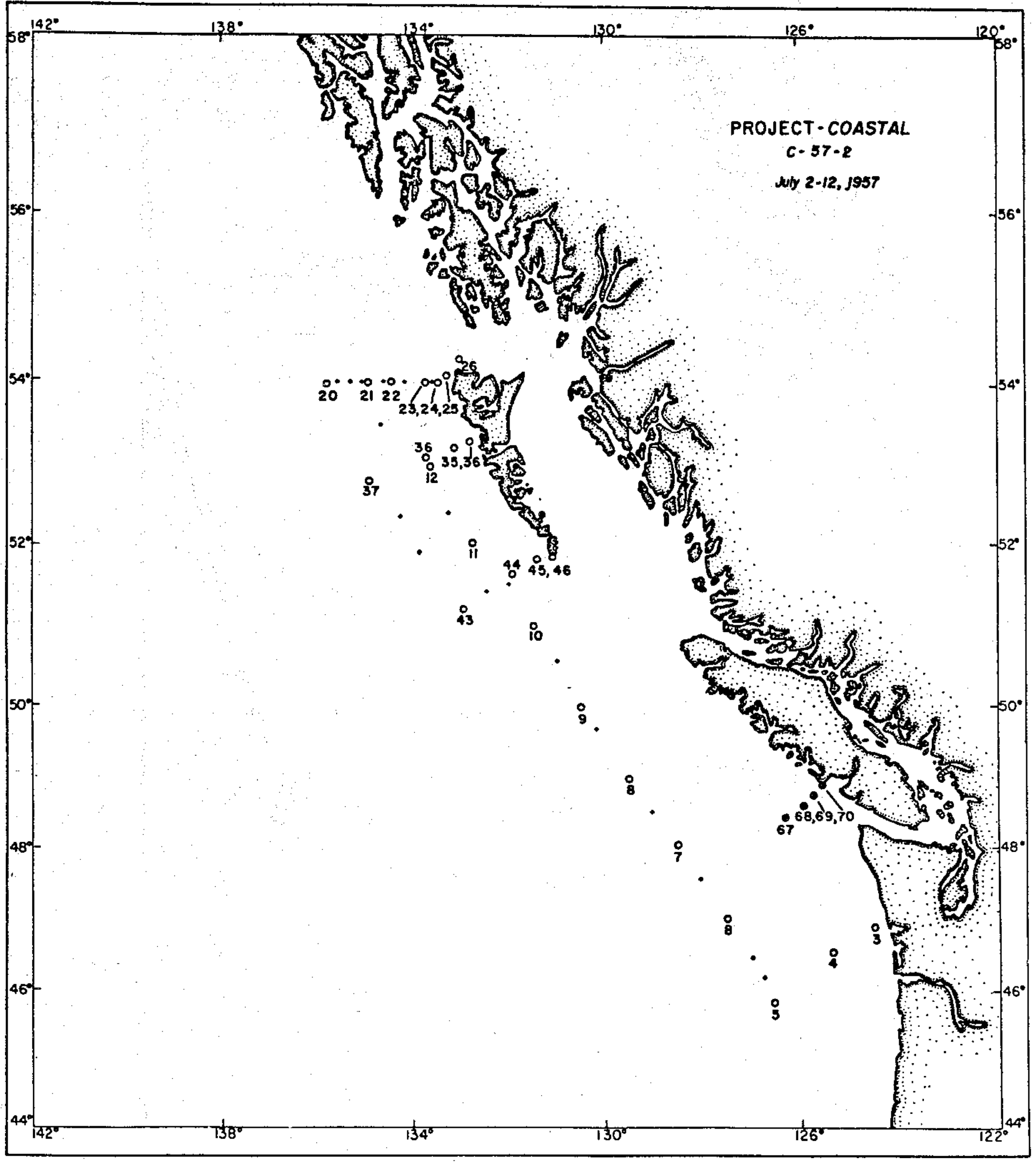

Fig. 39. Coastal project, July 2-22, 1957. Large solid circles indicate stations used in the sections.

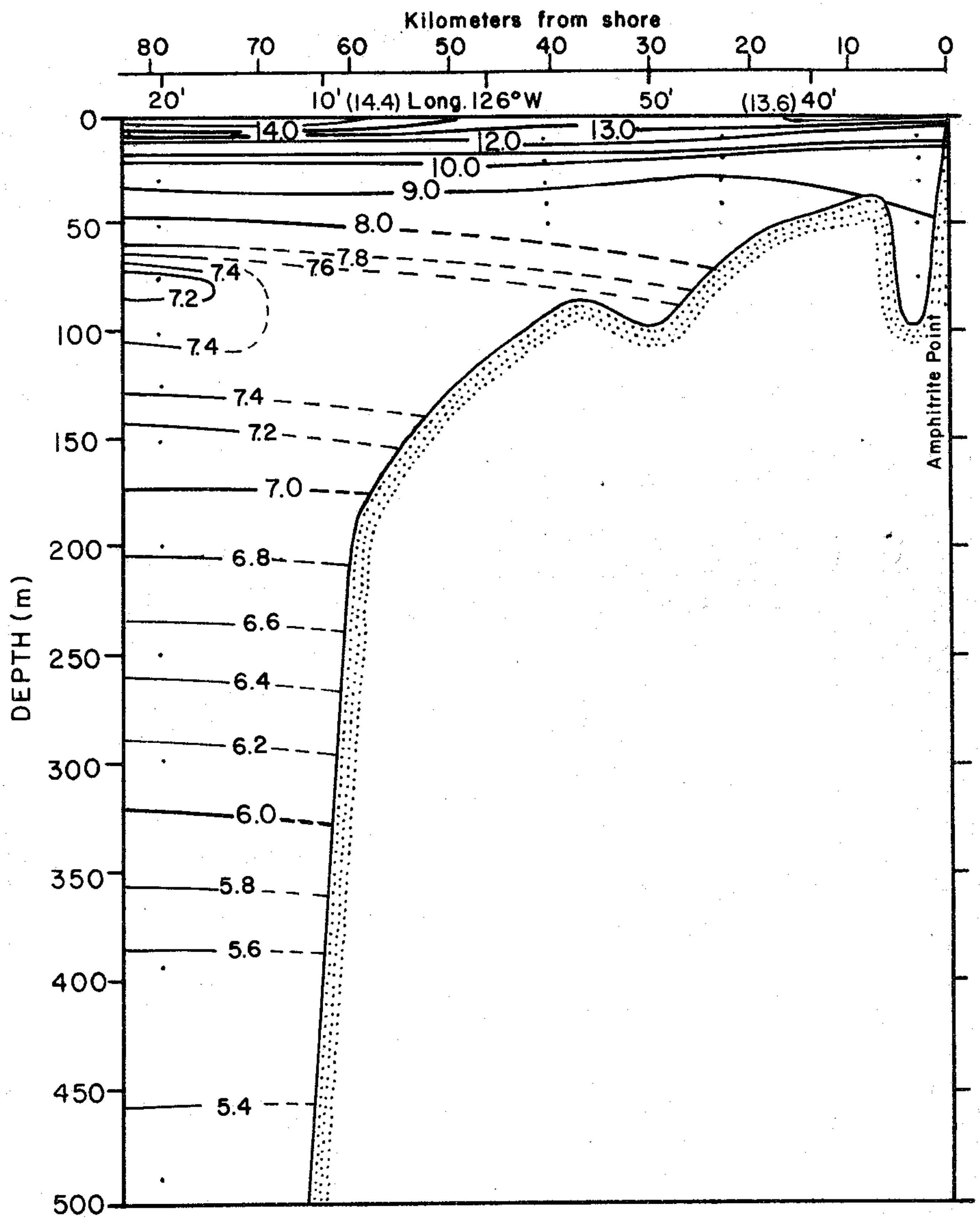

Fig. 40a. Temperature ($^{\circ}$C) seaward of Amphitrite Point, July 12, 1957.

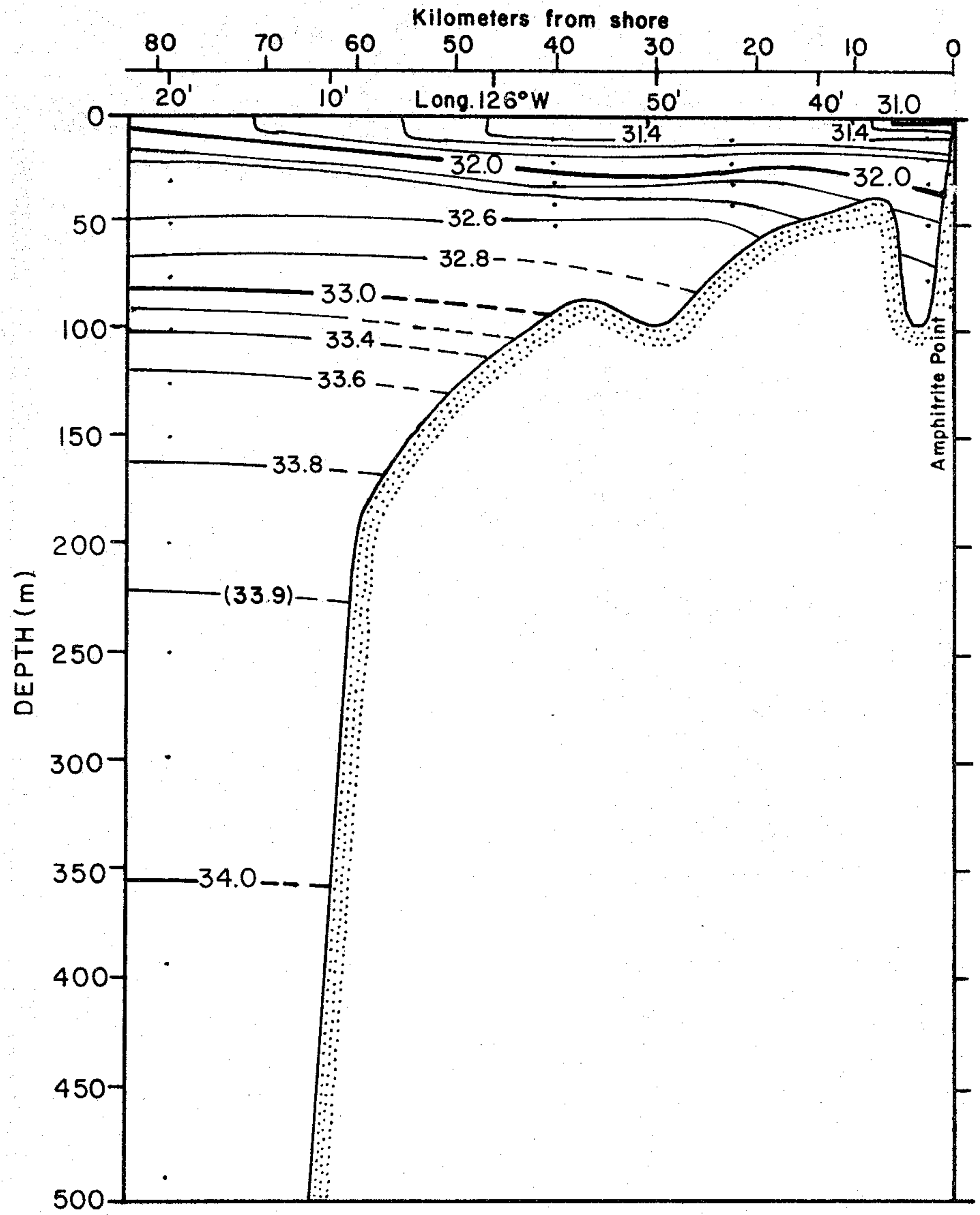

Fig. 40b. Salinity (°/oo) seaward of Amphitrite Point, July 12, 1957.

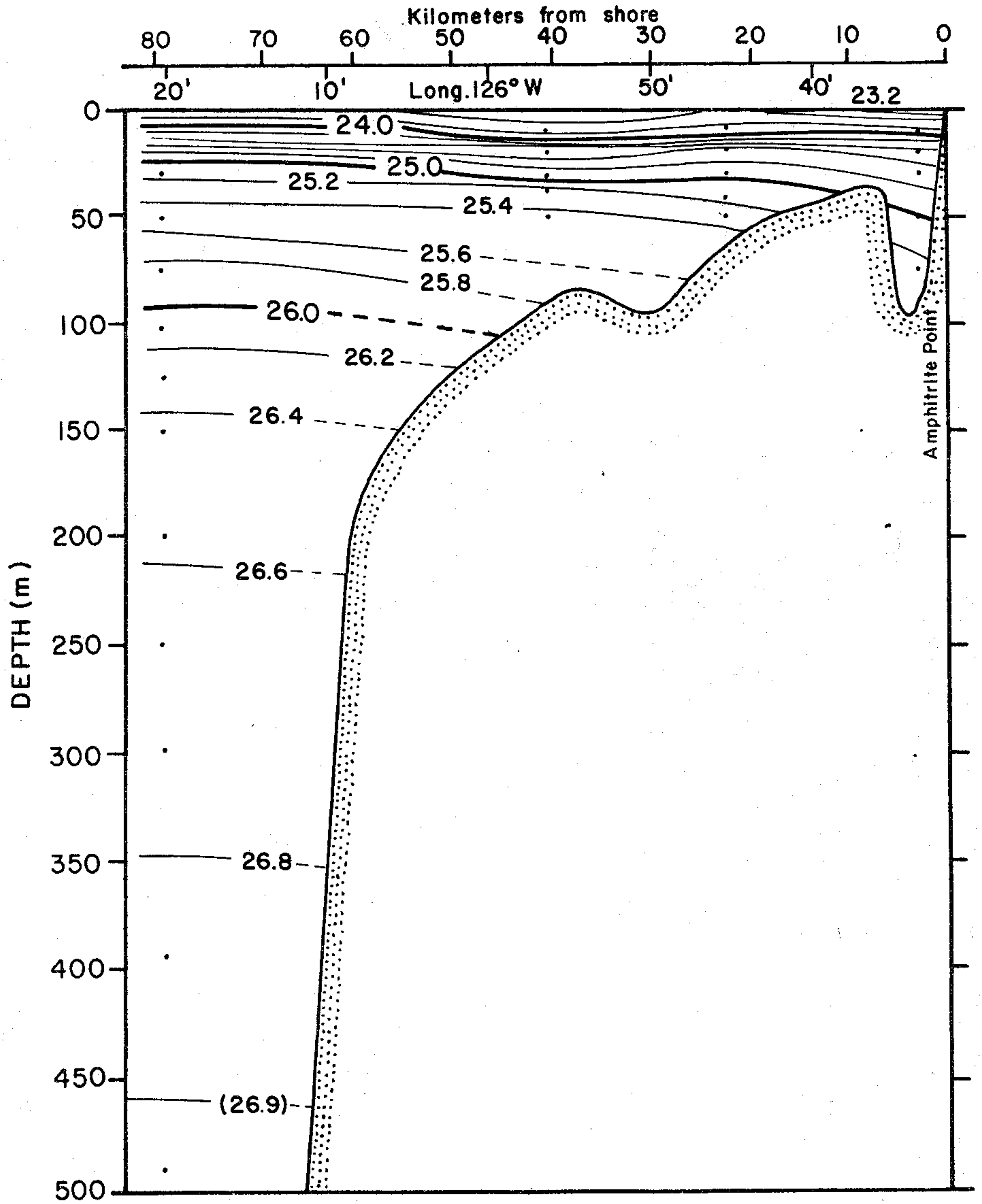

Fig. 40c. Density (σ_t) seaward of Amphitrite Point, July 12, 1957.

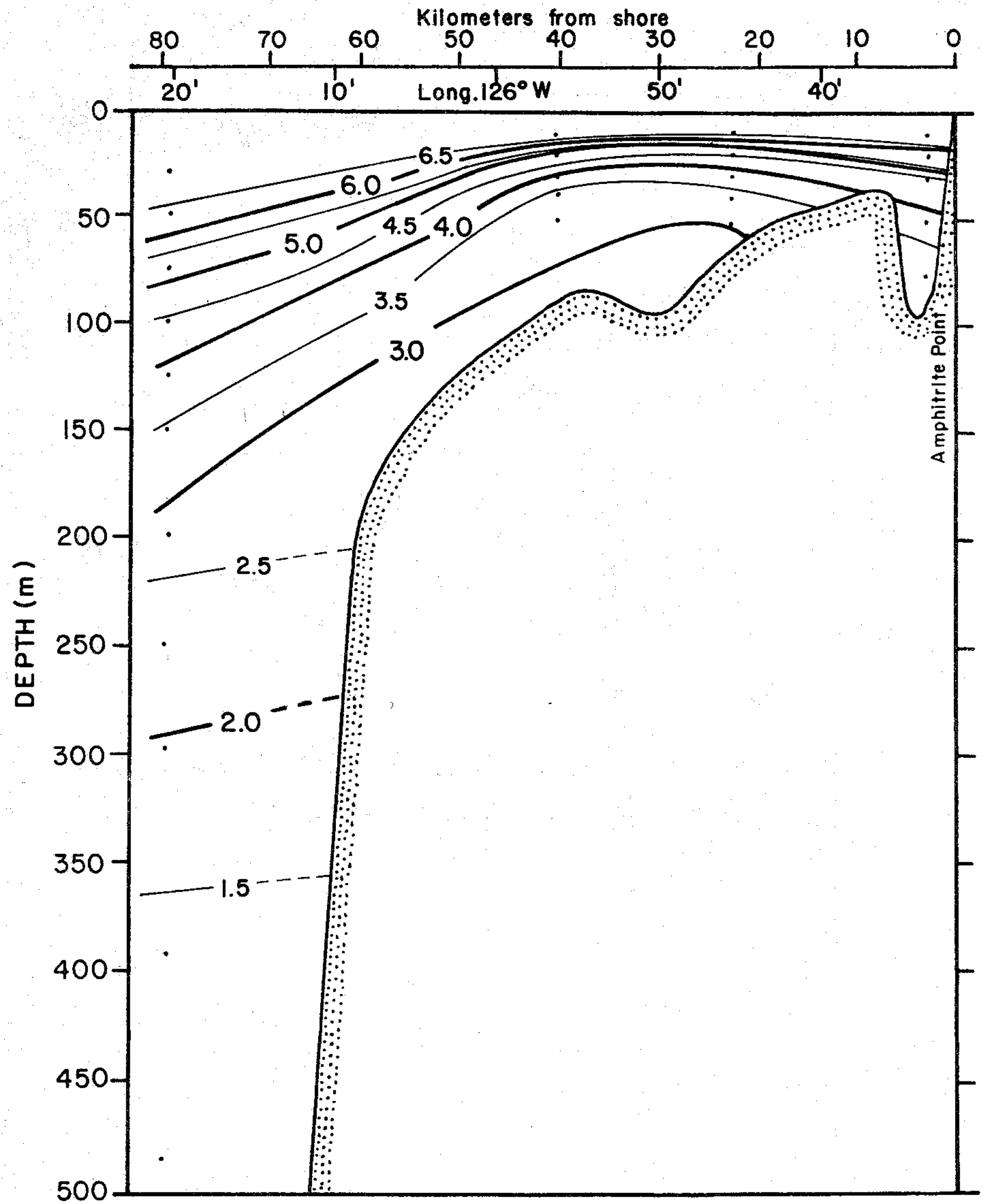

Fig. 40d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, July 12, 1957.

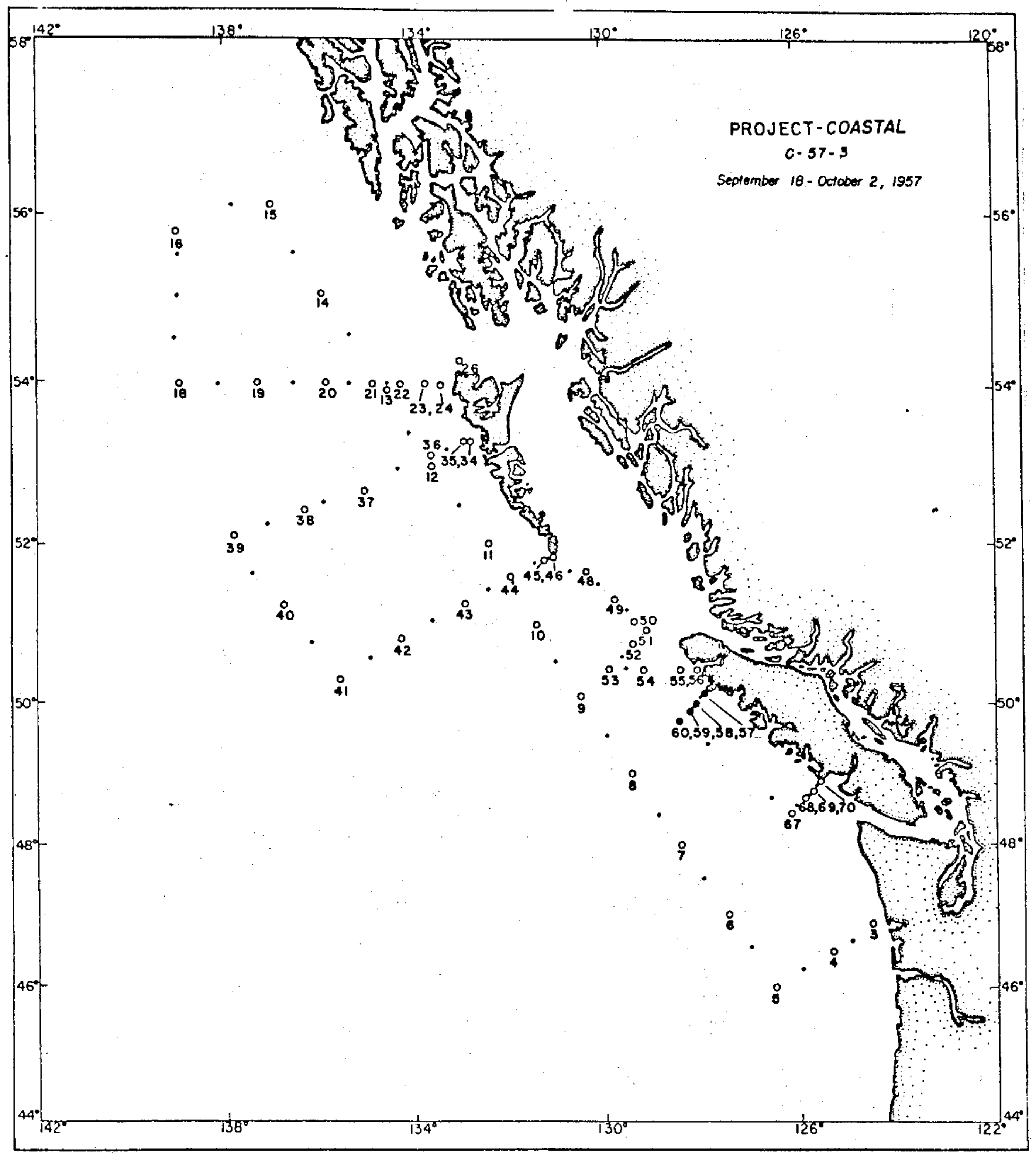

Fig. 41. Coastal project, September 18-October 2, 1957. Large solid circles indicate stations used in the sections.

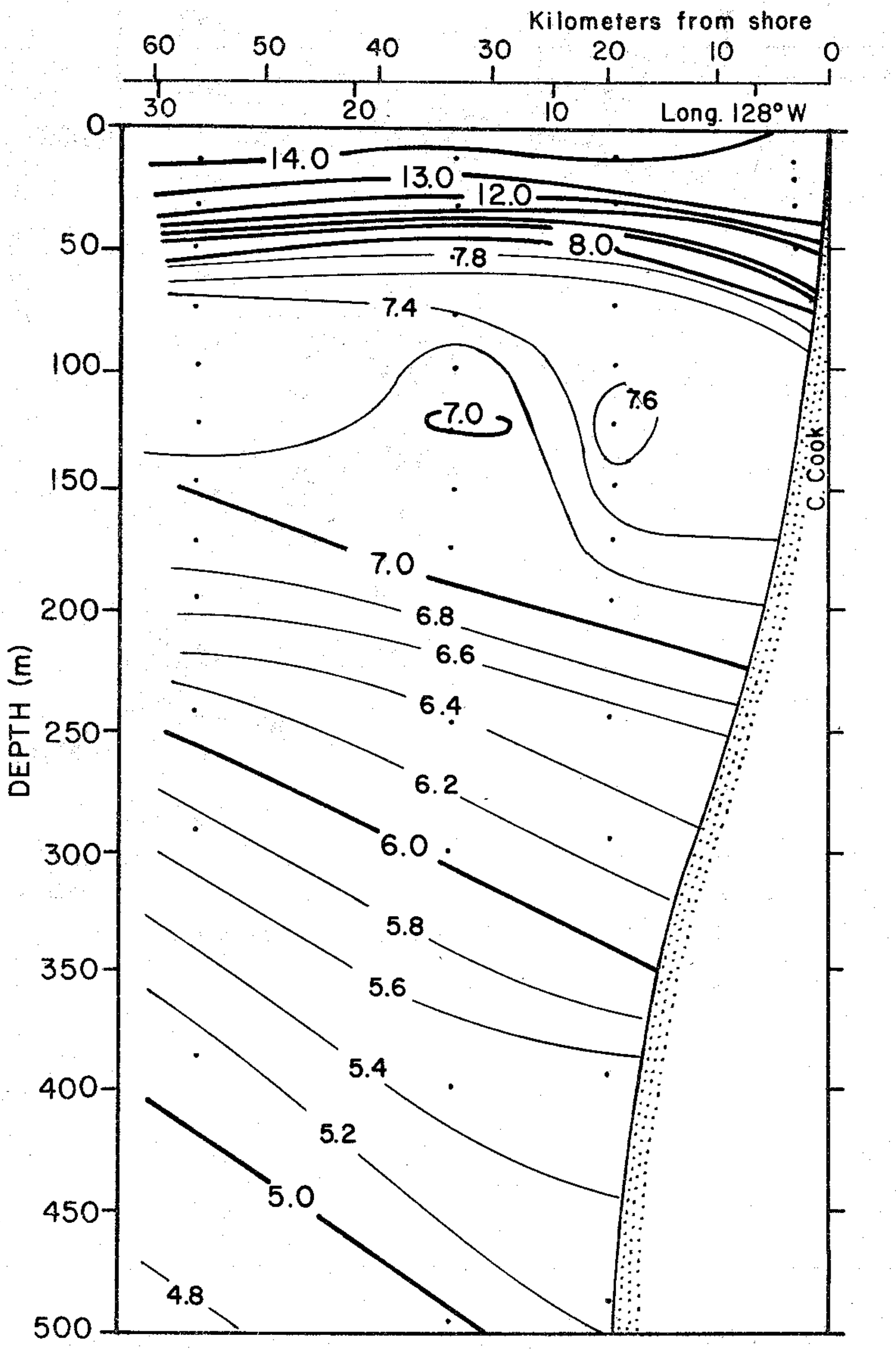

Fig. 42a. Temperature (°C) seaward of Cape Cook, October 1-2, 1957.

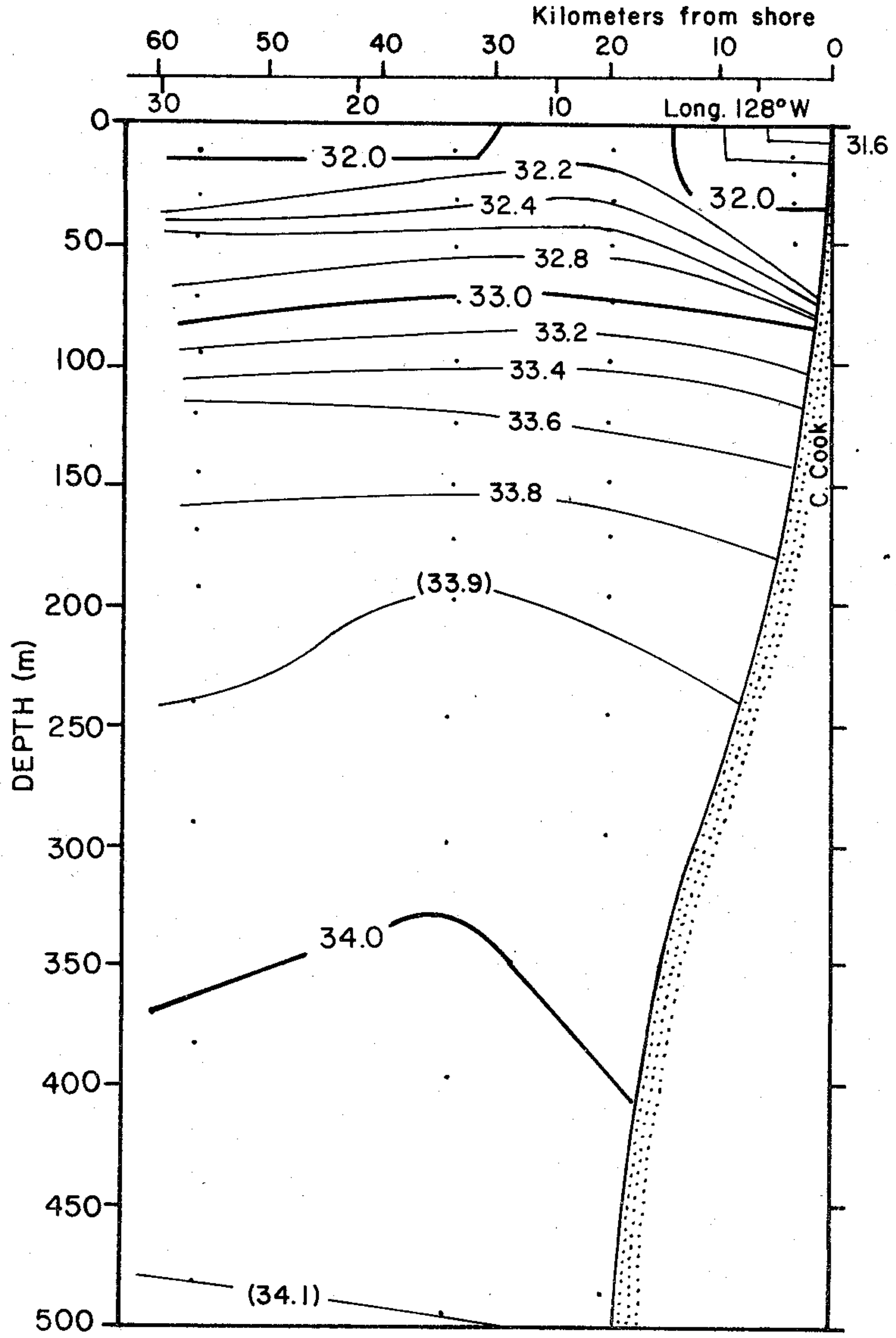

Fig. 42b. Salinity (‰) seaward of Cape Cook, October 1-2, 1957.

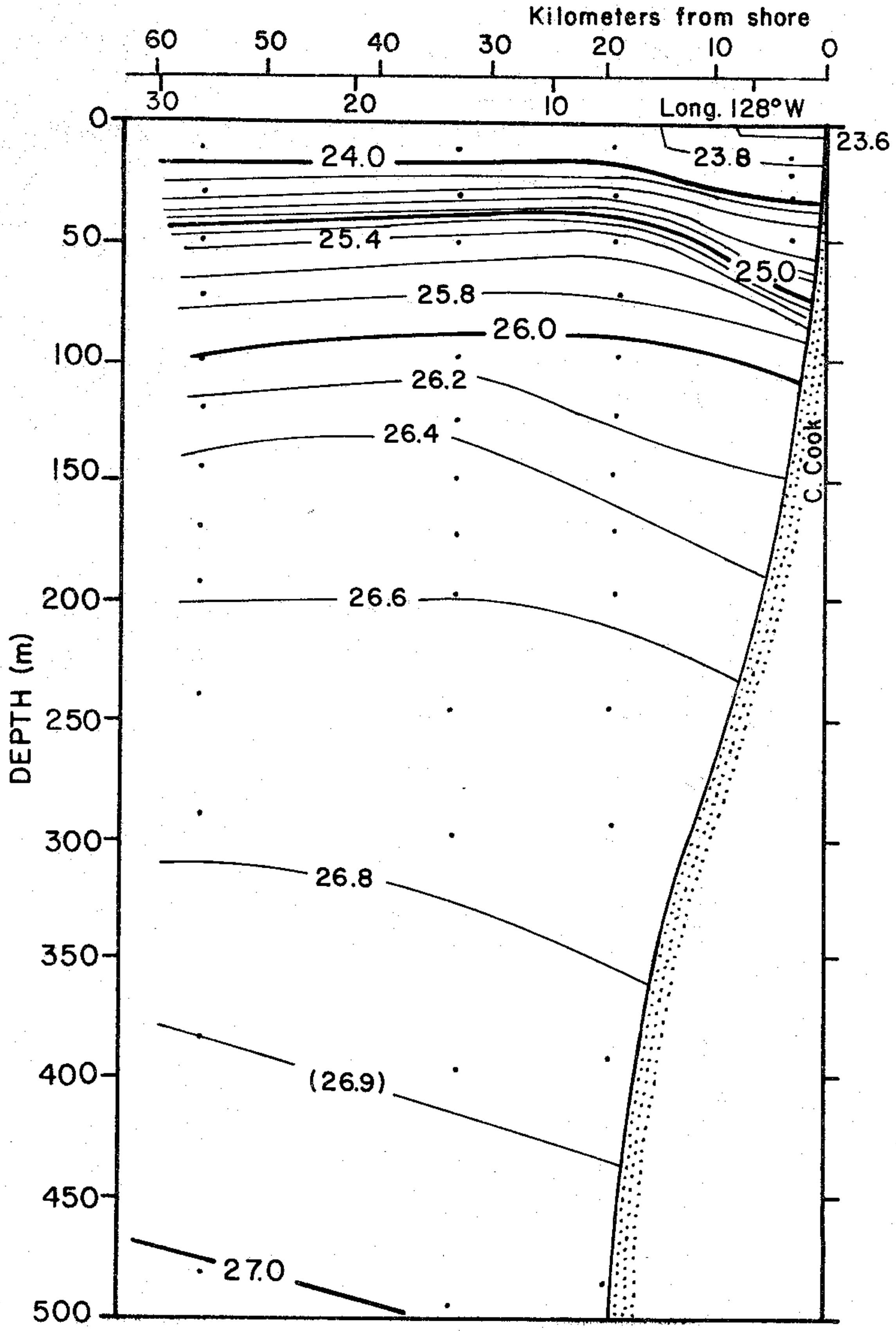

Fig. 42c. Density (σ_t) seaward of Cape Cook, October 1-2, 1957.

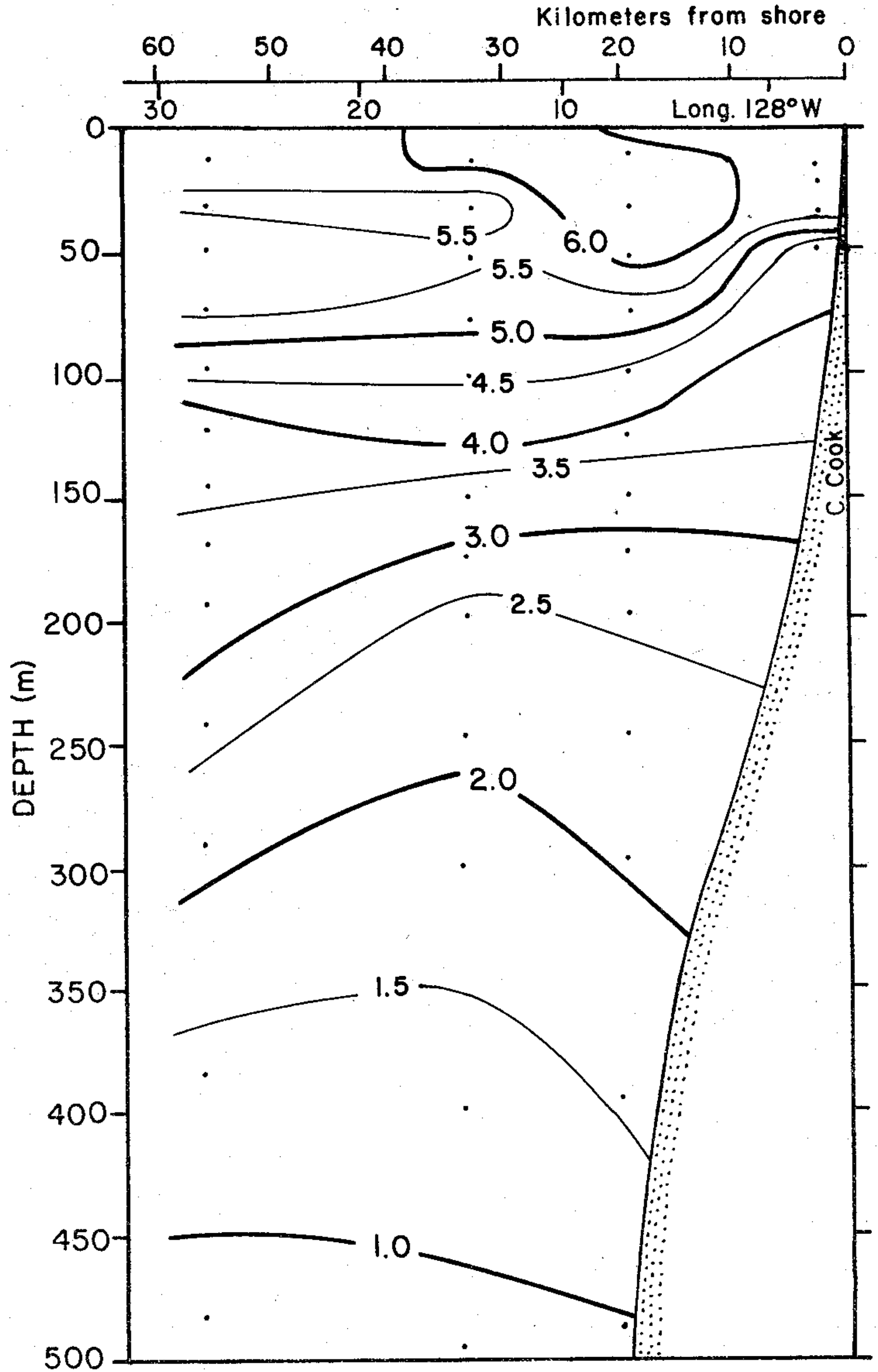

Fig. 42d. Dissolved oxygen (mL/L) seaward of Cape Cook, October 1-2, 1957.

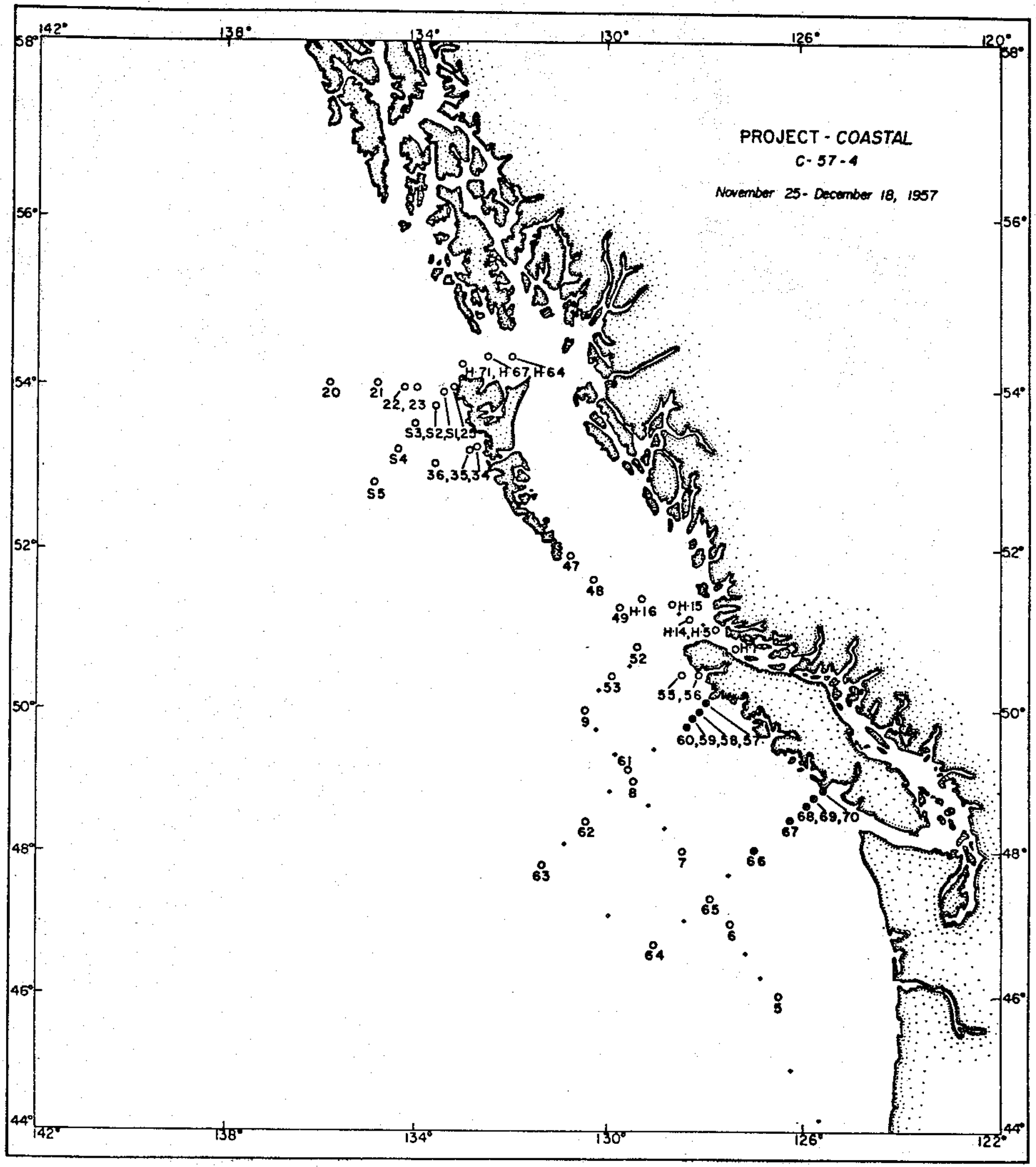

Fig. 43. Coastal project, November 25-December 18, 1957. Large solid circles indicate stations used in the sections.

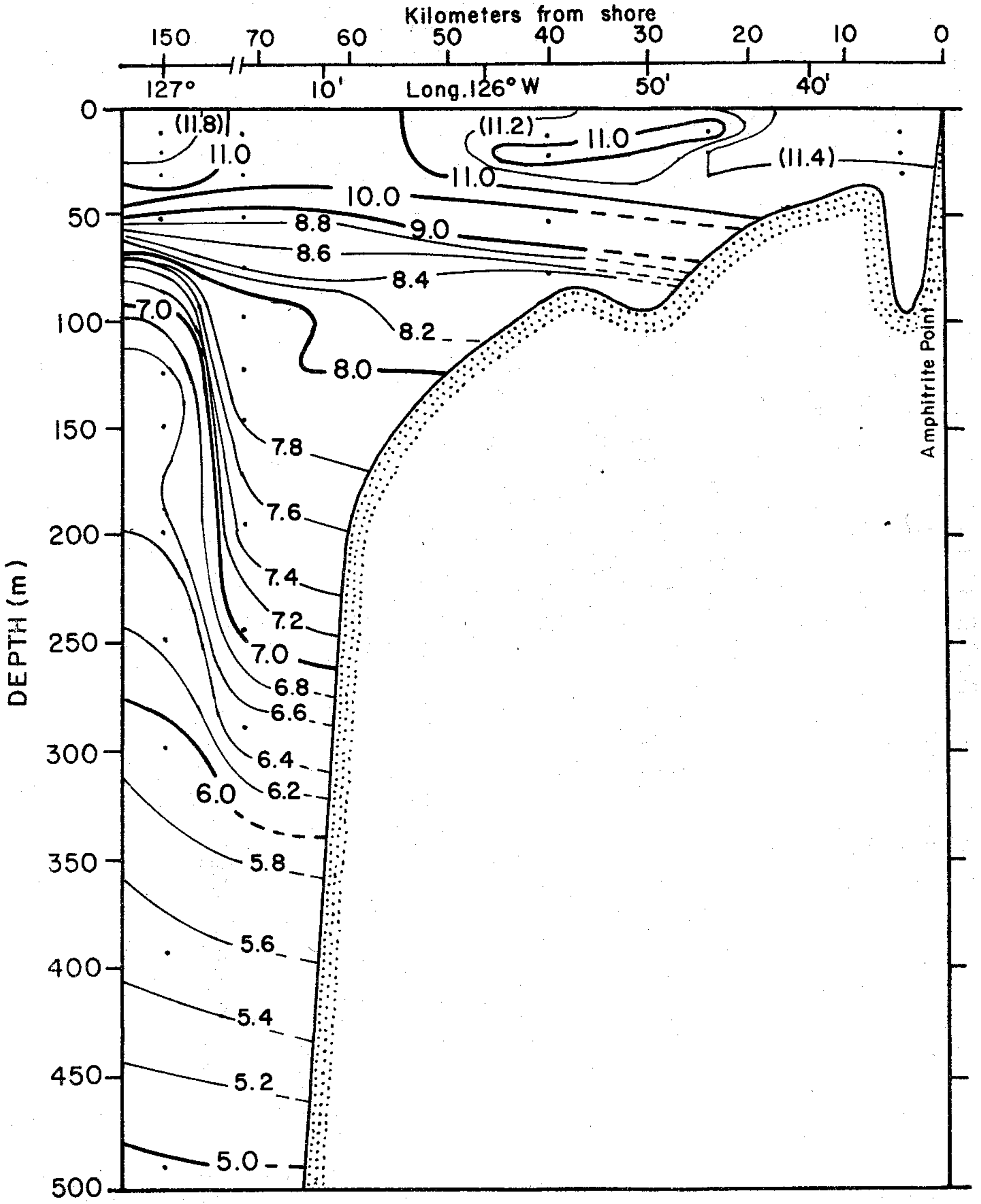

Fig. 44a. Temperature (°C) seaward of Amphitrite Point, November 25-26, 1957.

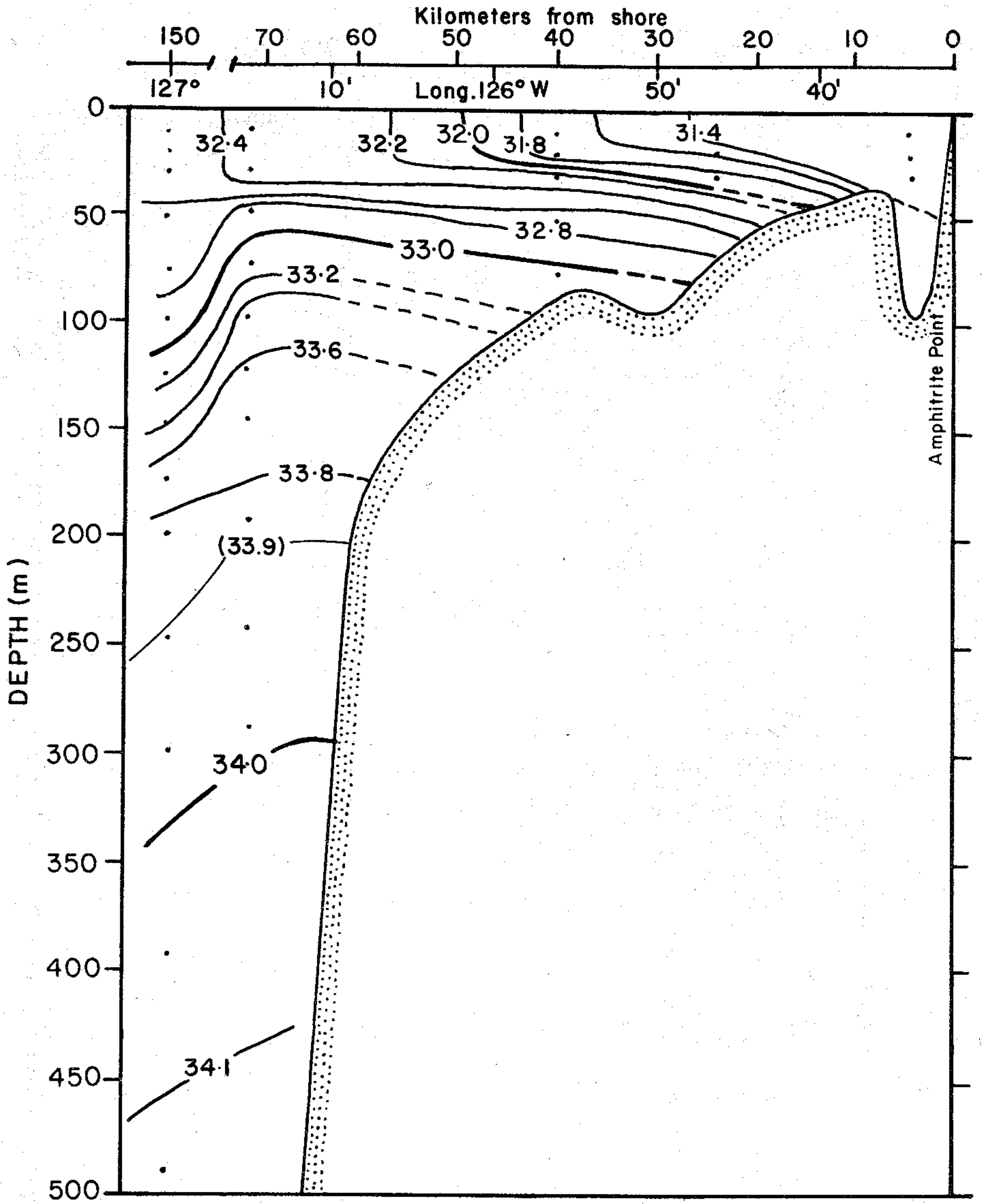

Fig. 44b. Salinity (⁰/₀₀) seaward of Amphitrite Point, November 25-26, 1957.

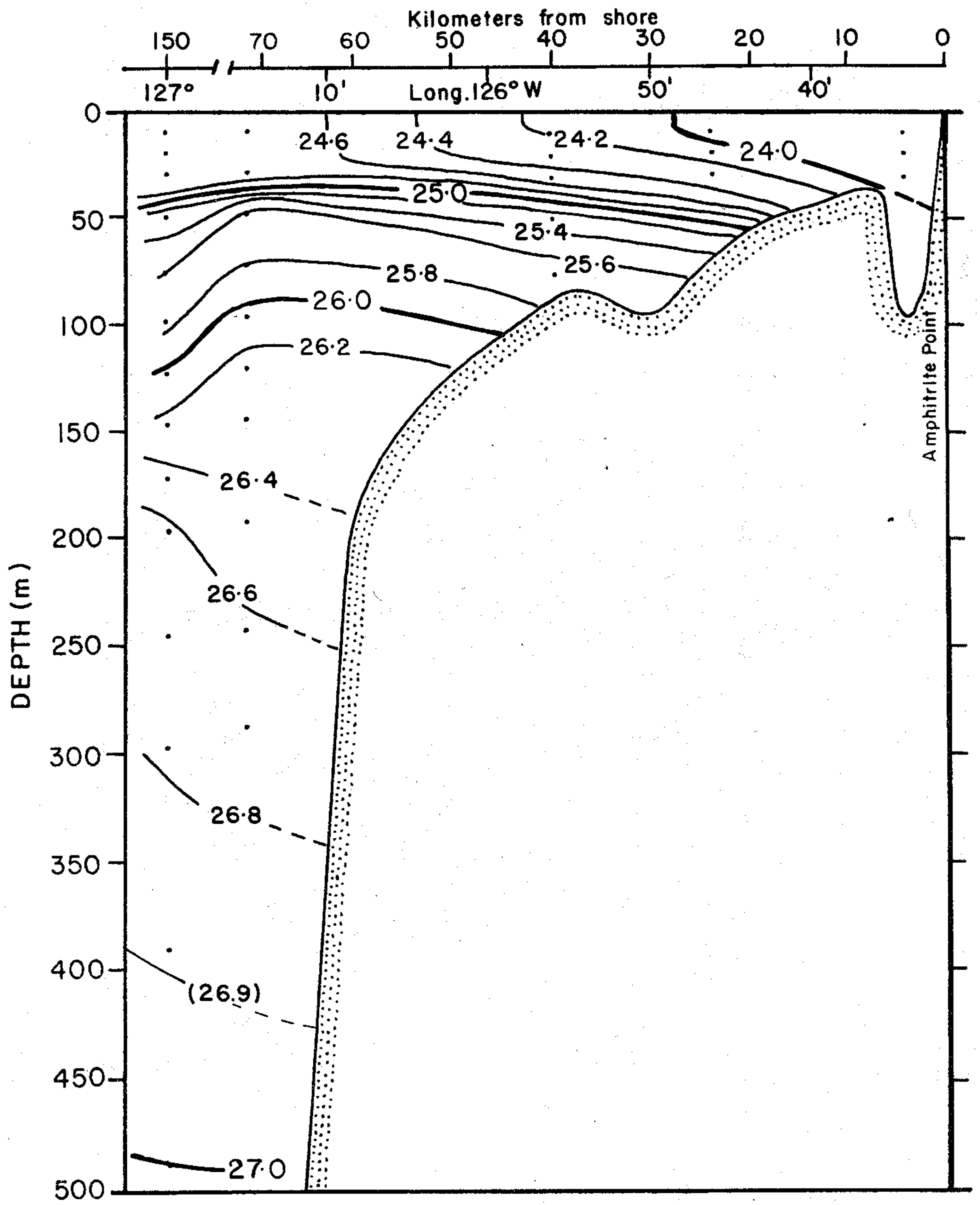

Fig. 44c. Density ($_t$) seaward of Amphitrite Point, November 25-26, 1957.

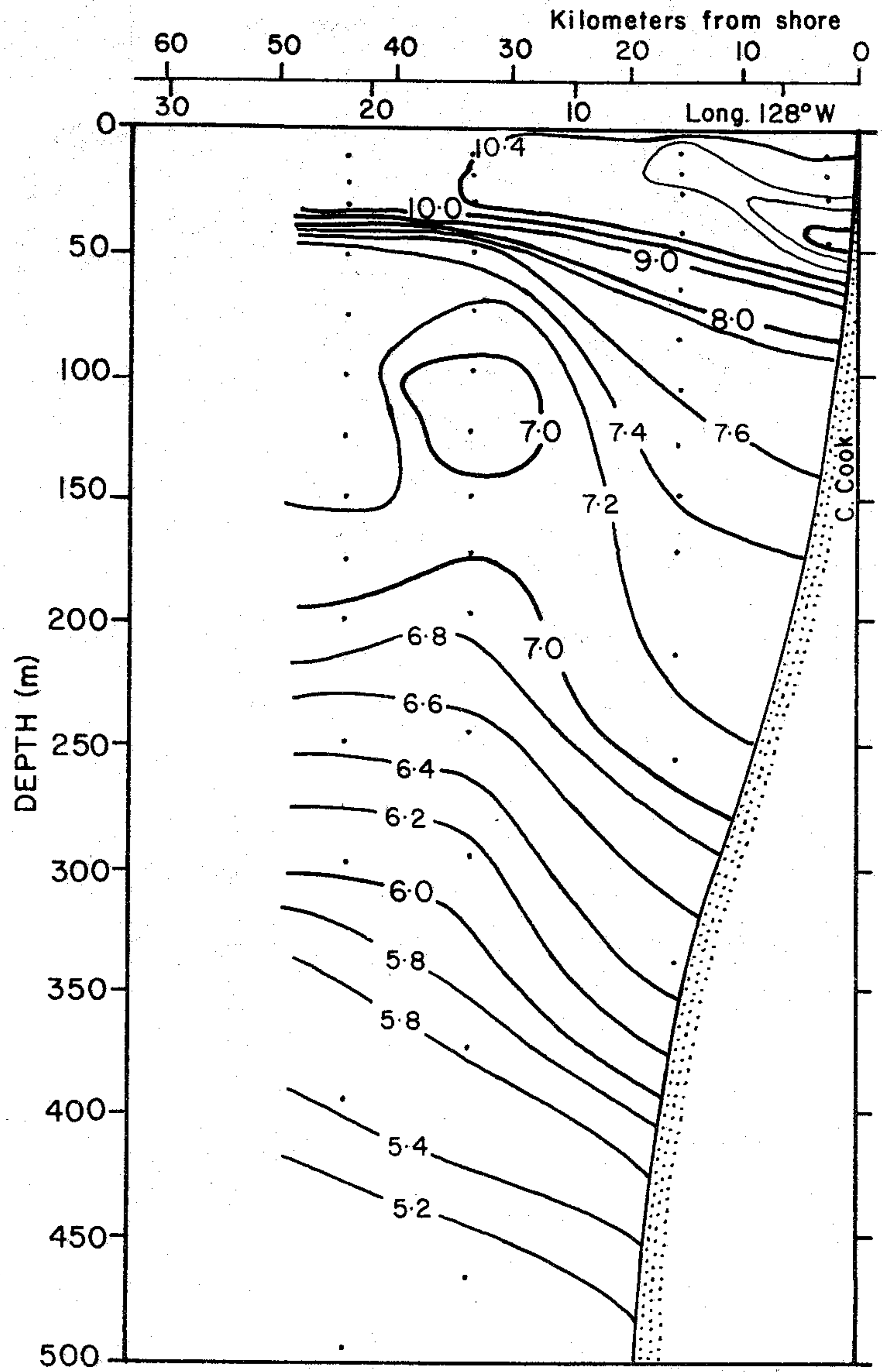

Fig. 45a. Temperature (°C) seaward of Cape Cook, November 28, 1957.

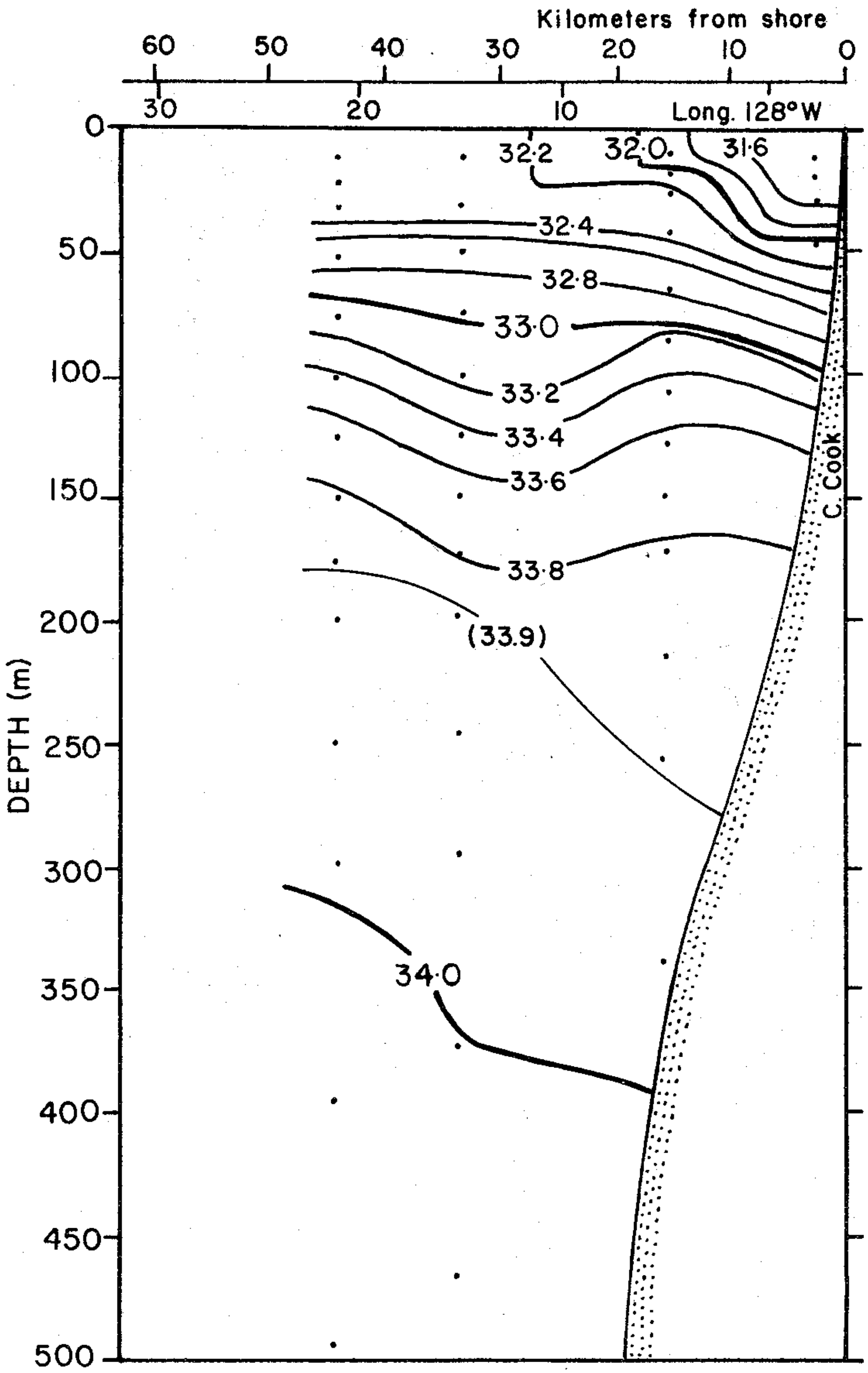

Fig. 45b. Salinity (°/oo) seaward of Cape Cook, November 28, 1957.

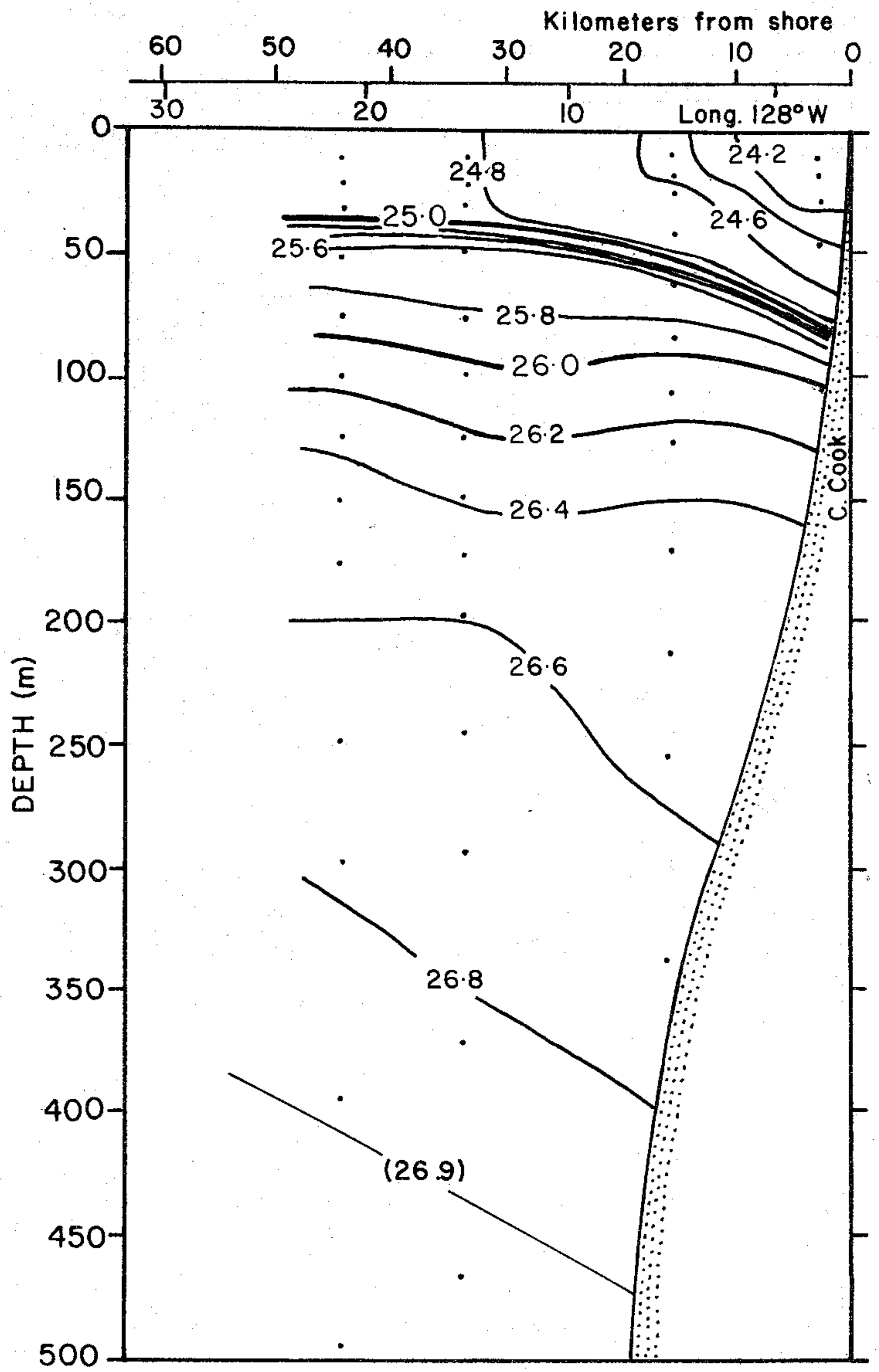

Fig. 45c. Density (σ_t) seaward of Cape Cook, November 28, 1957.

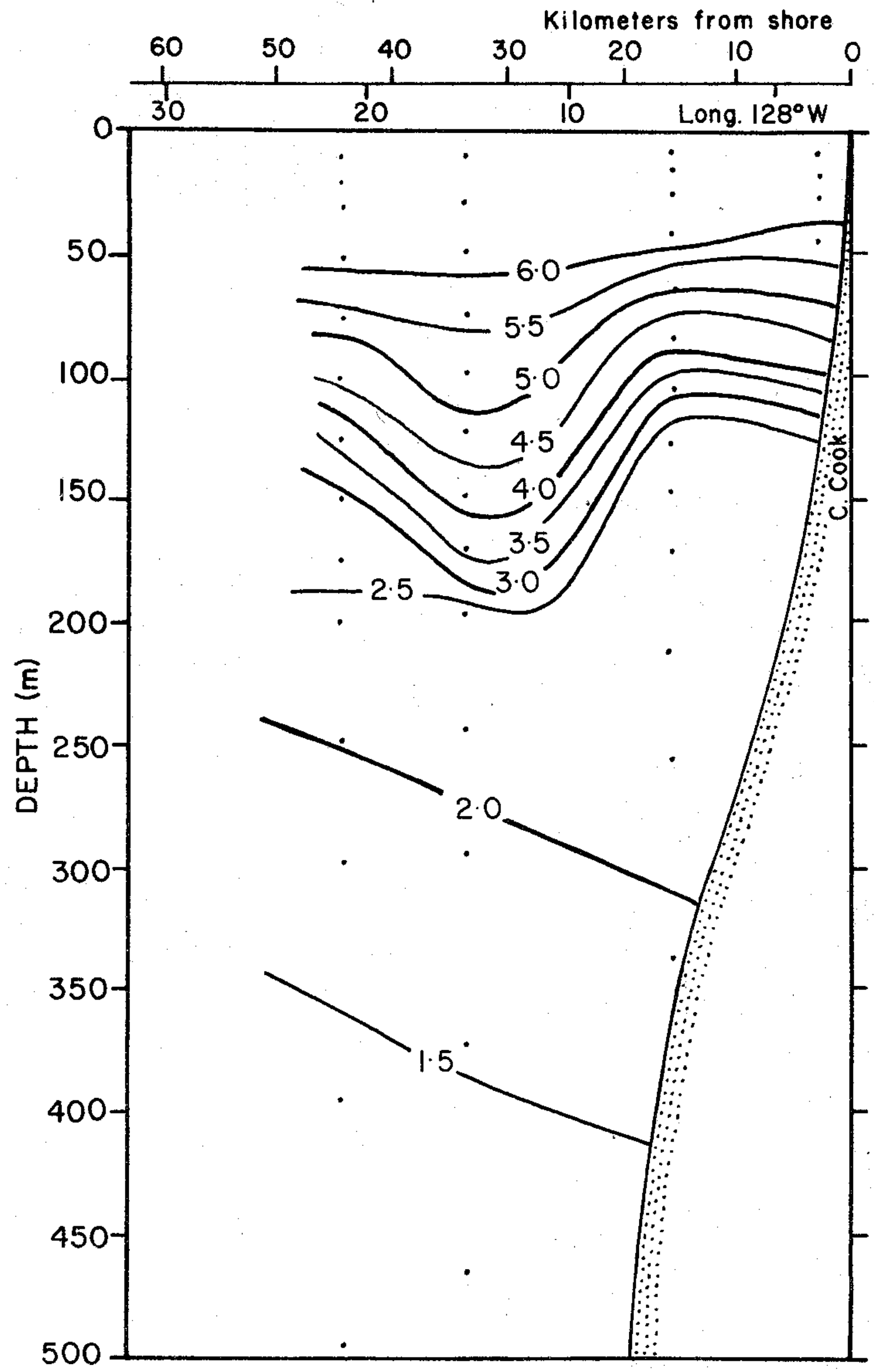

Fig. 45d. Dissolved oxygen (mL/L) seaward of Cape Cook, November 28, 1957.

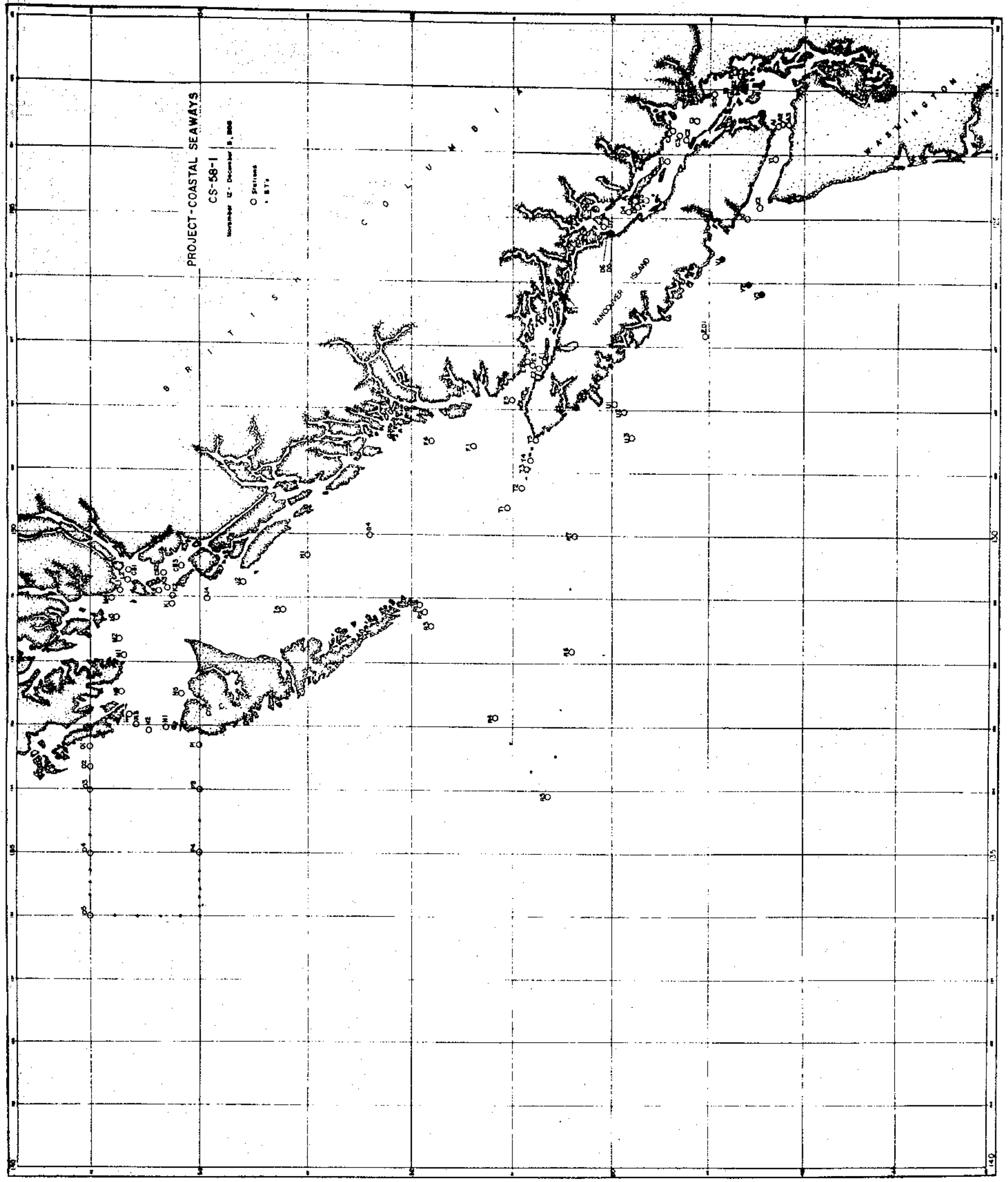

Fig. 46. Coastal seaways project, November 12-December 5, 1958. Solid circles indicate stations used in the sections.

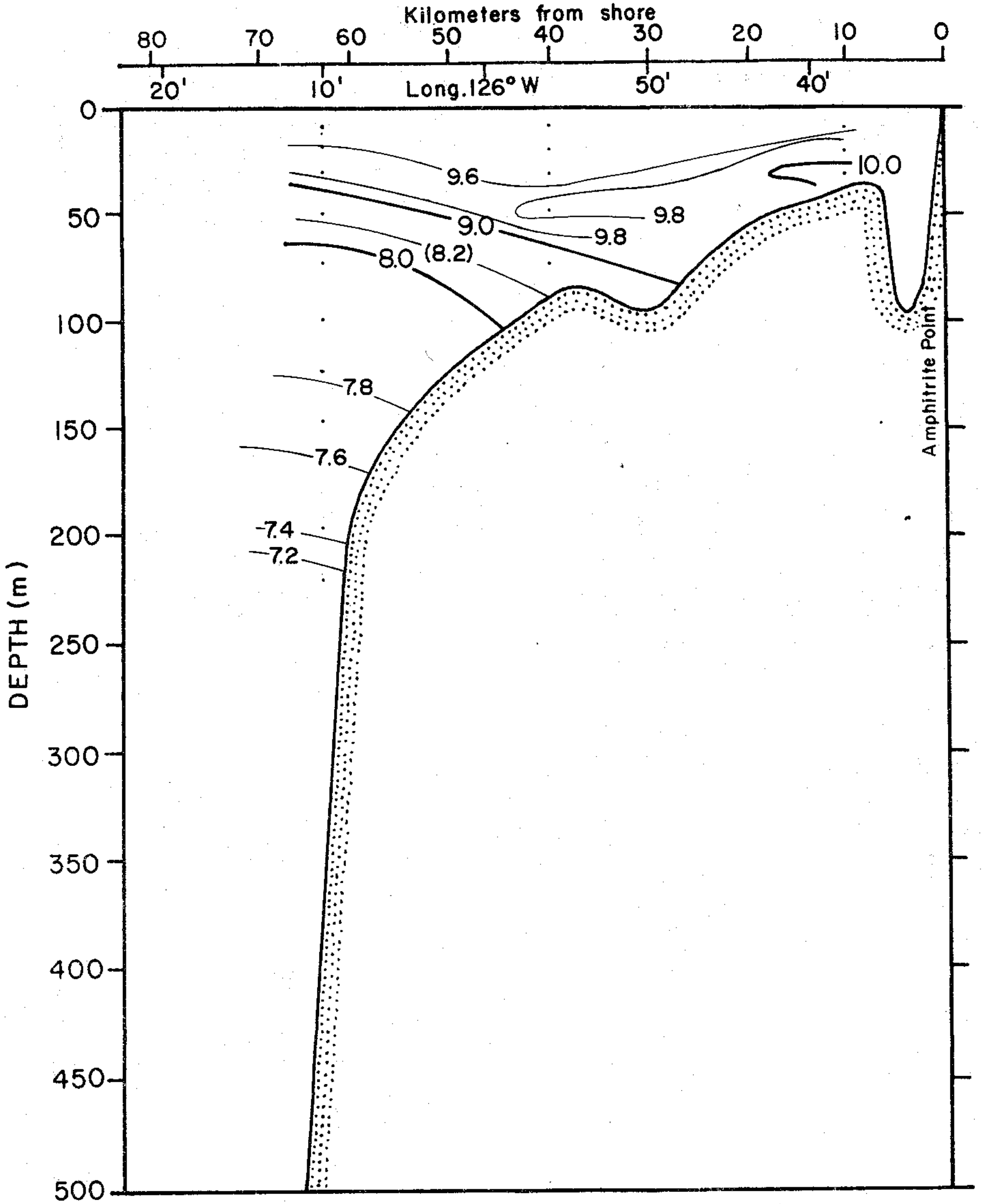

Fig. 47a. Temperature (°C) seaward of Amphitrite Point, December 5, 1958.

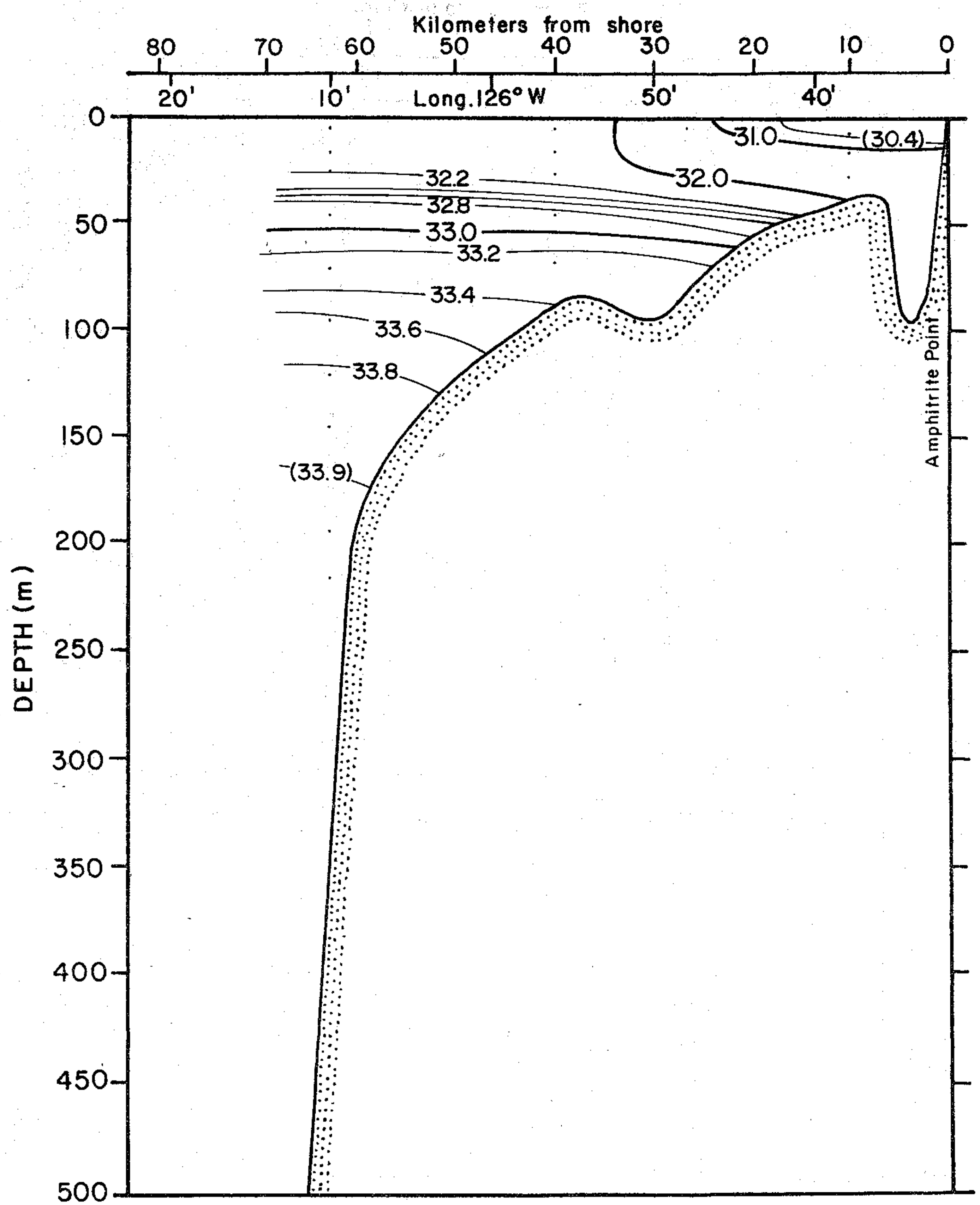

Fig. 47b. Salinity (°/oo) seaward of Amphitrite Point, December 5, 1958.

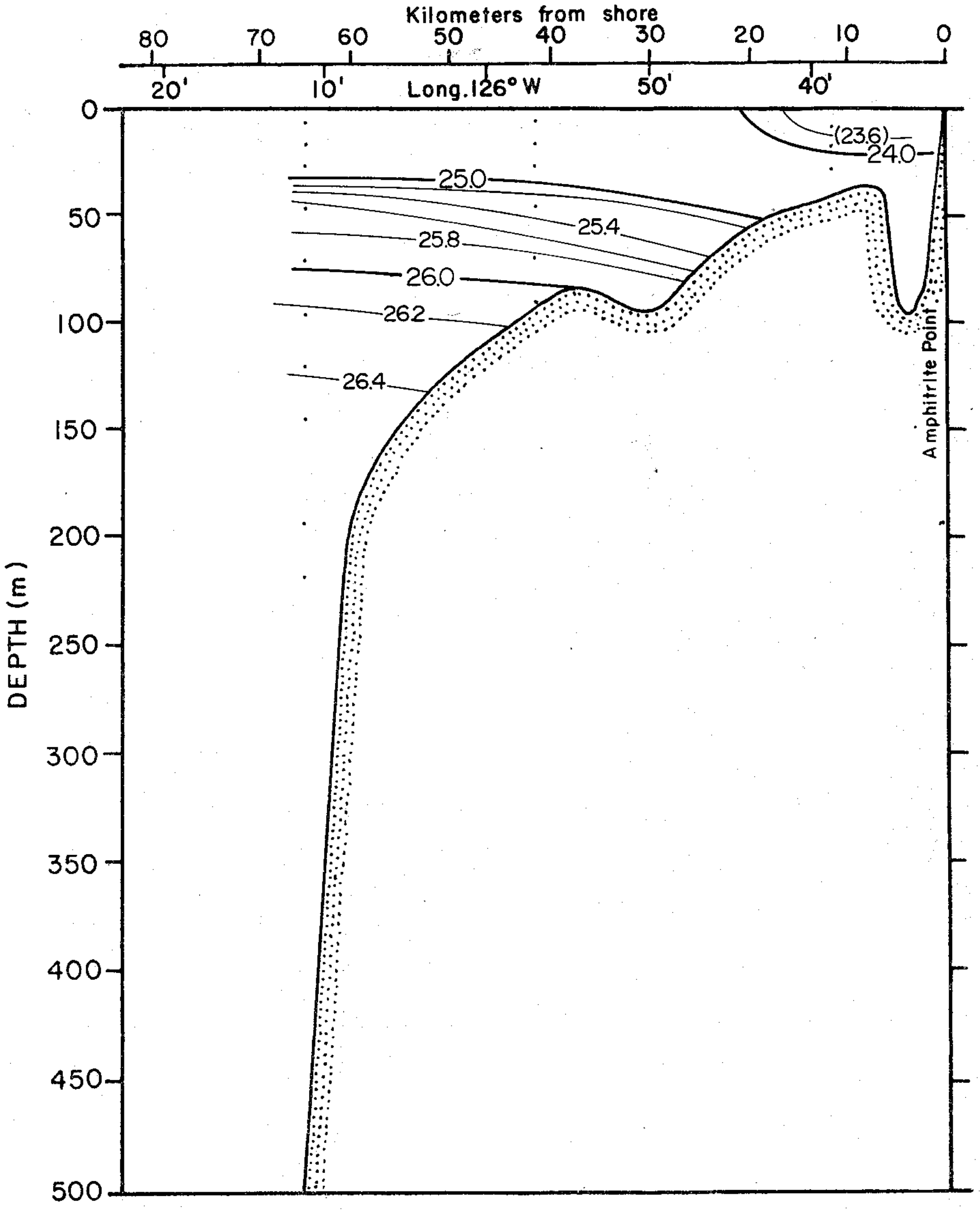

Fig. 47c. Density (σ_t) seaward of Amphitrite Point, December 5, 1958.

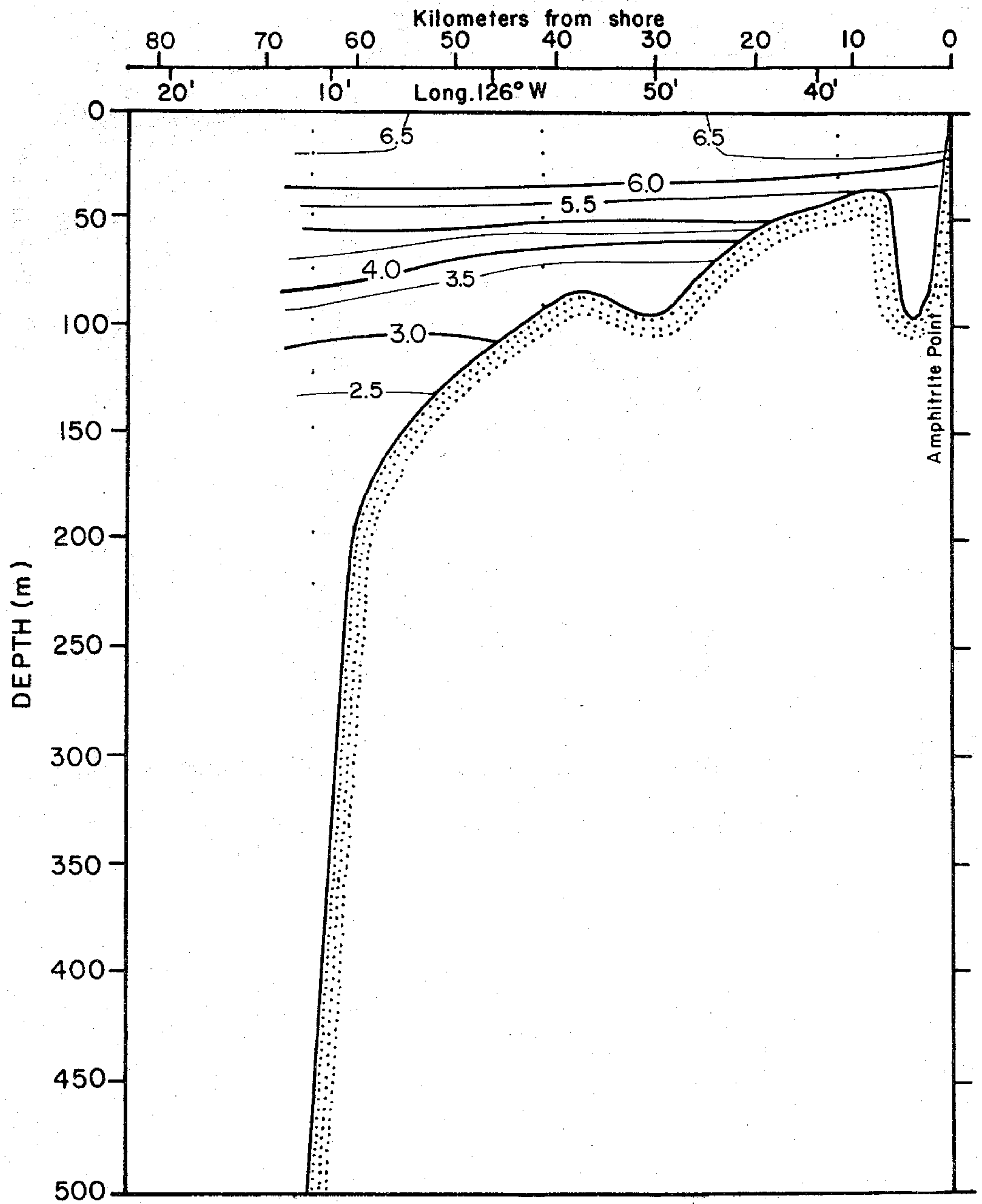

Fig. 47d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, December 5, 1958.

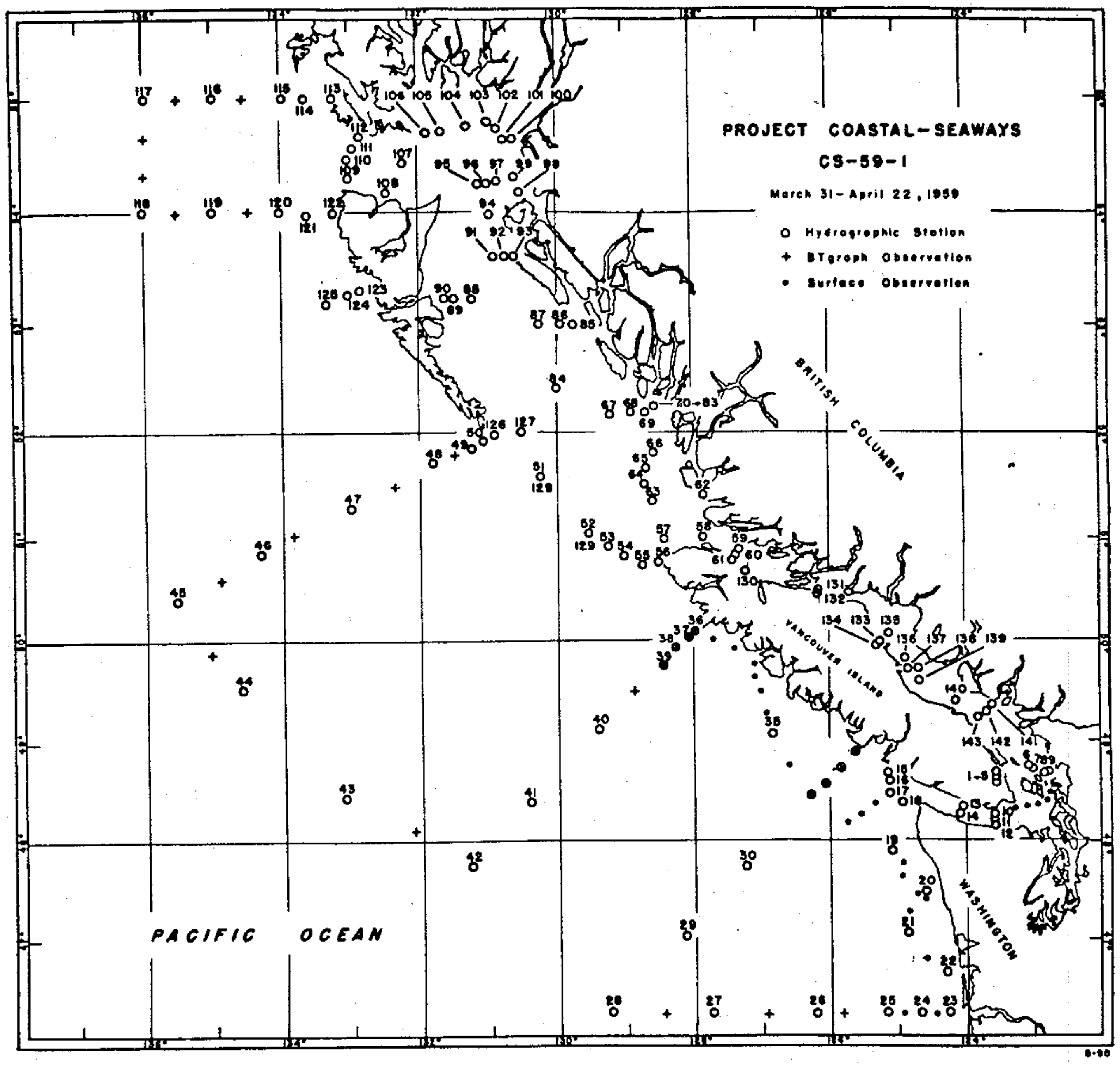

Fig. 48. Coastal Seaways Project, March 31 to April 22, 1959. Solid circles indicate stations used in the sections.

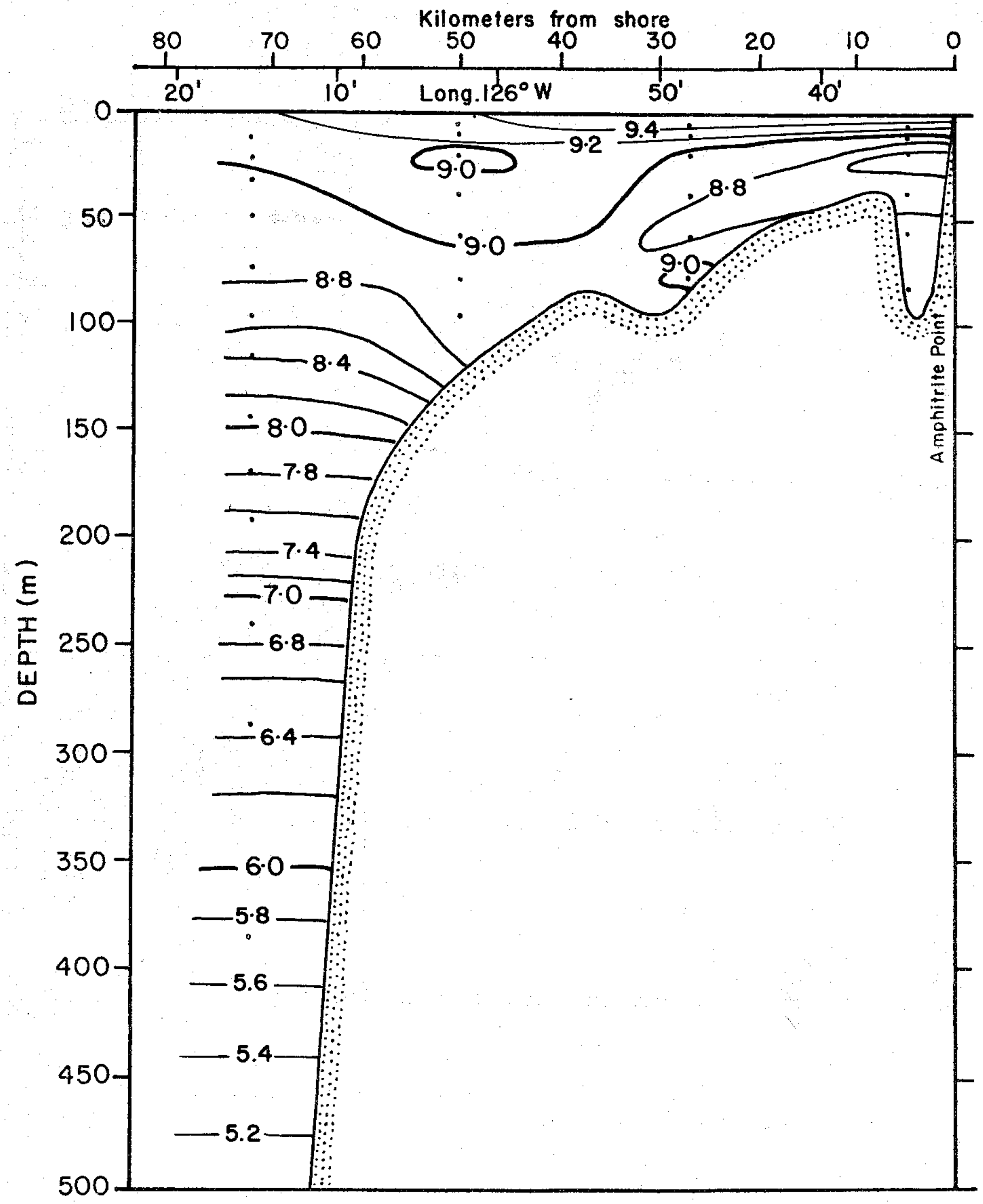

Fig. 49a. Temperature (°C) seaward of Amphitrite Point, April 8, 1959.

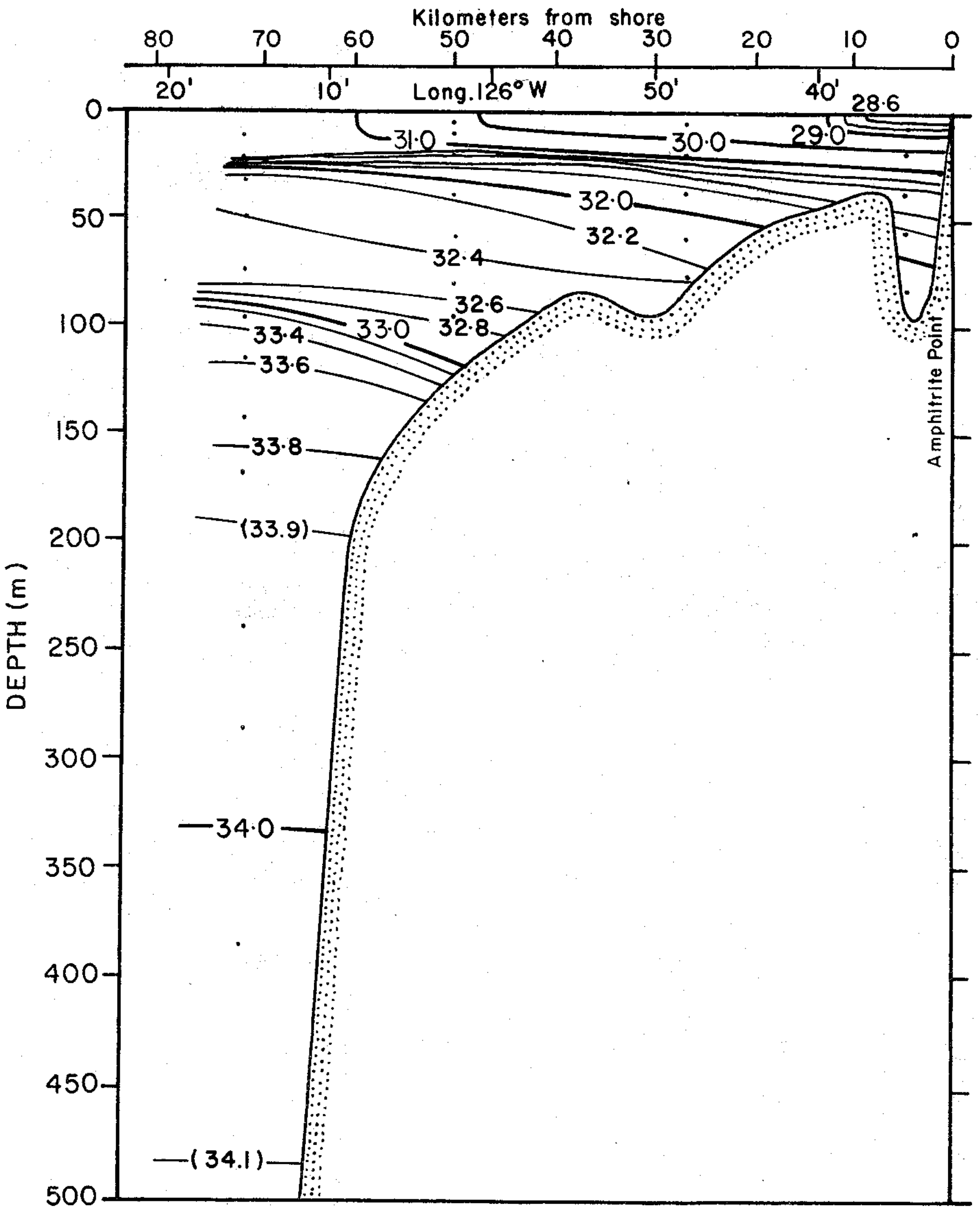

Fig. 49b. Salinity (°/$_{oo}$) seaward of Amphitrite Point, April 8, 1959.

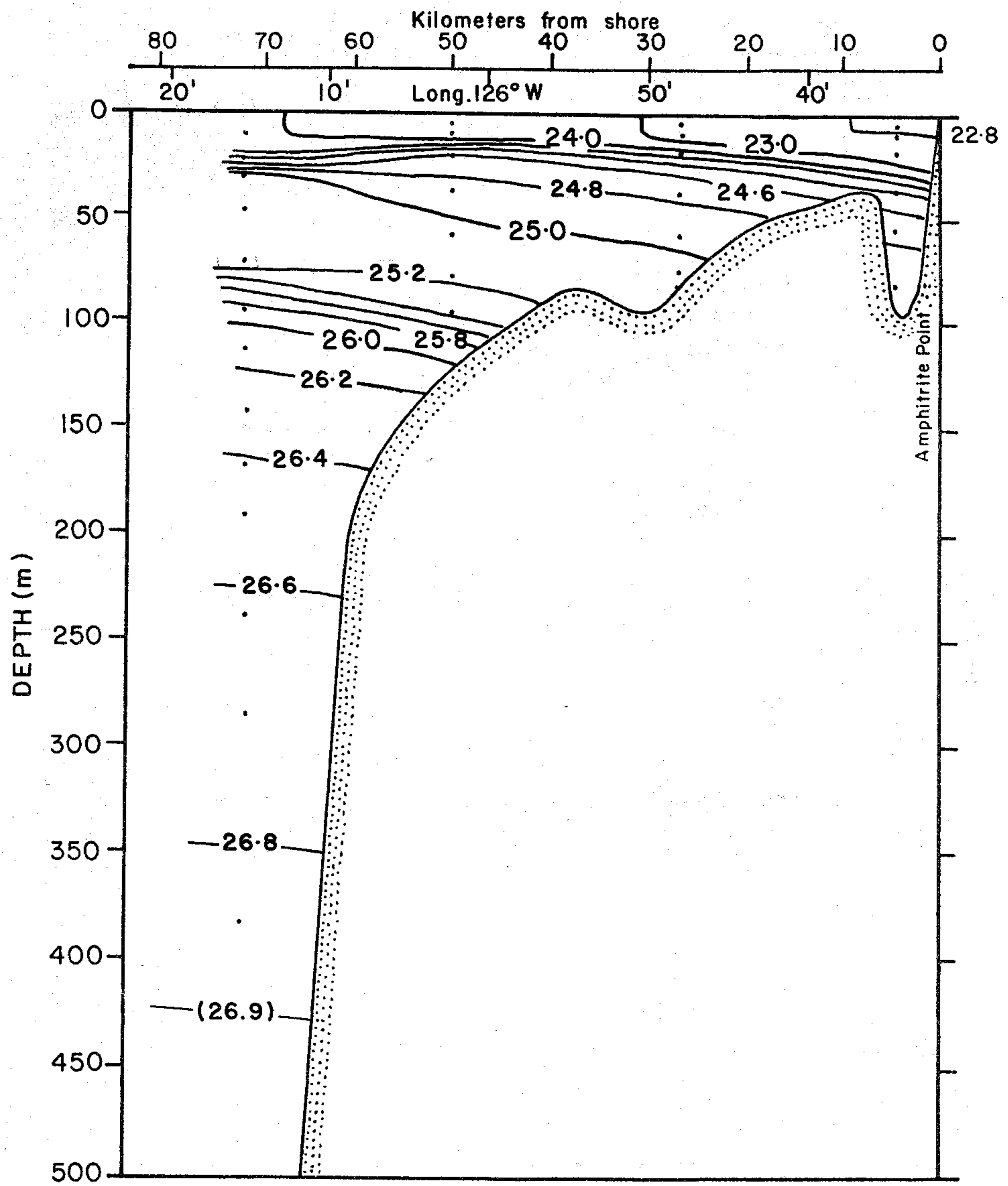

Fig. 49c. Density (σ_t) seaward of Amphitrite Point, April 8, 1959.

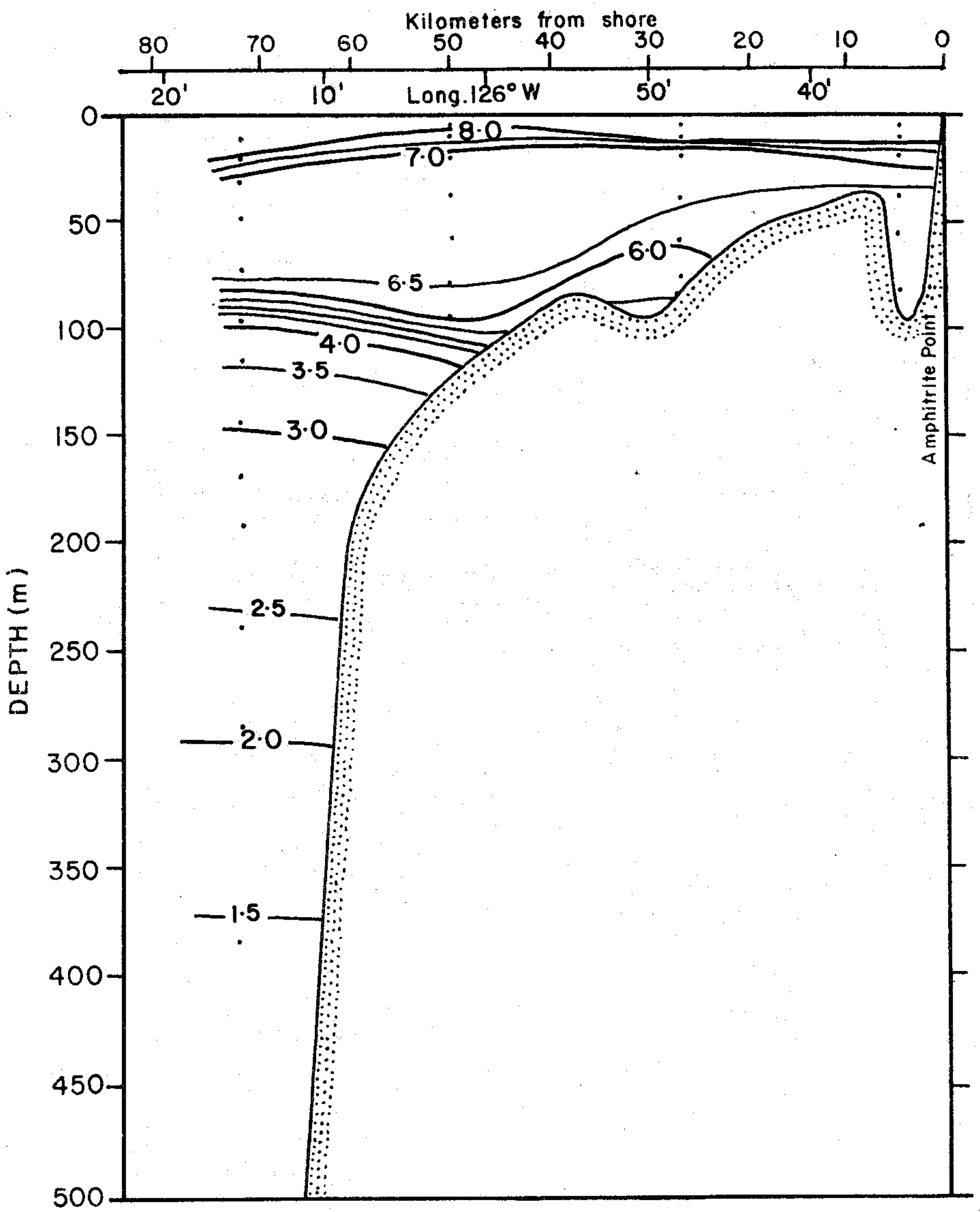

Fig. 49d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, April 8, 1959.

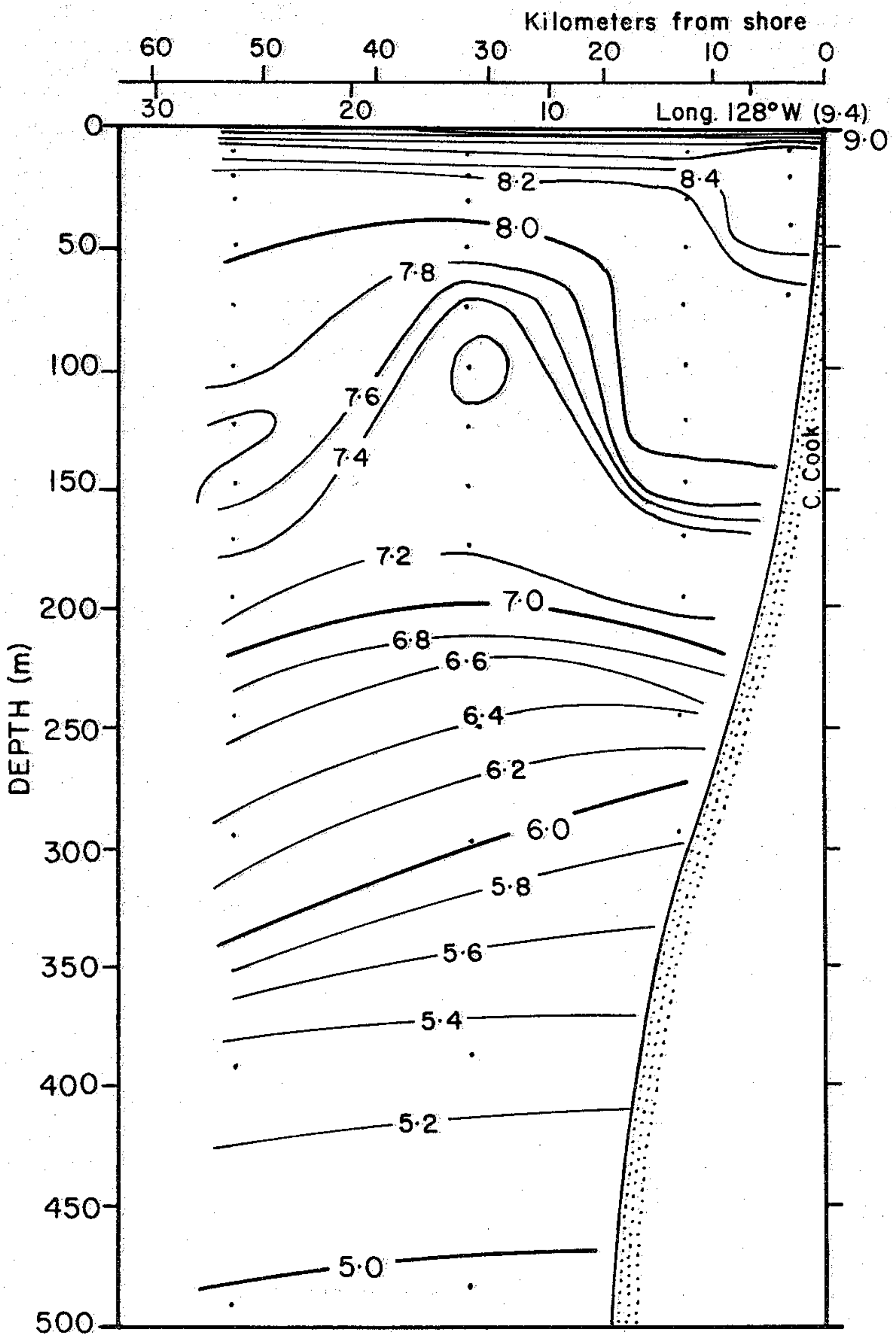

Fig. 50a. Temperature (°C) seaward of Cape Cook, April 9, 1959.

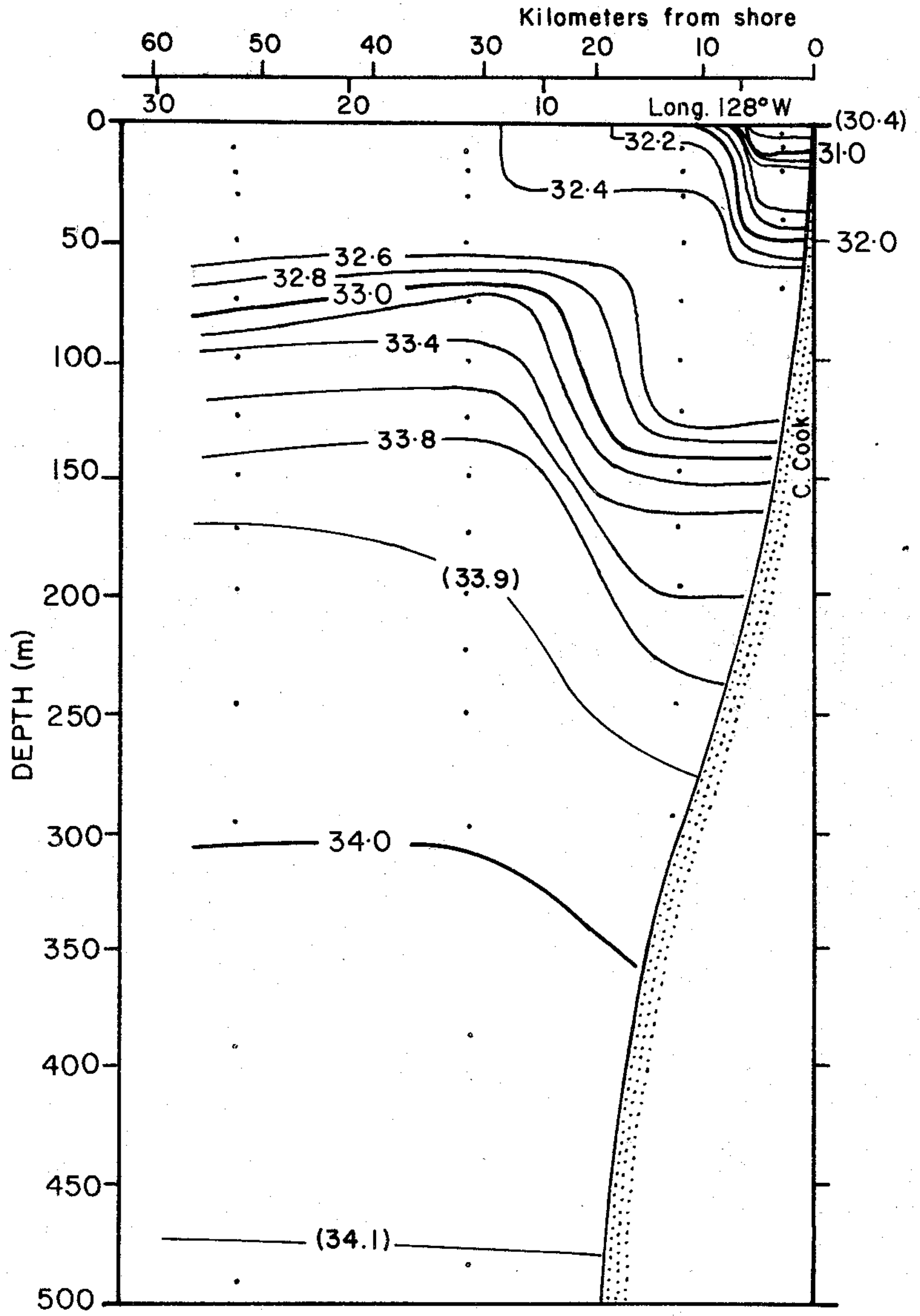

Fig. 50b. Salinity (°/oo) seaward of Cape Cook, April 9, 1959.

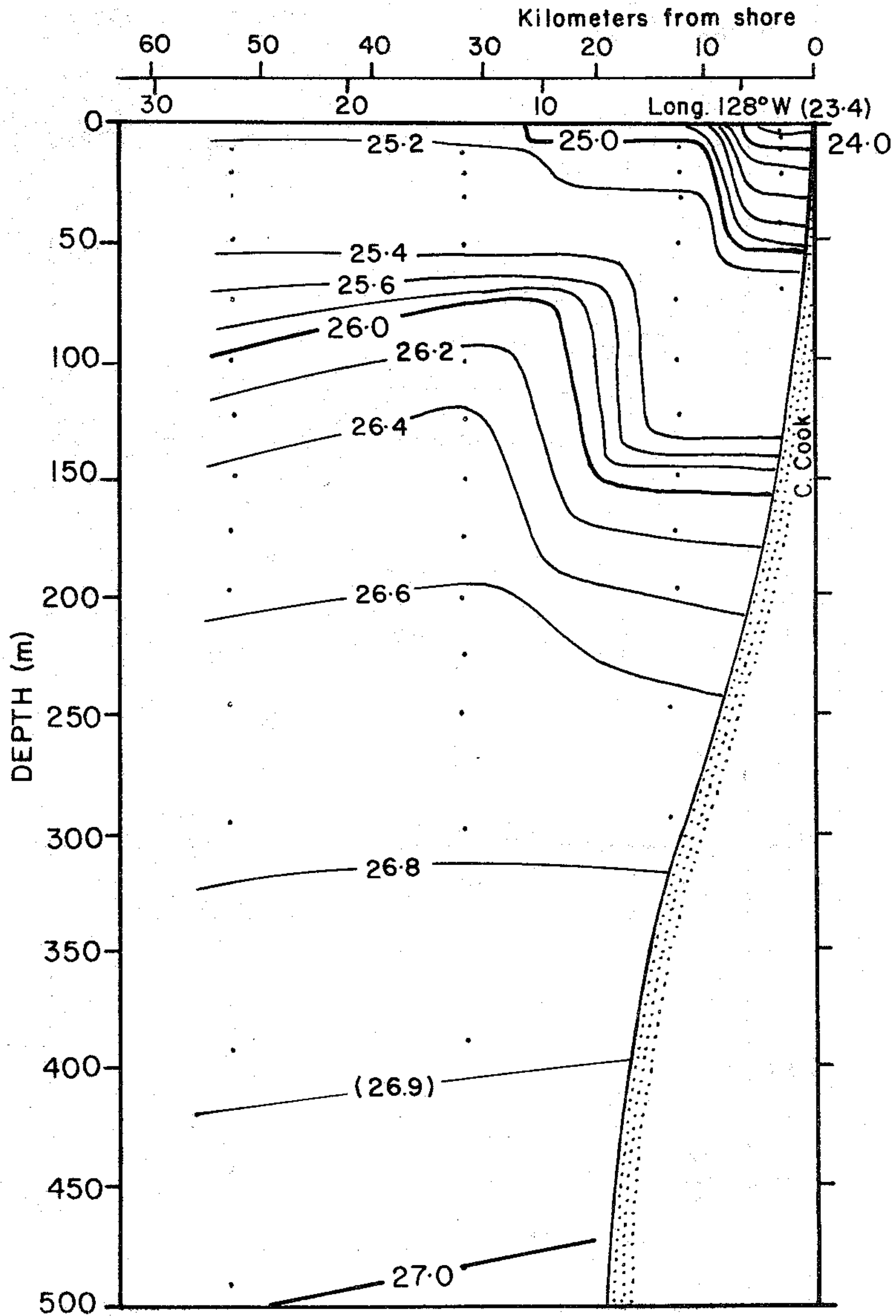

Fig. 50c. Density (σ_t) seaward of Cape Cook, April 9, 1959.

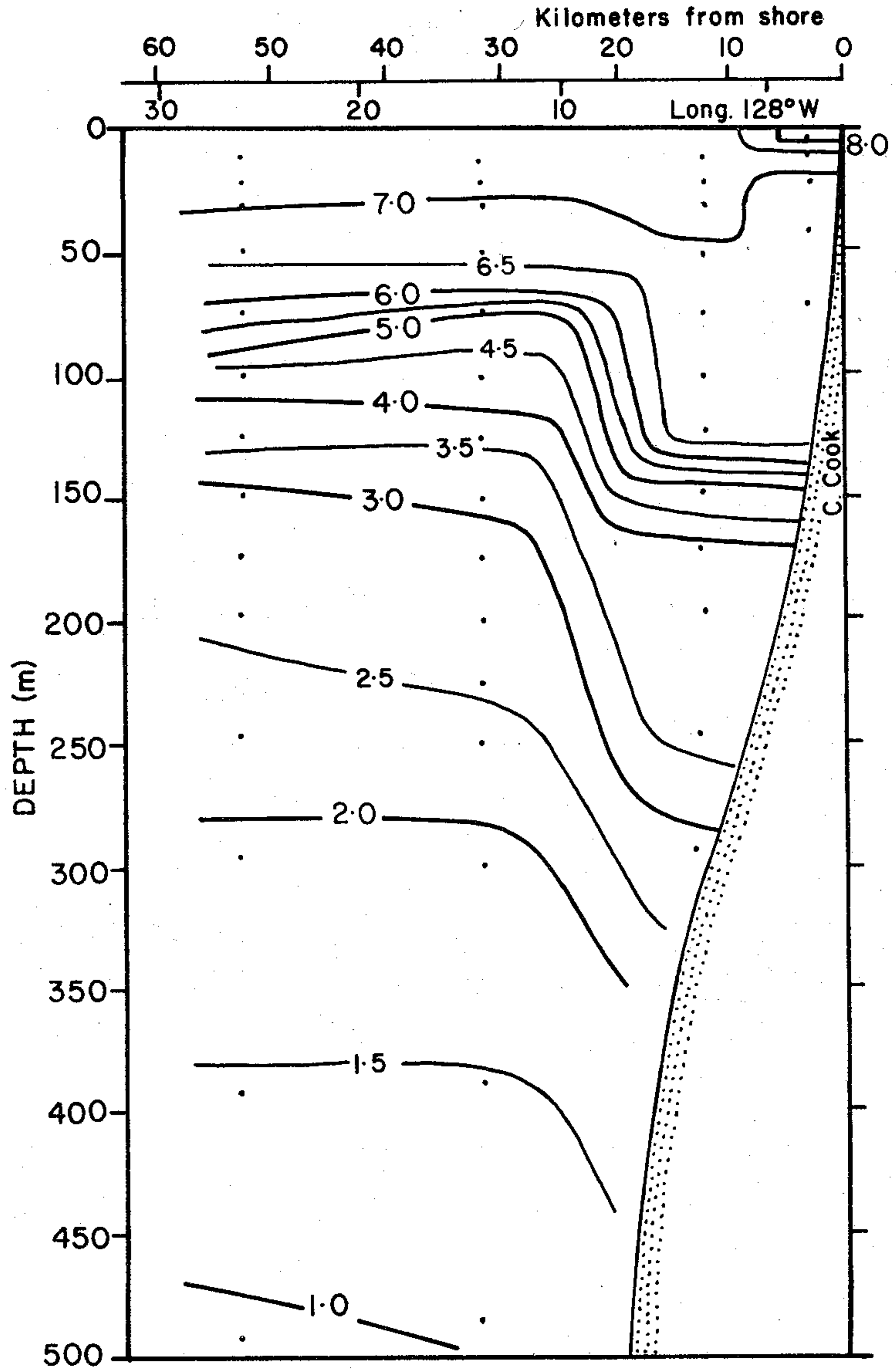

Fig. 50d. Dossolved oxygen (mL/L) seaward of Cape Cook, April 9, 1959.

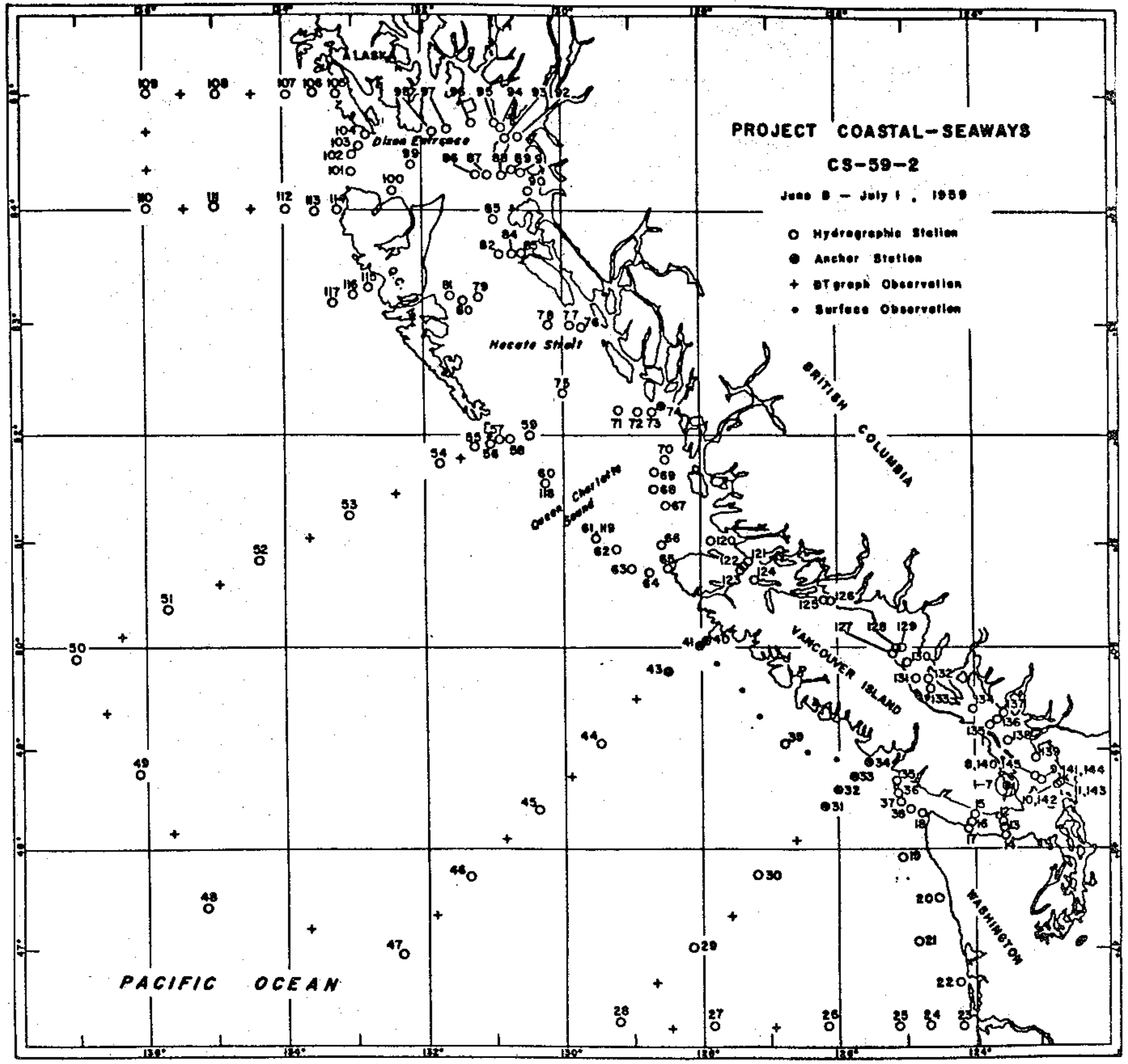

Fig. 51. Coastal - seaways project, June 8 - July 1, 1959. Solid circles indicate stations used in the sections.

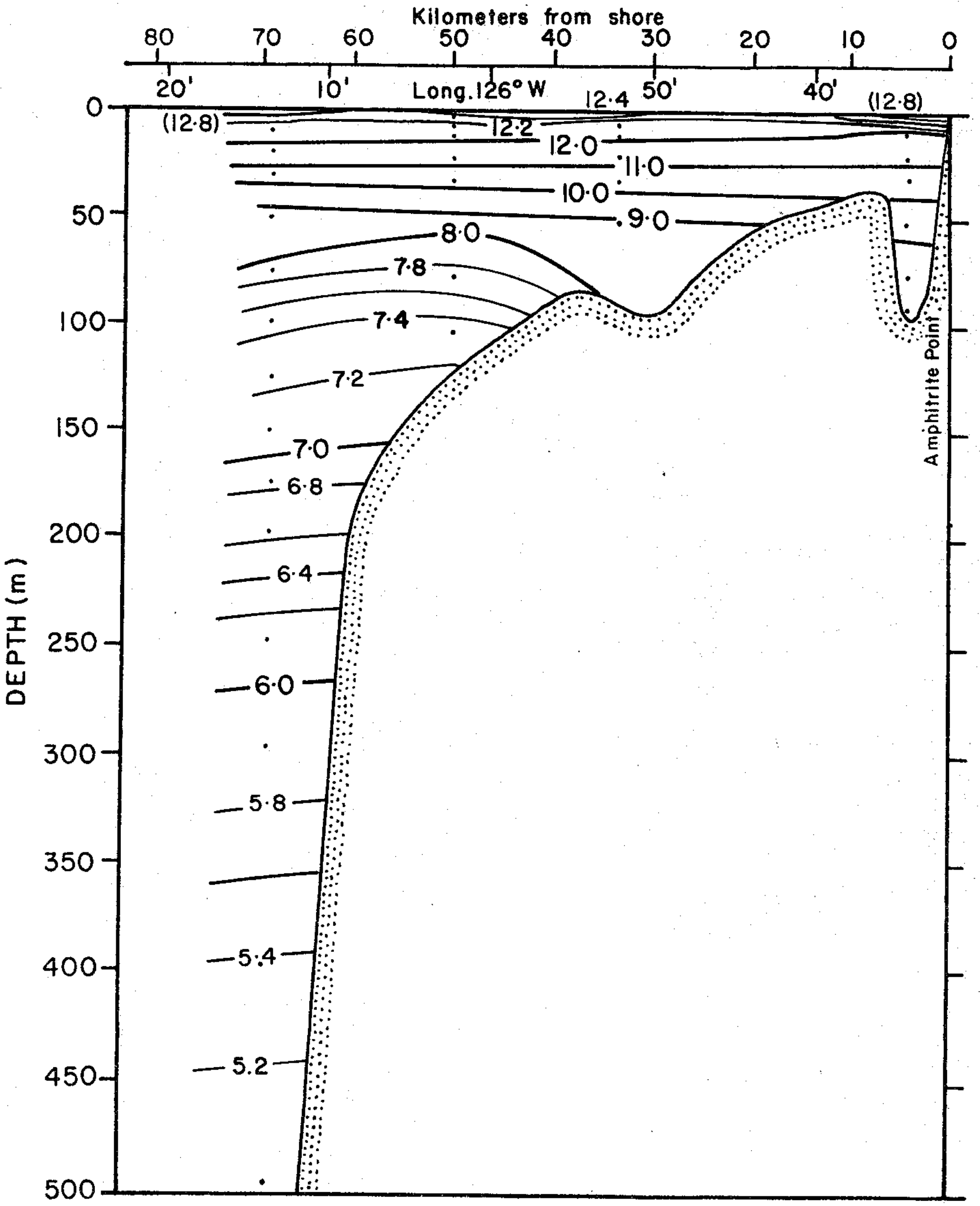

Fig. 52a. Temperature (^{o}C) seaward of Amphitrite Point, June 14, 1959.

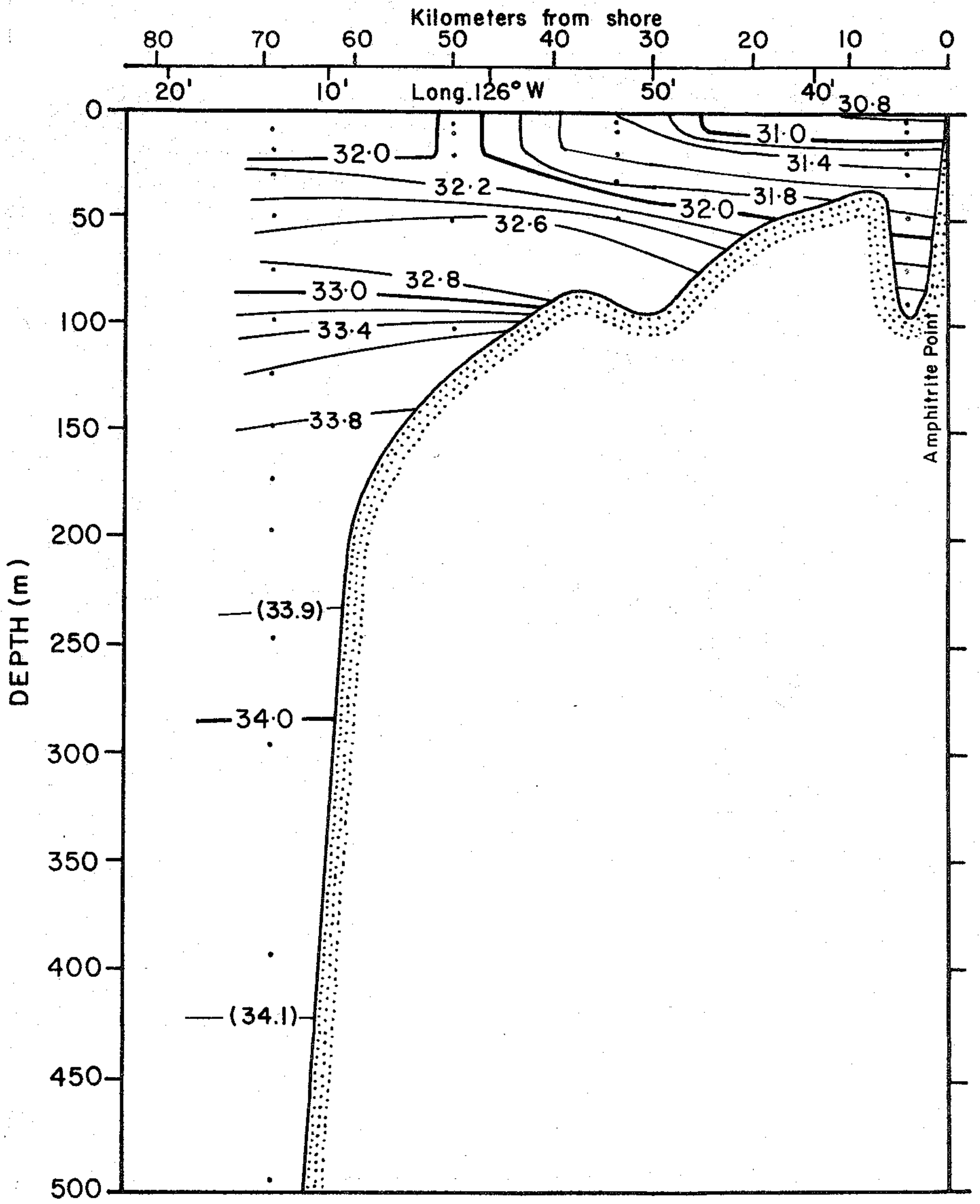

Fig. 52b. Salinity ($^{0}/_{00}$) seaward of Amphitrite Point, June 14, 1959.

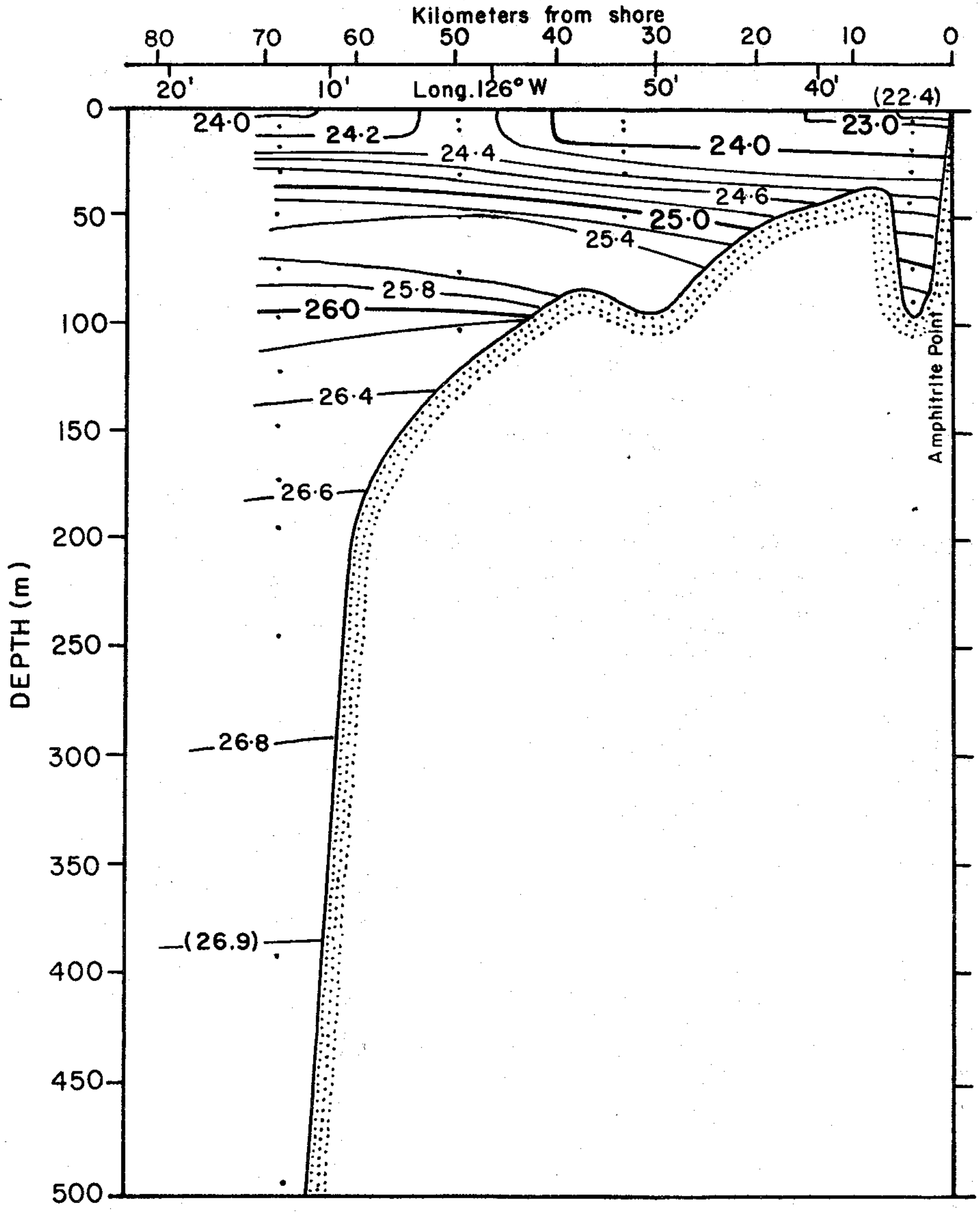

Fig. 52c. Density (σ_t) seaward of Amphitrite Point, June 14, 1959.

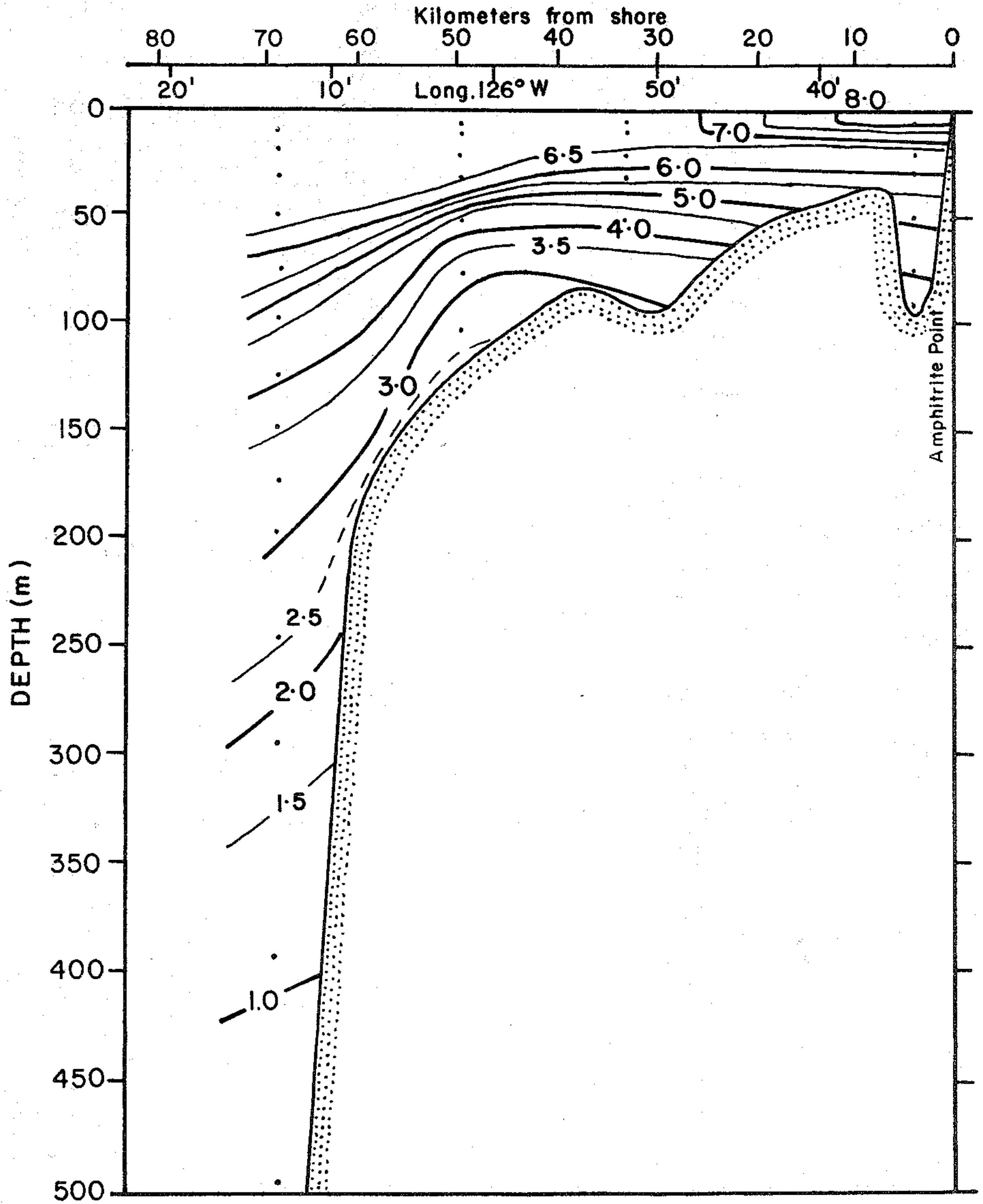

Fig. 52d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, June 14, 1959.

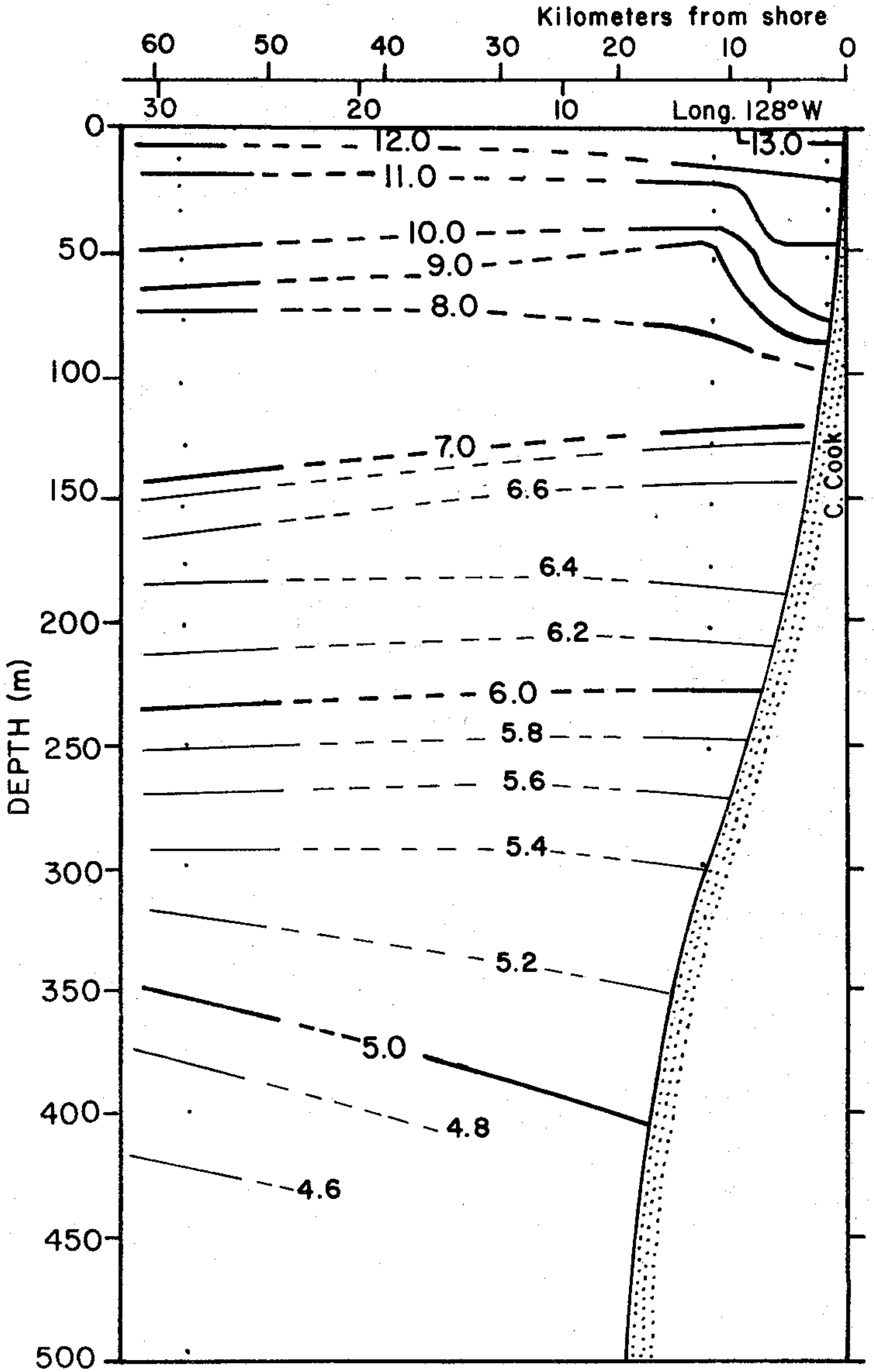

Fig. 53a. Temperature (°C) seaward of Cape Cook, June 18, 1959.

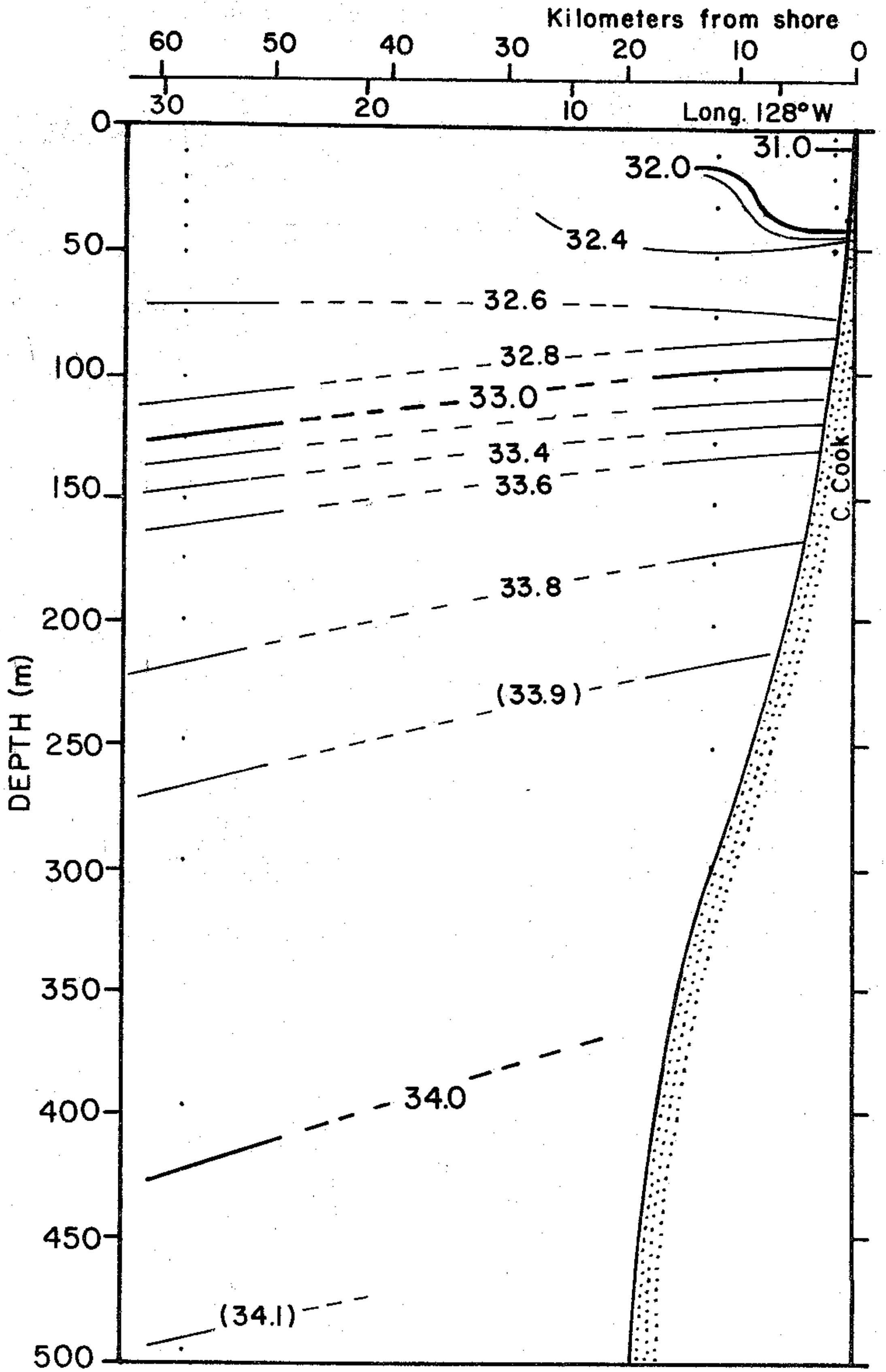

Fig. 53b. Salinity ($^{o}/_{oo}$) seaward of Cape Cook, June 18, 1959.

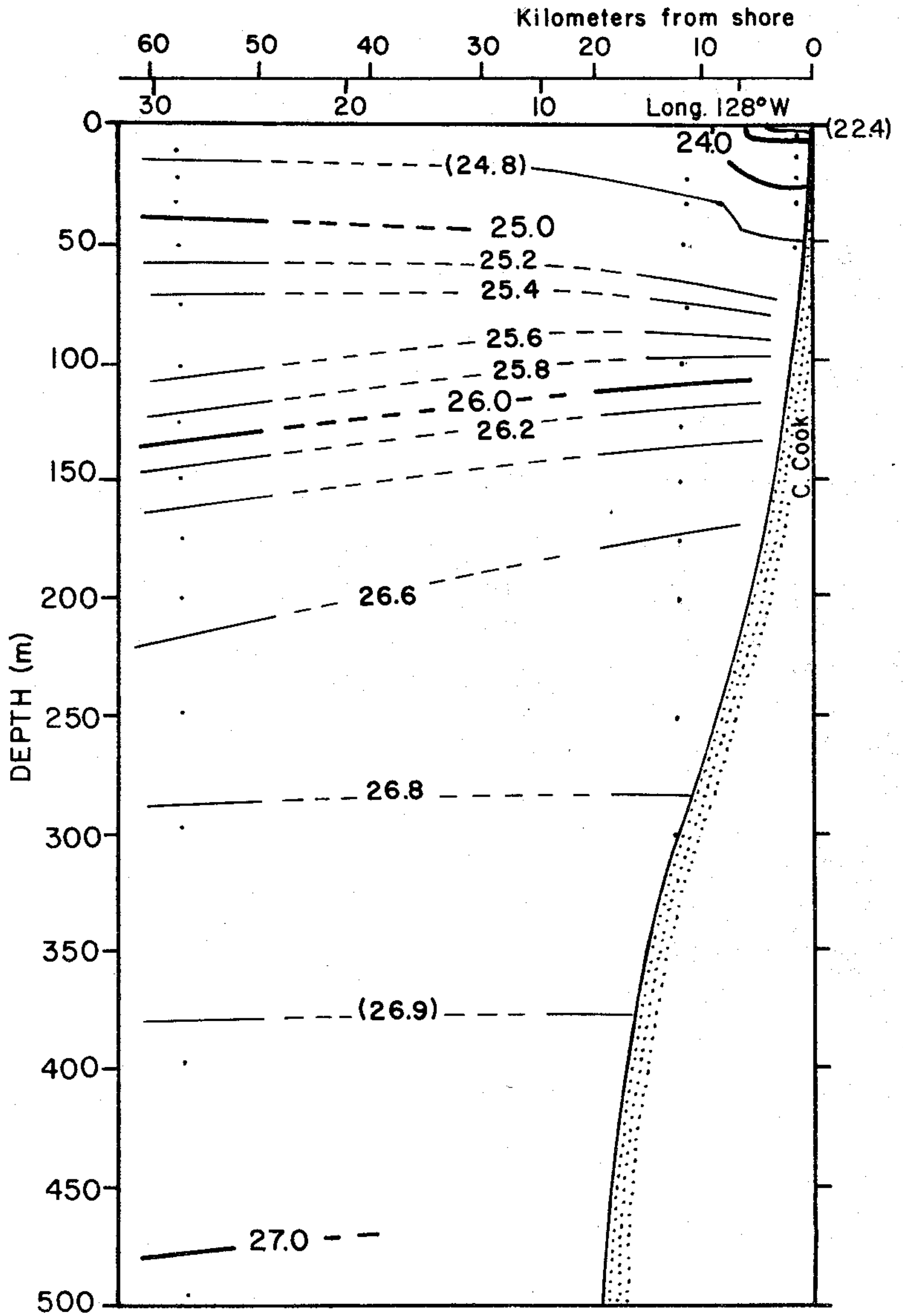

Fig. 53c. Density (σ_t) seaward of Cape Cook, June 18, 1959.

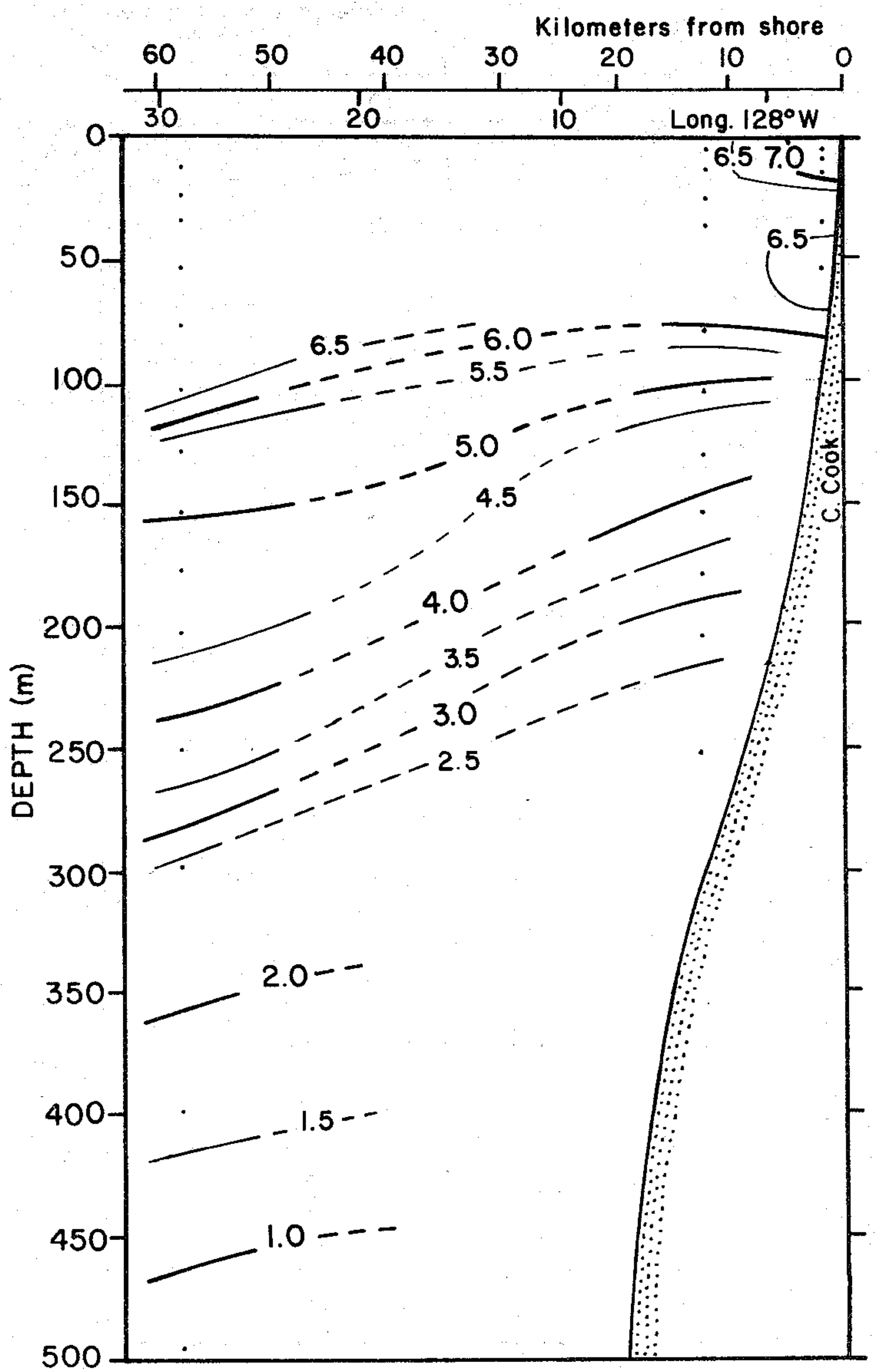

Fig. 53d. Dissolved oxygen (mL/L) seaward of Cape Cook, June 18, 1959.

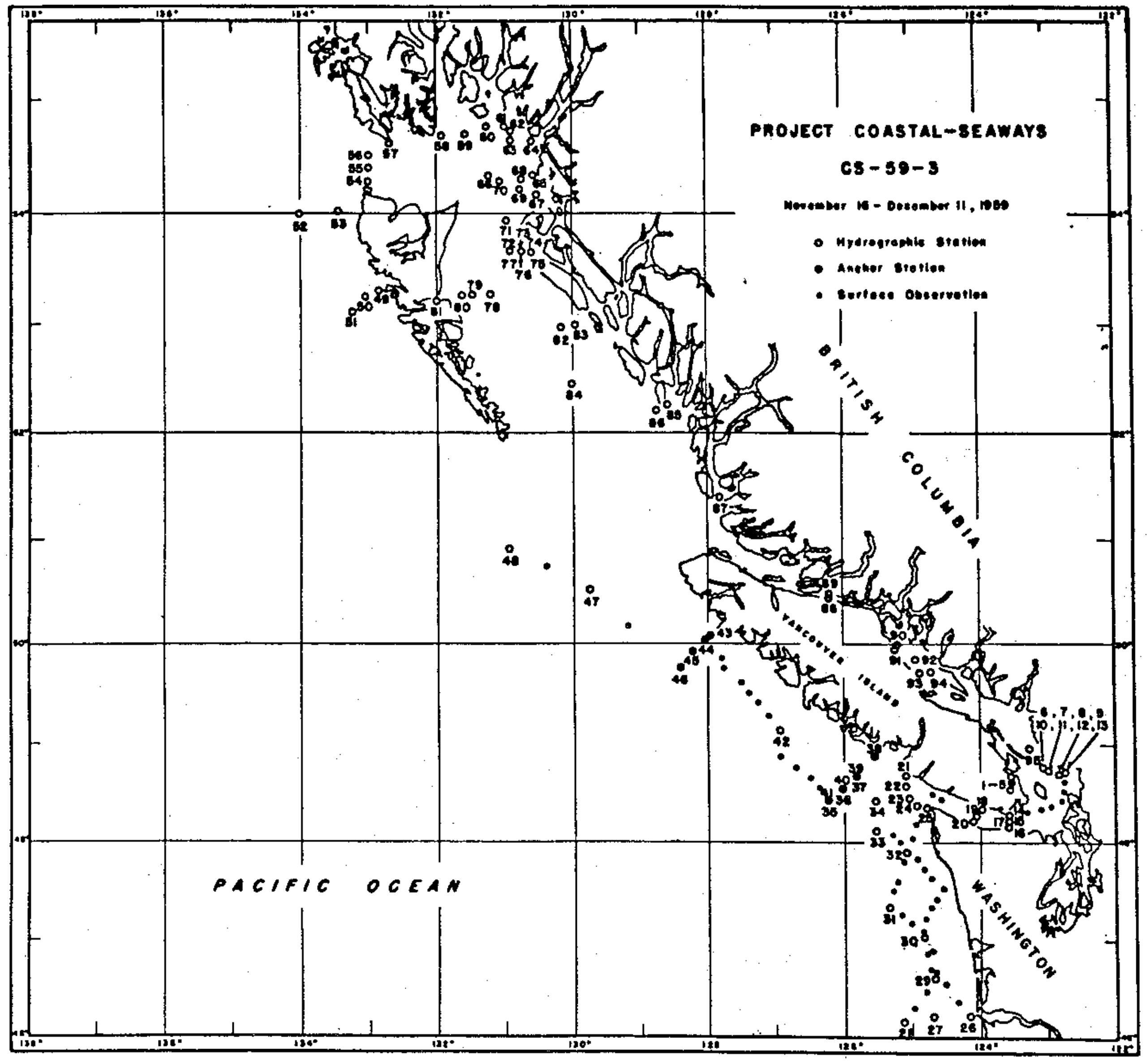

Fig. 54. Coastal - seaways project, November 14 - December 11, 1959. Large solid circles indicate stations used in the sections.

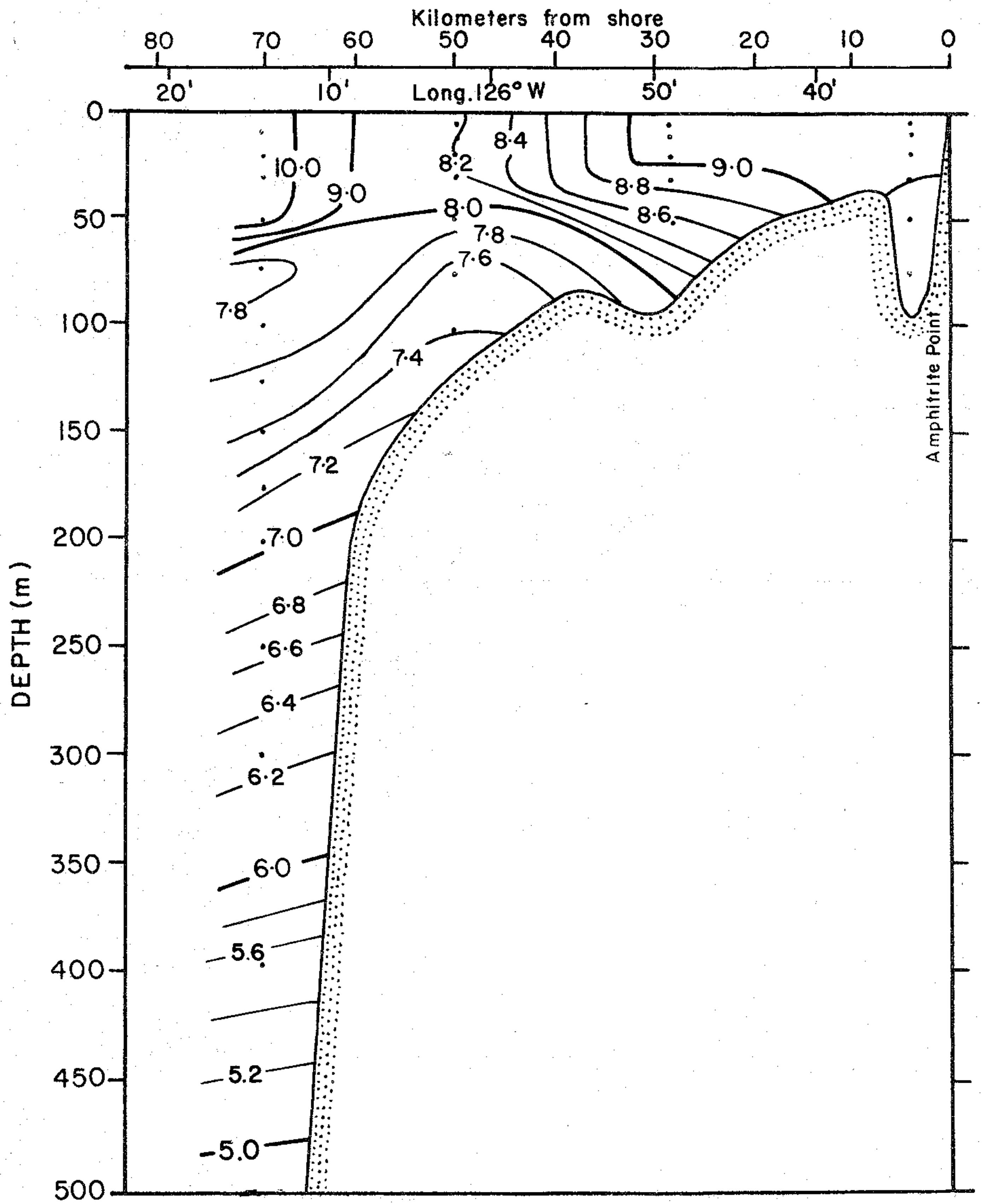

Fig. 55a. Temperature (°C) seaward of Amphitrite Point, November 26, 1959.

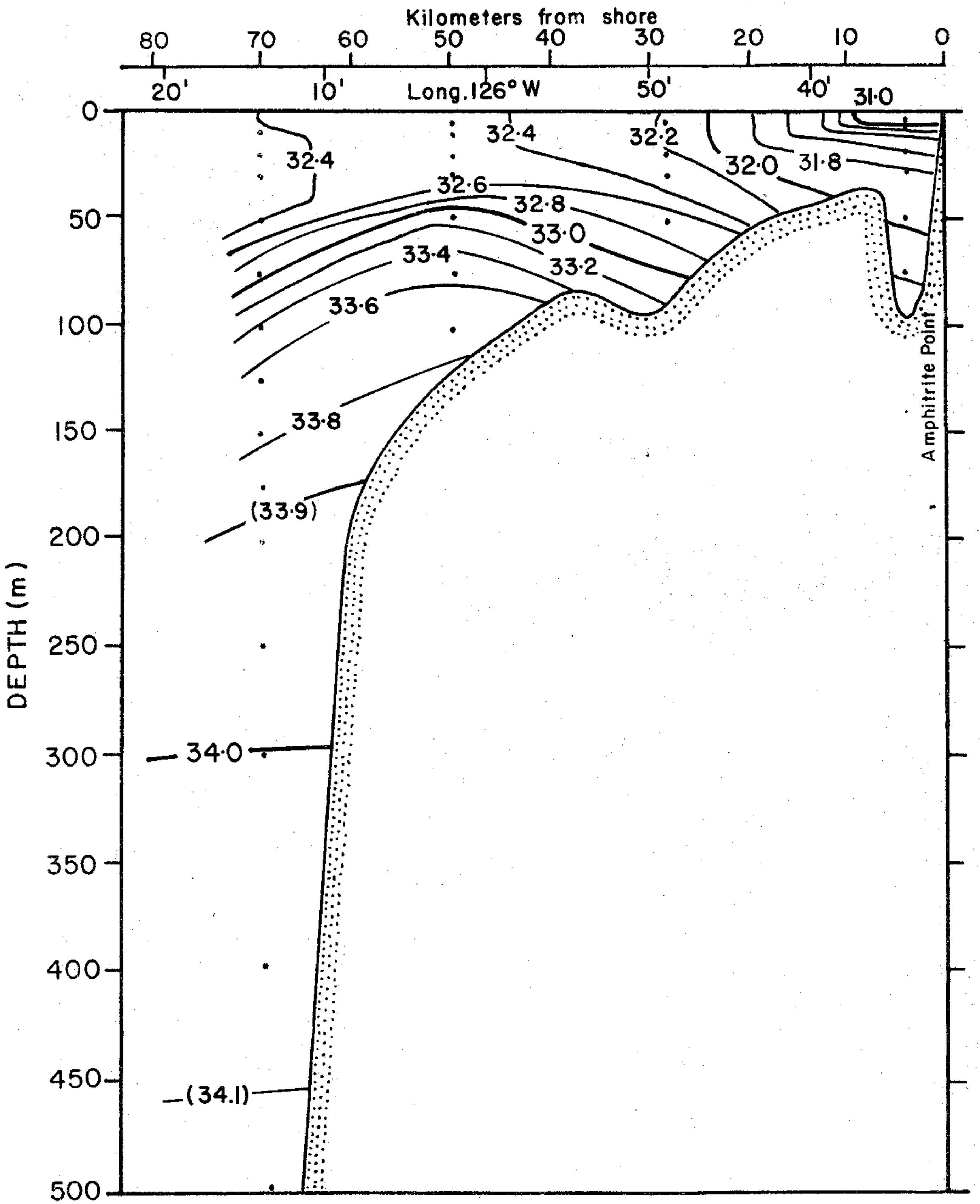

Fig. 55b. Salinity (°/oo) seaward of Amphitrite Point, November 26, 1959.

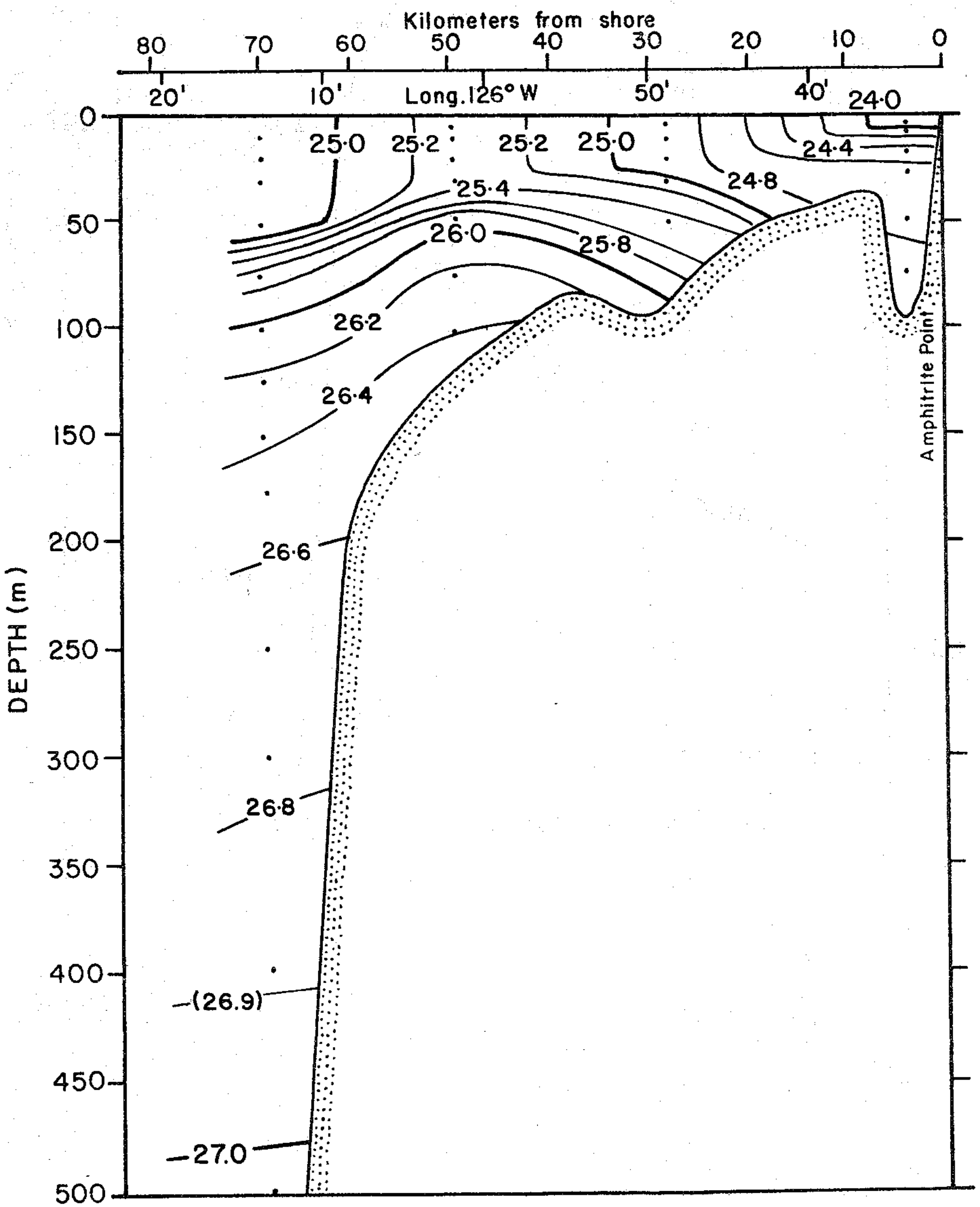

Fig. 55c. Density (σ_t) seaward of Amphitrite Point, November 26, 1959.

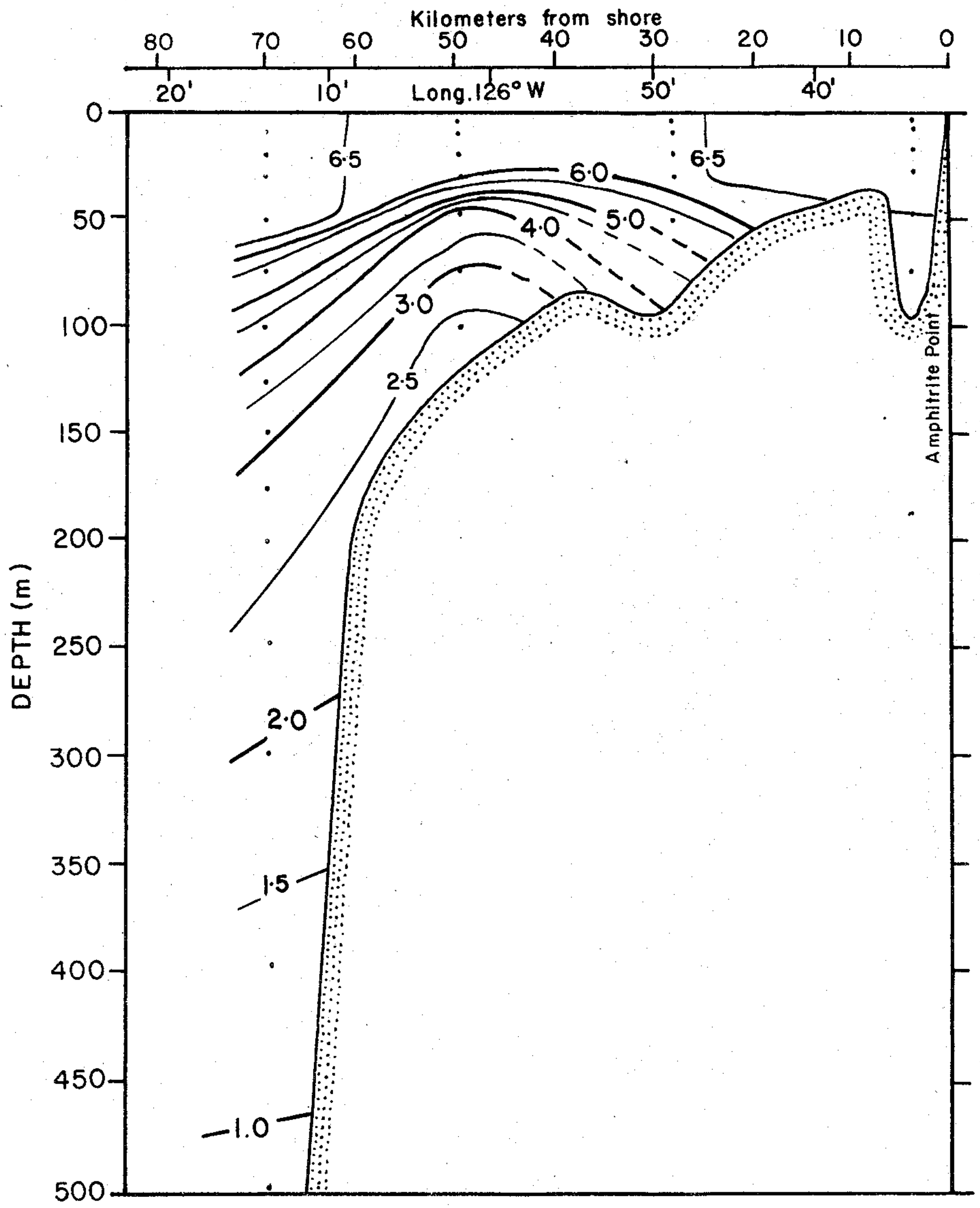

Fig. 55d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, November 26, 1959.

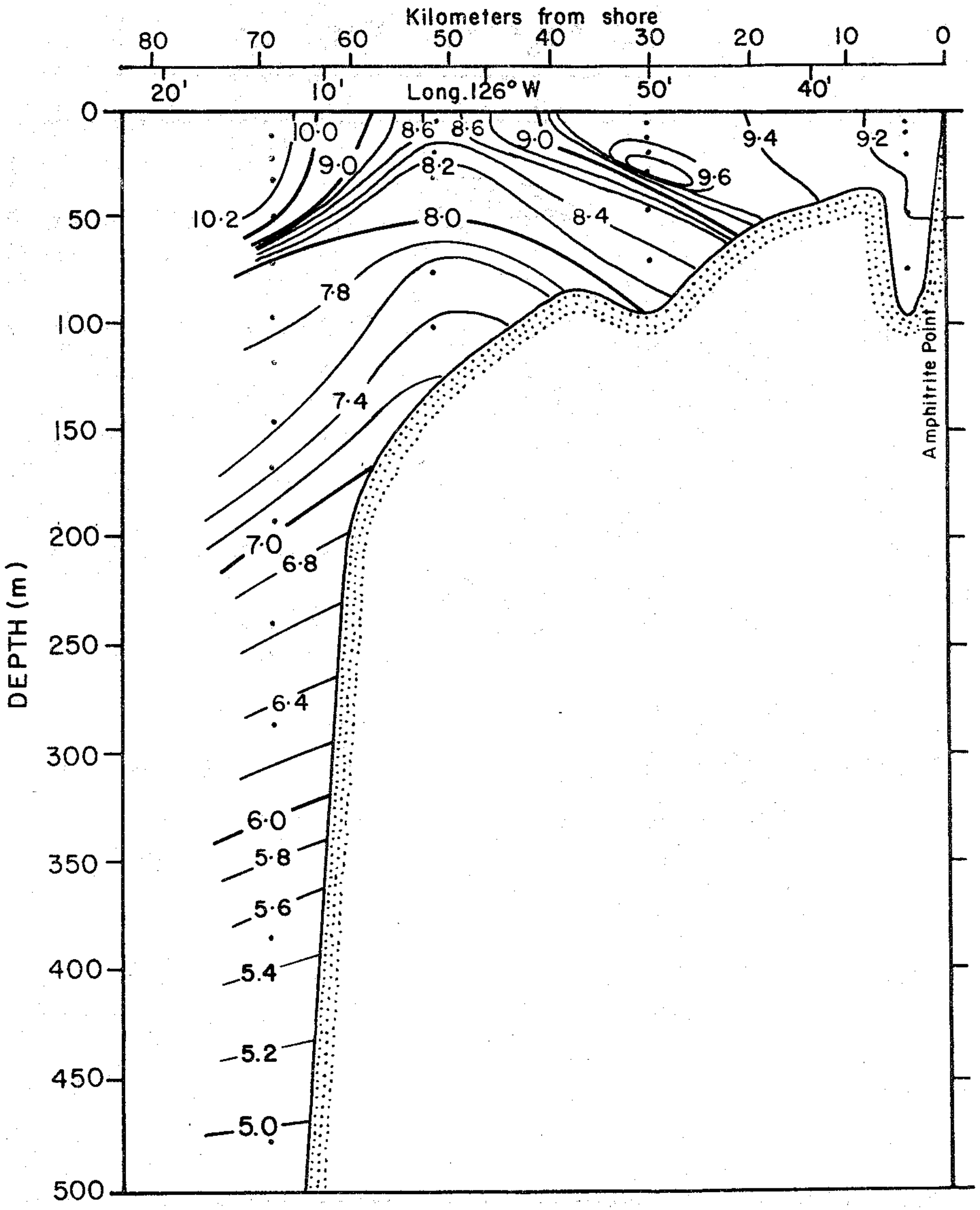

Fig. 56a. Temperature (°C) seaward of Amphitrite Point, November 27, 1959.

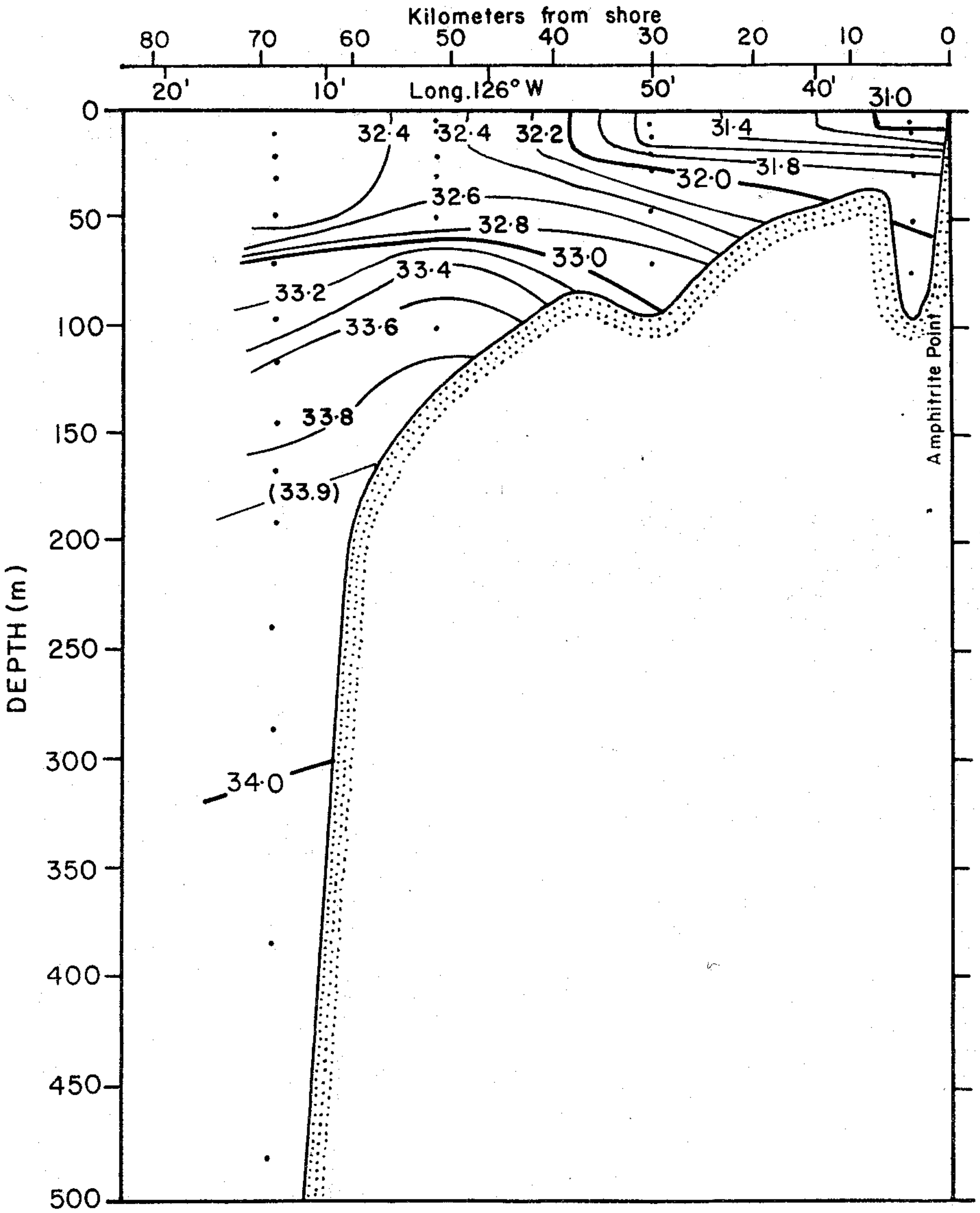

Fig. 56b. Salinity (°/₀₀) seaward of Amphitrite Point, November 27, 1959.

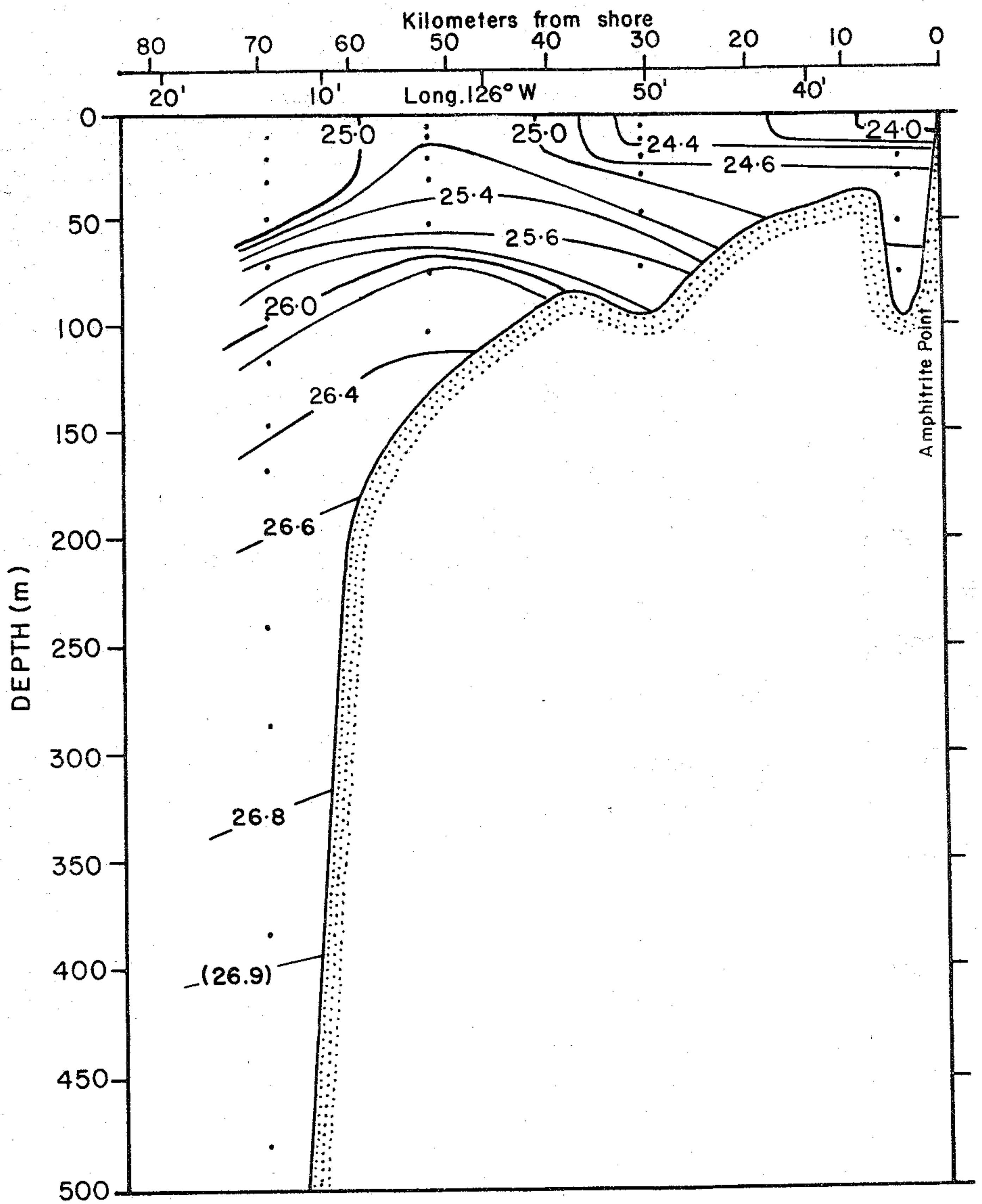

Fig. 56c. Density (σ_t) seaward of Amphitrite Point, November 27, 1959.

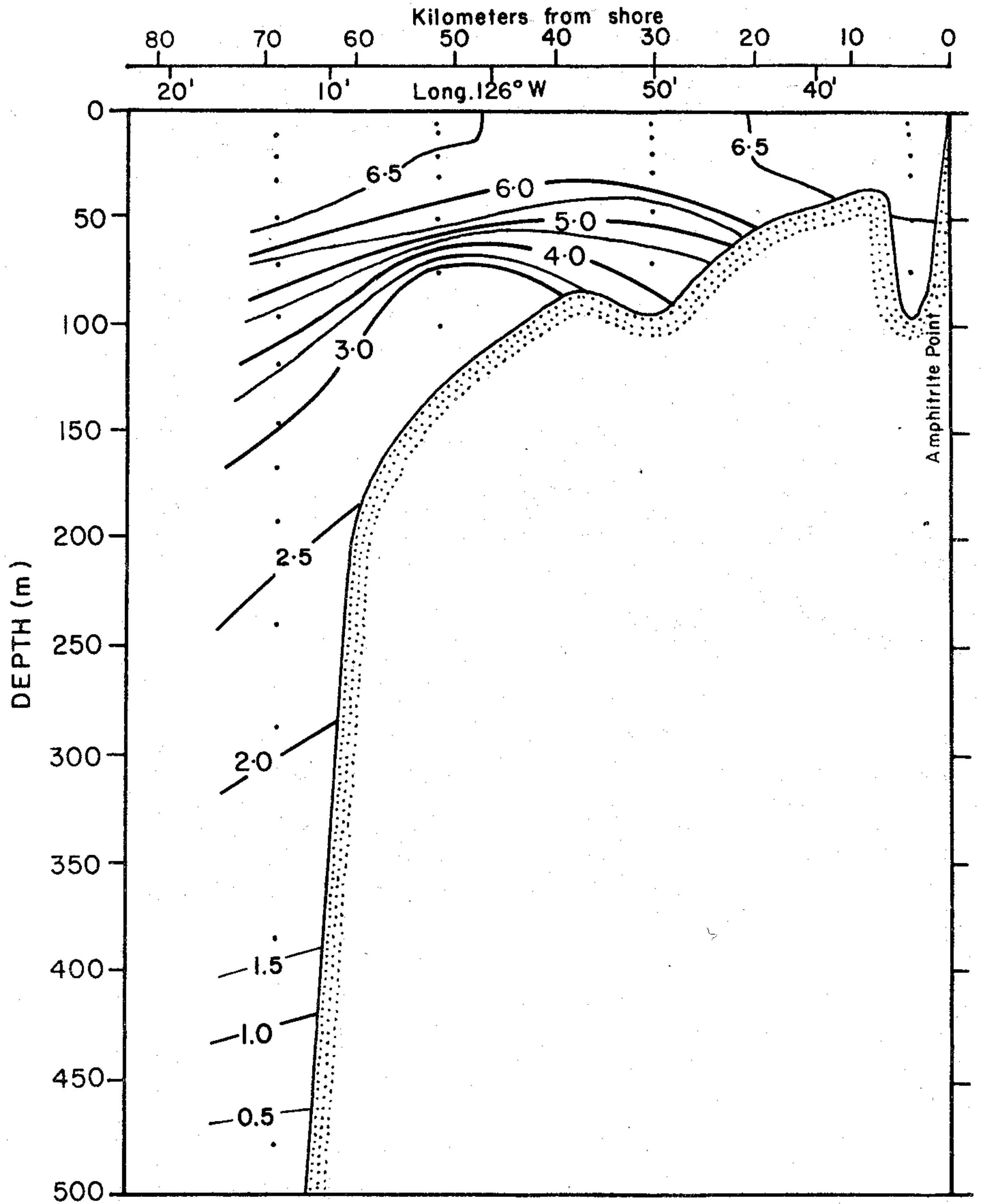

Fig. 56d. Disssolved oxygen (mL/L) seaward of Amphitrite Point, November 27, 1959.

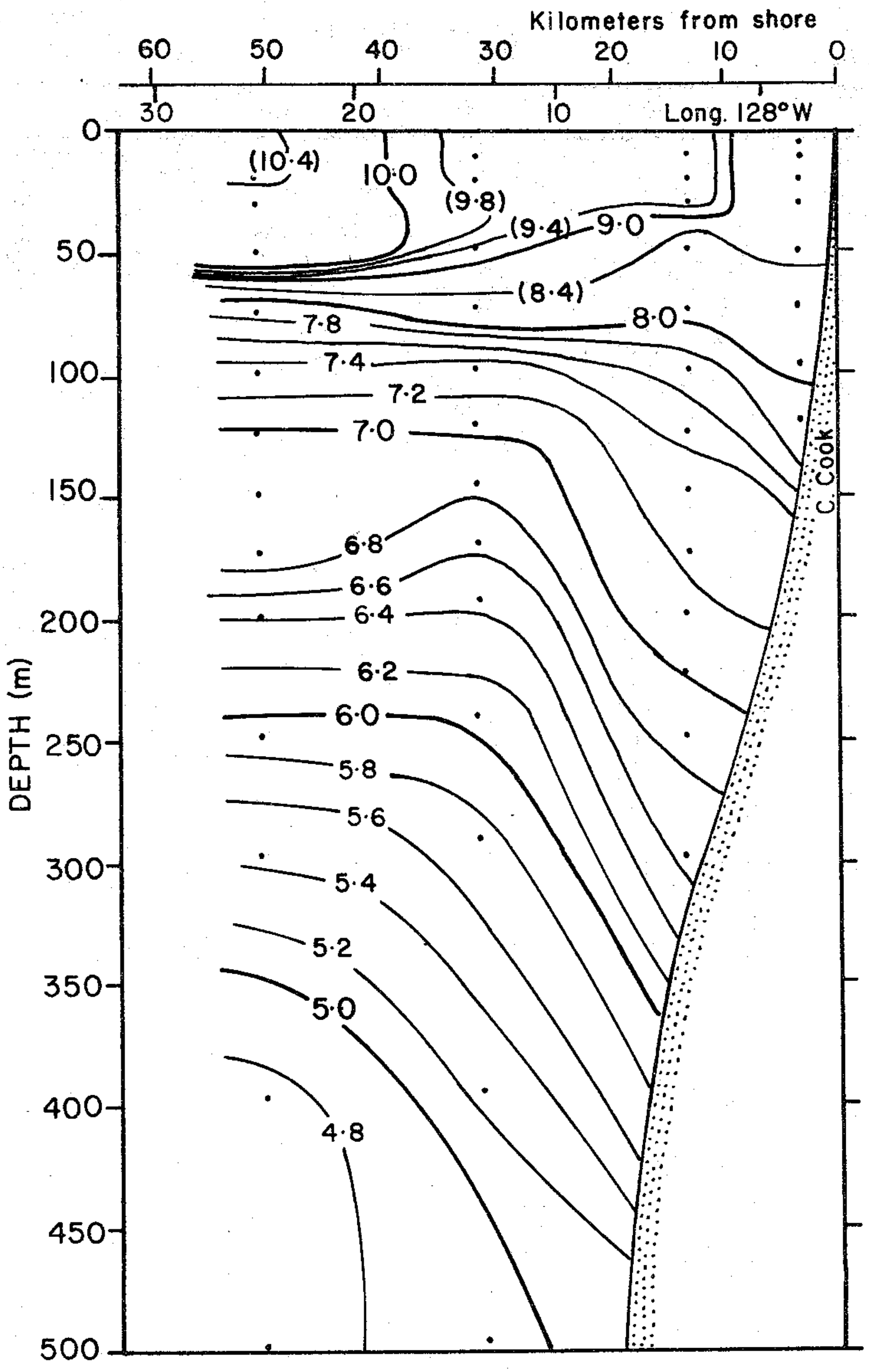

Fig. 57a. Temperature (°C) seaward of Cape Cook, November 27, 1959.

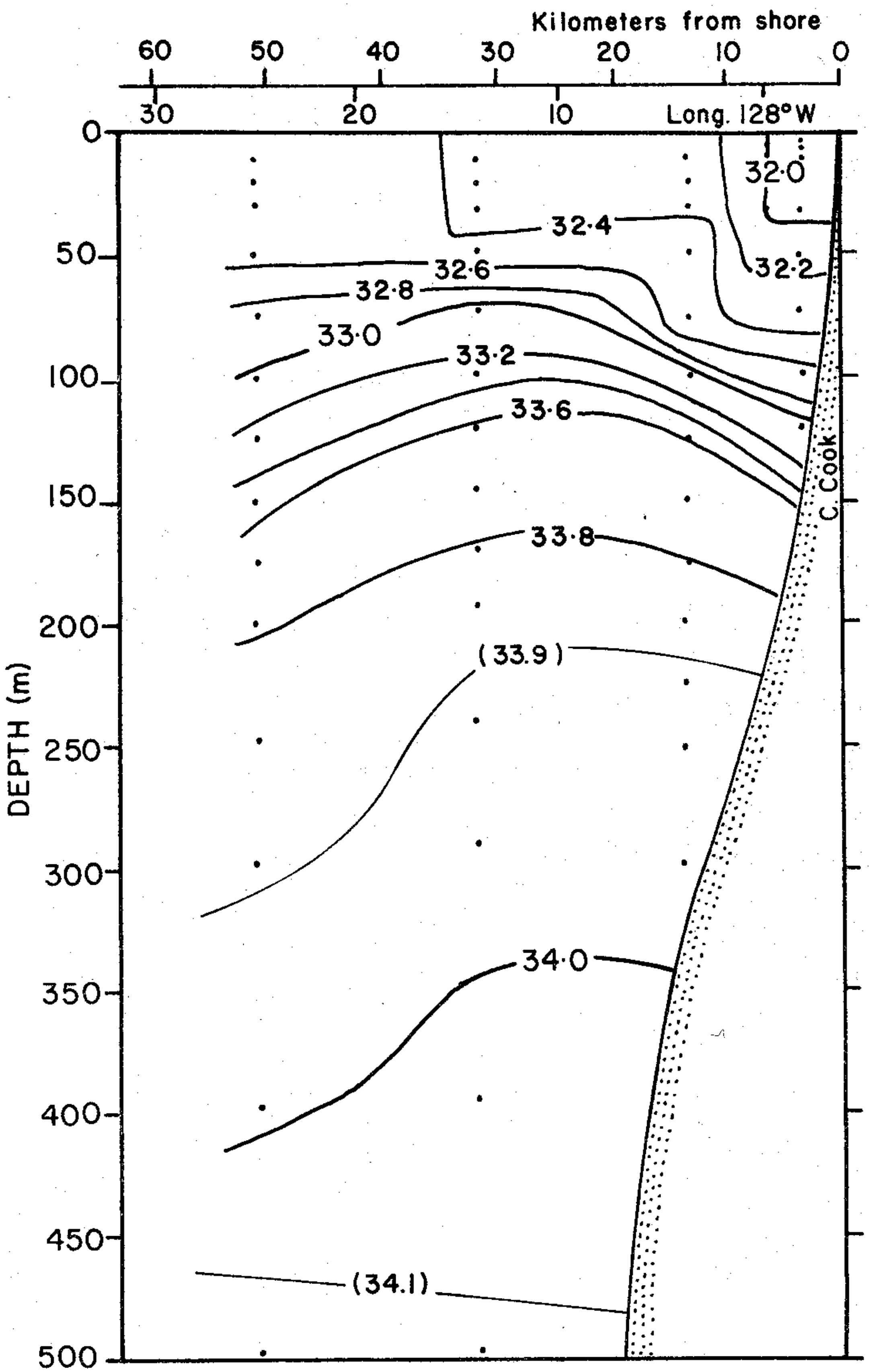

Fig. 57b. Salinity (°/oo) seaward of Cape Cook, November 27, 1959.

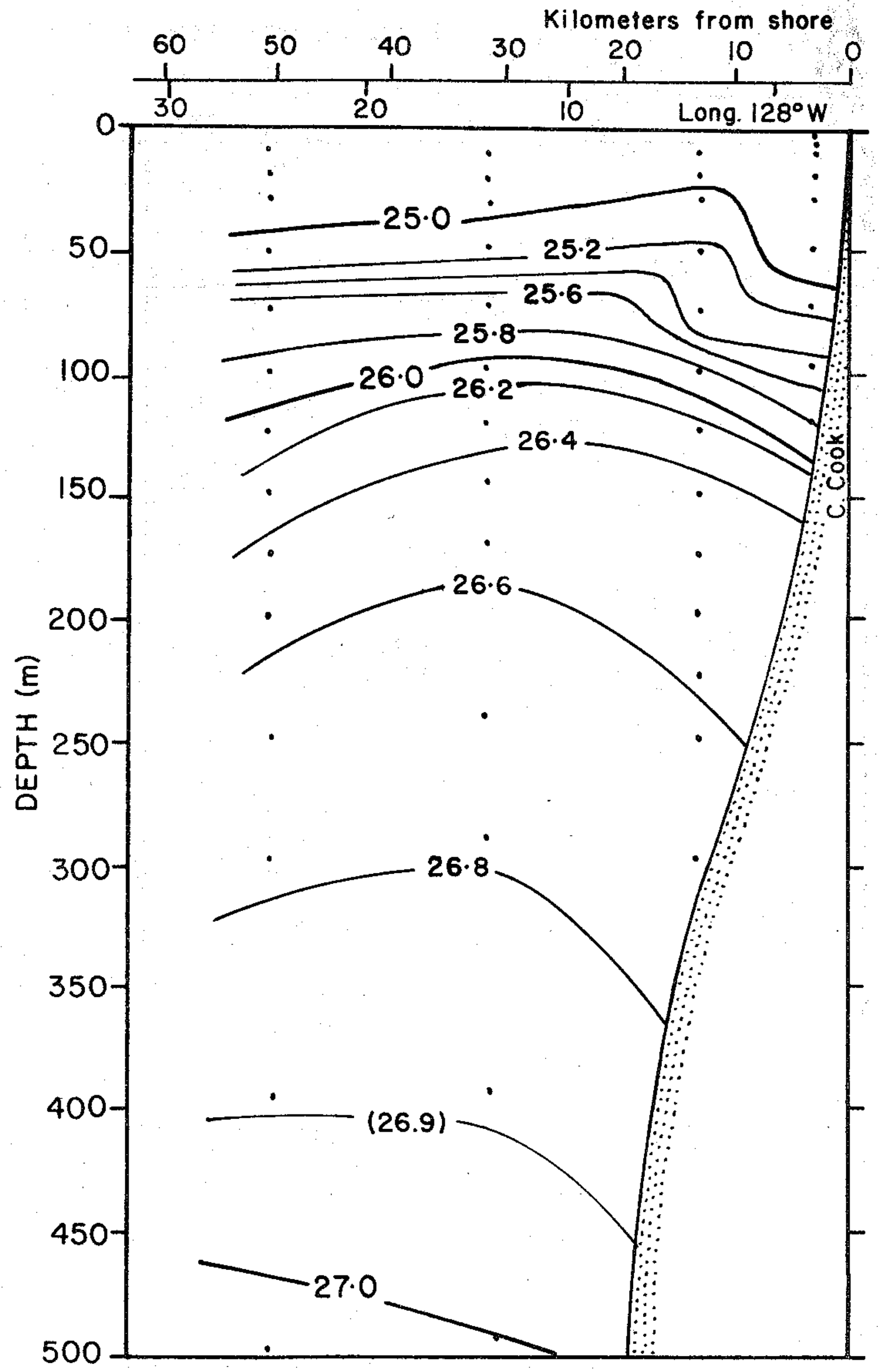

Fig. 57c. Density (σ_t) seaward of Cape Cook, November 27, 1959.

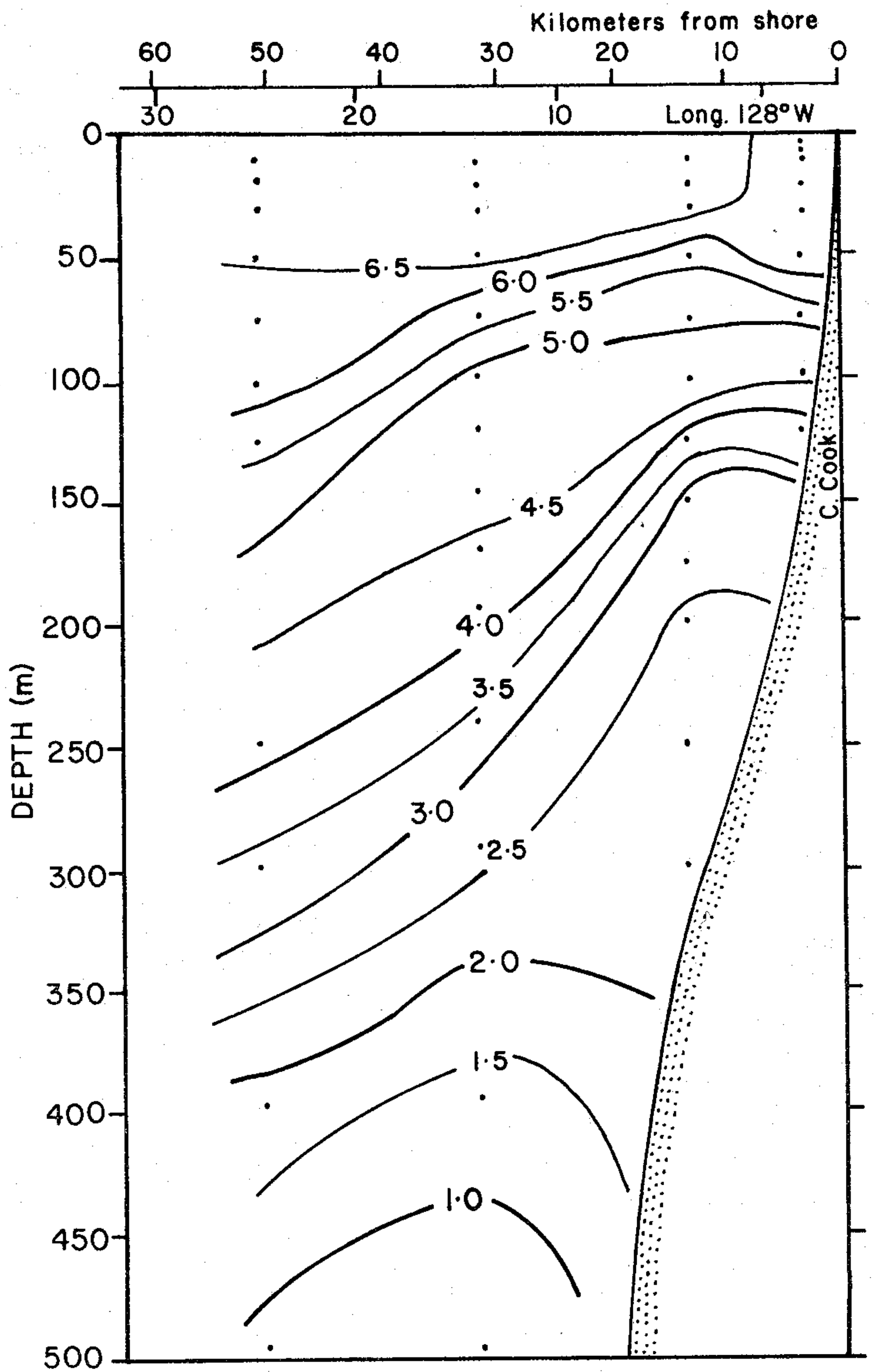

Fig. 57d. Dissovled oxygen (mL/L) seaward of Cape Cook, November 27, 1959.

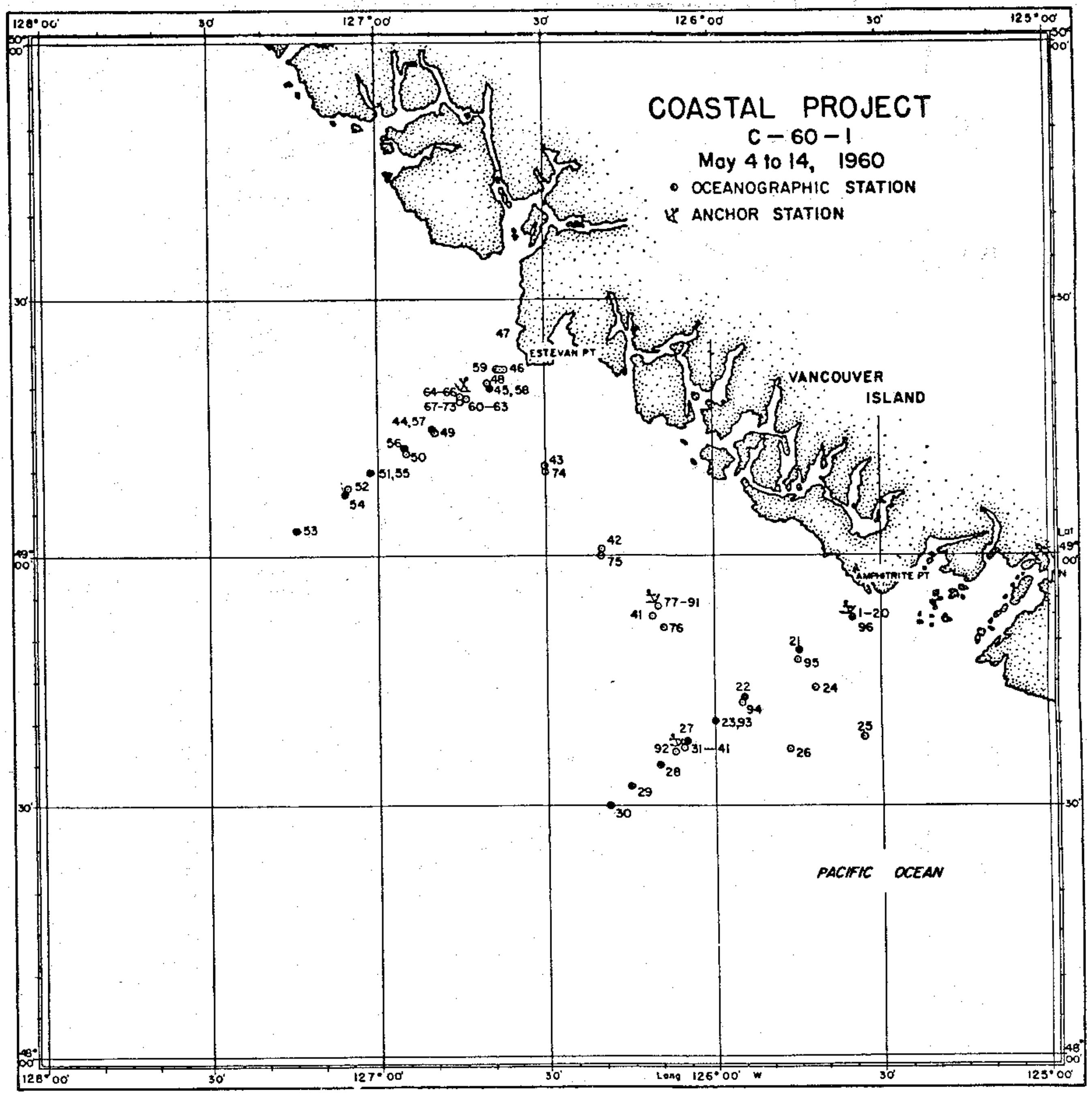

Fig. 58. Coastal project, May 4-14, 1960. Solid circles indicate stations used in the sections.

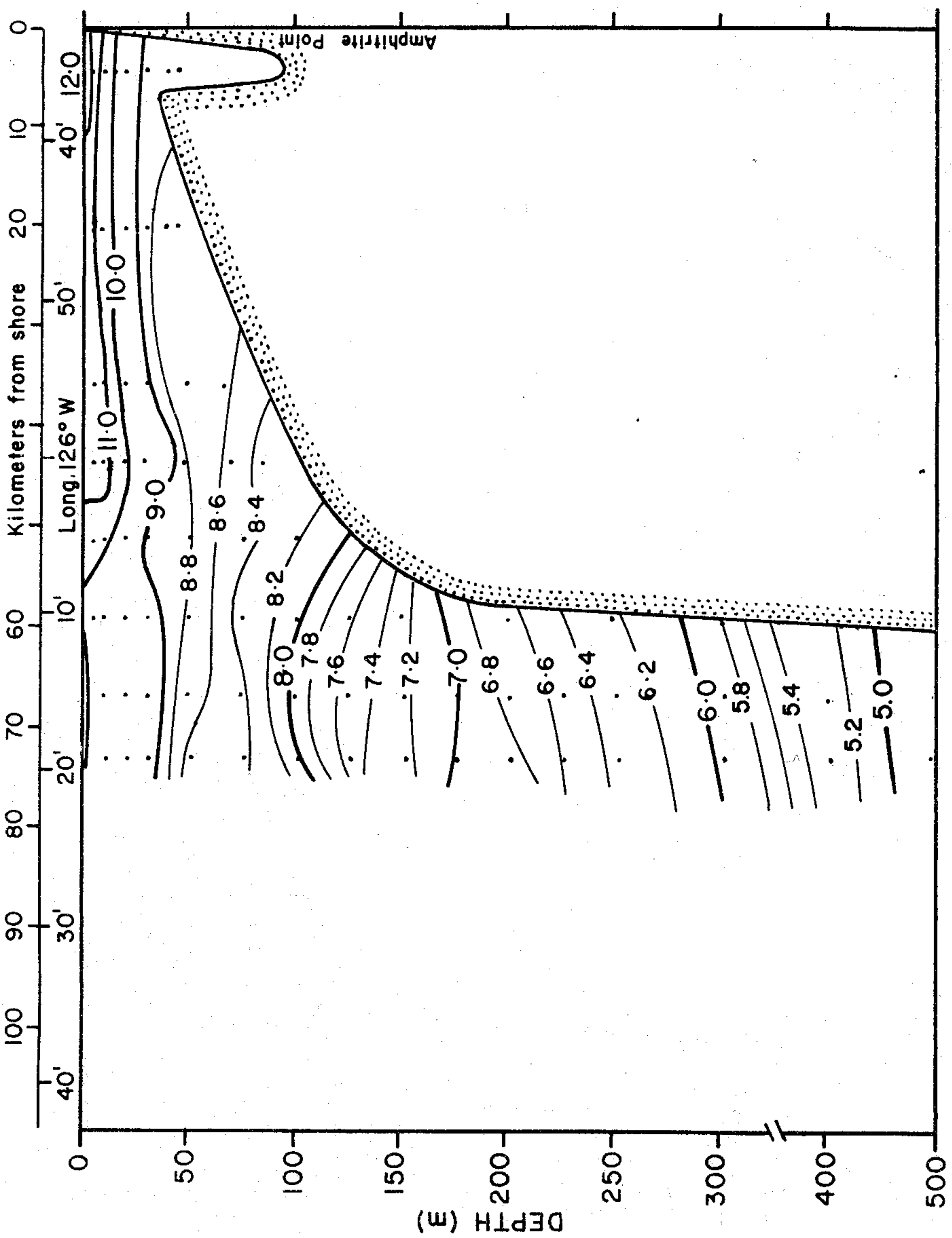

Fig. 59a. Temperature (°C) seaward of Amphitrite Point, May 5-6, 1960.

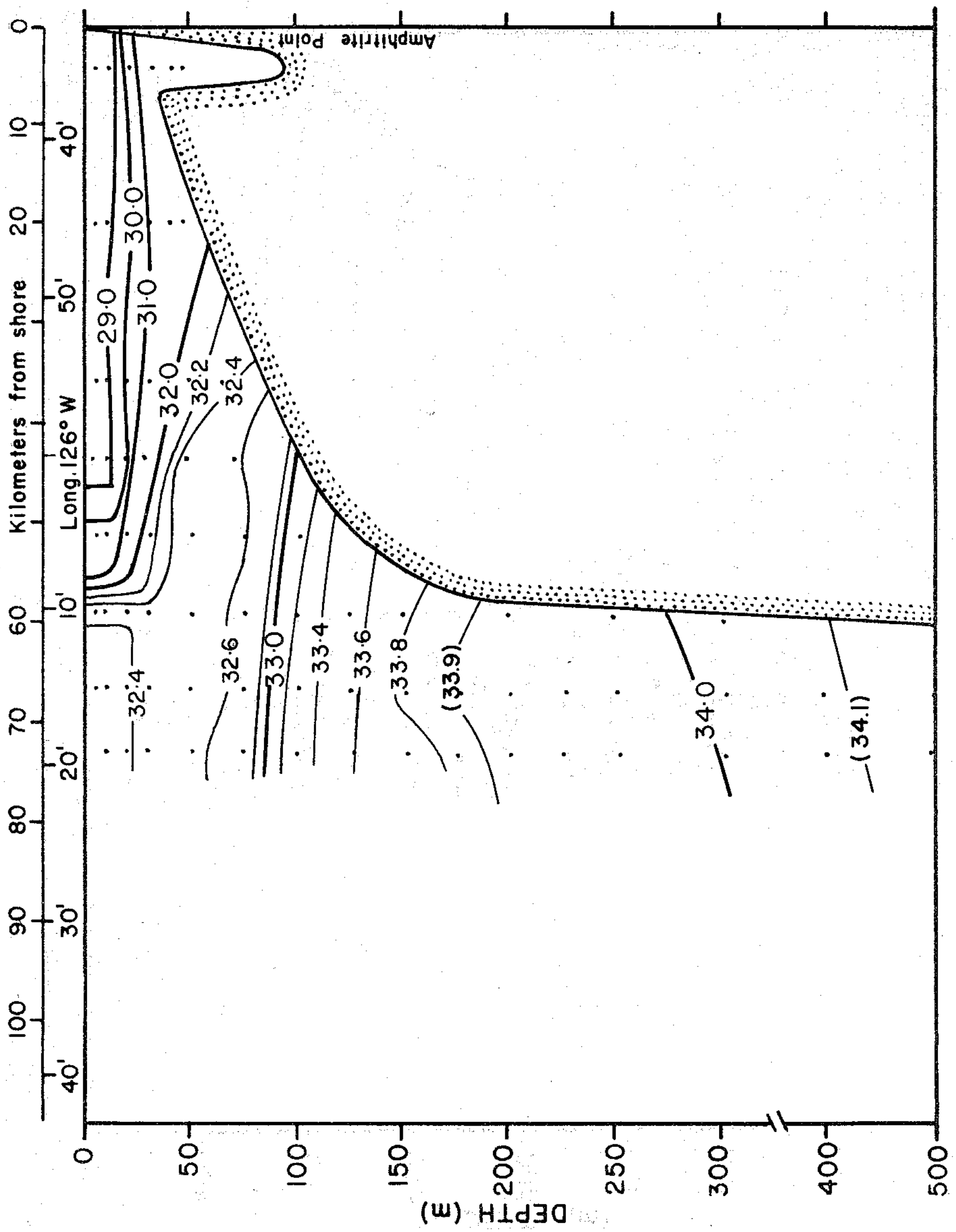

Fig. 59b. Salinity (⁰/₀₀) seaward of Amphitrite Point, May 5-6, 1960.

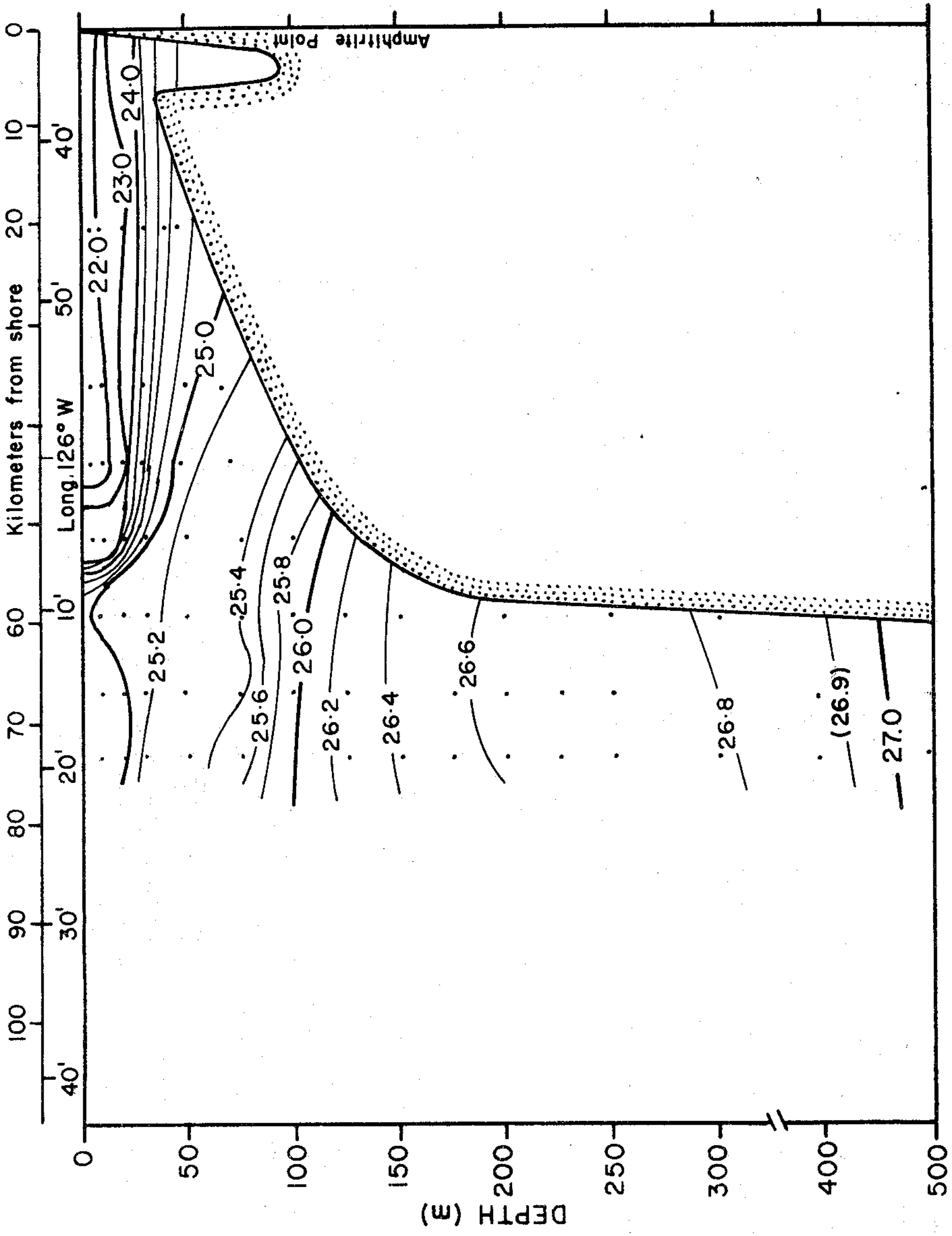

Fig. 59c. Density (σ_t) seaward of Amphitrite Point, May 5-6, 1960.

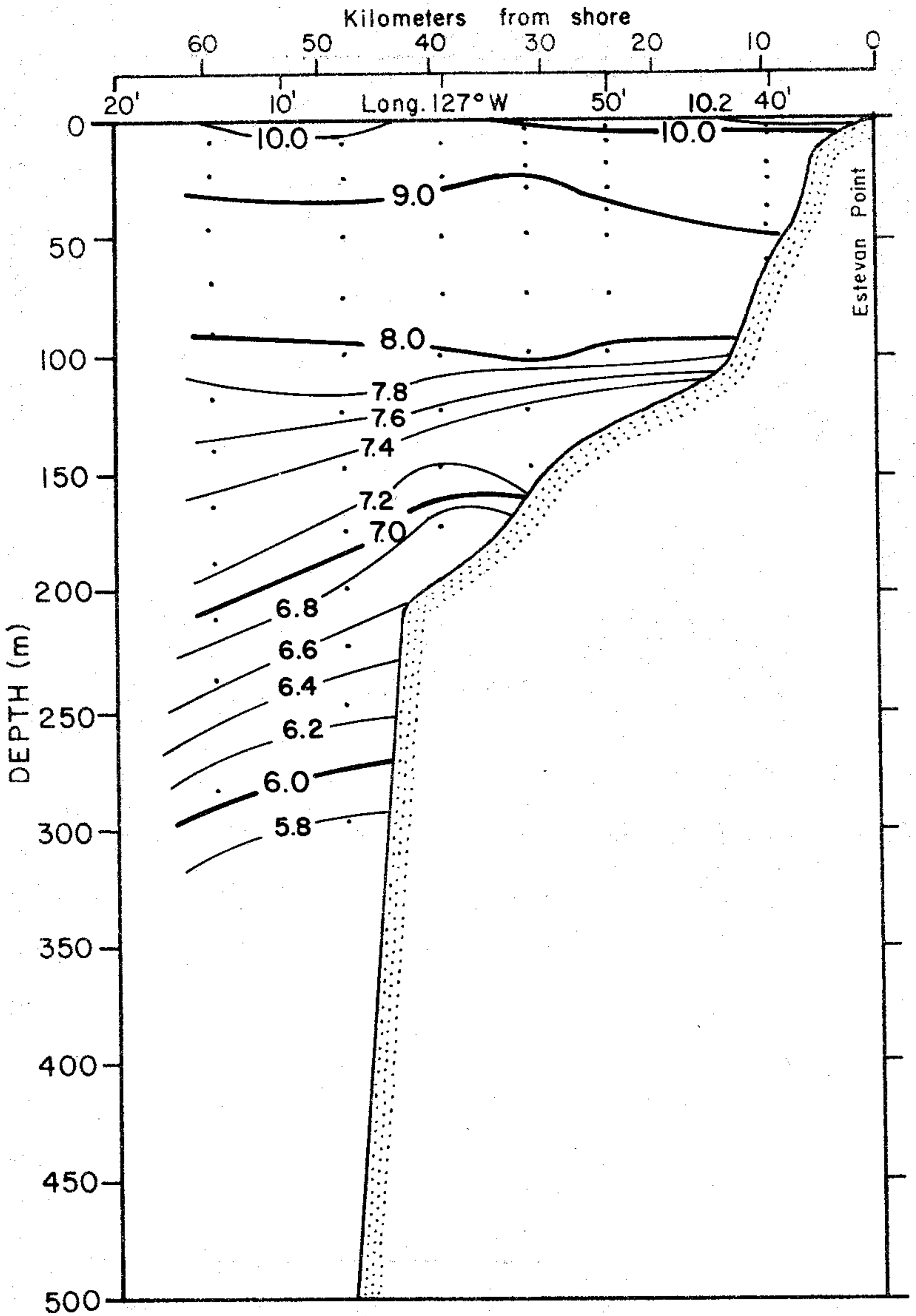

Fig. 60a. Temperature (°C) seaward of Estevan Point, May 10, 1960.

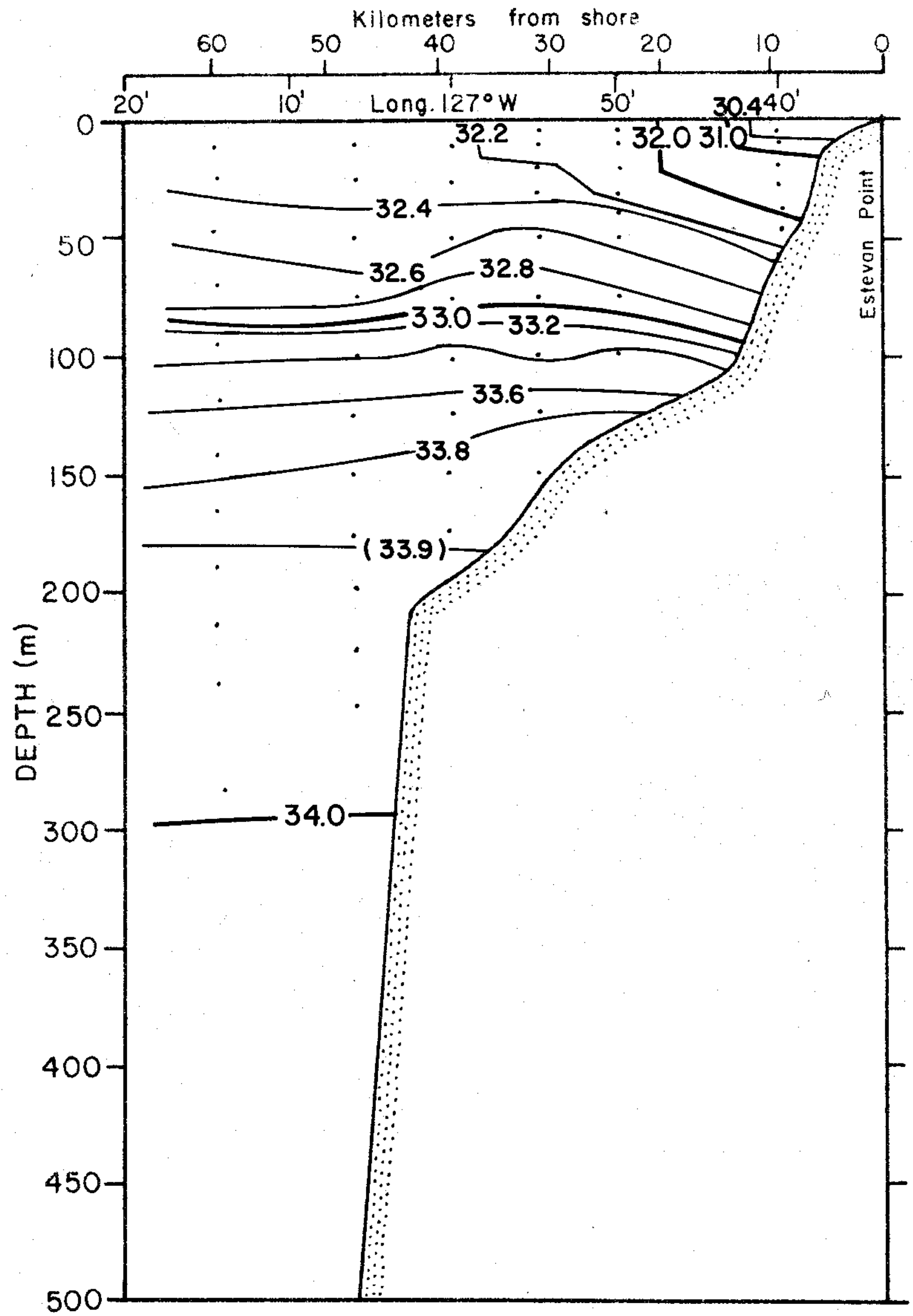

Fig. 60b. Salinity (°/oo) seaward of Estevan Point, May 10, 1960.

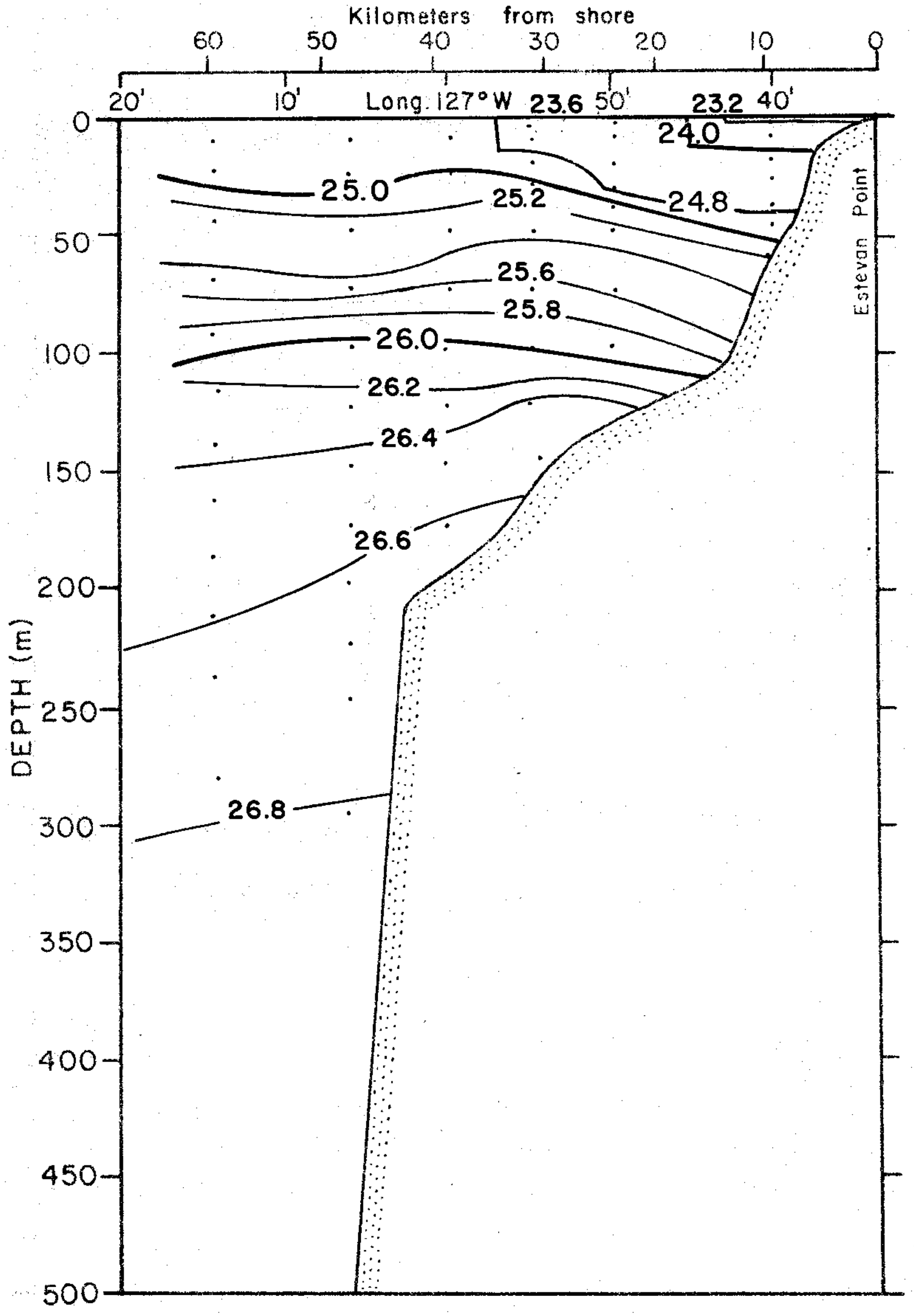

Fig. 60c. Density (σ_t) seaward of Estevan Point, May 10, 1960.

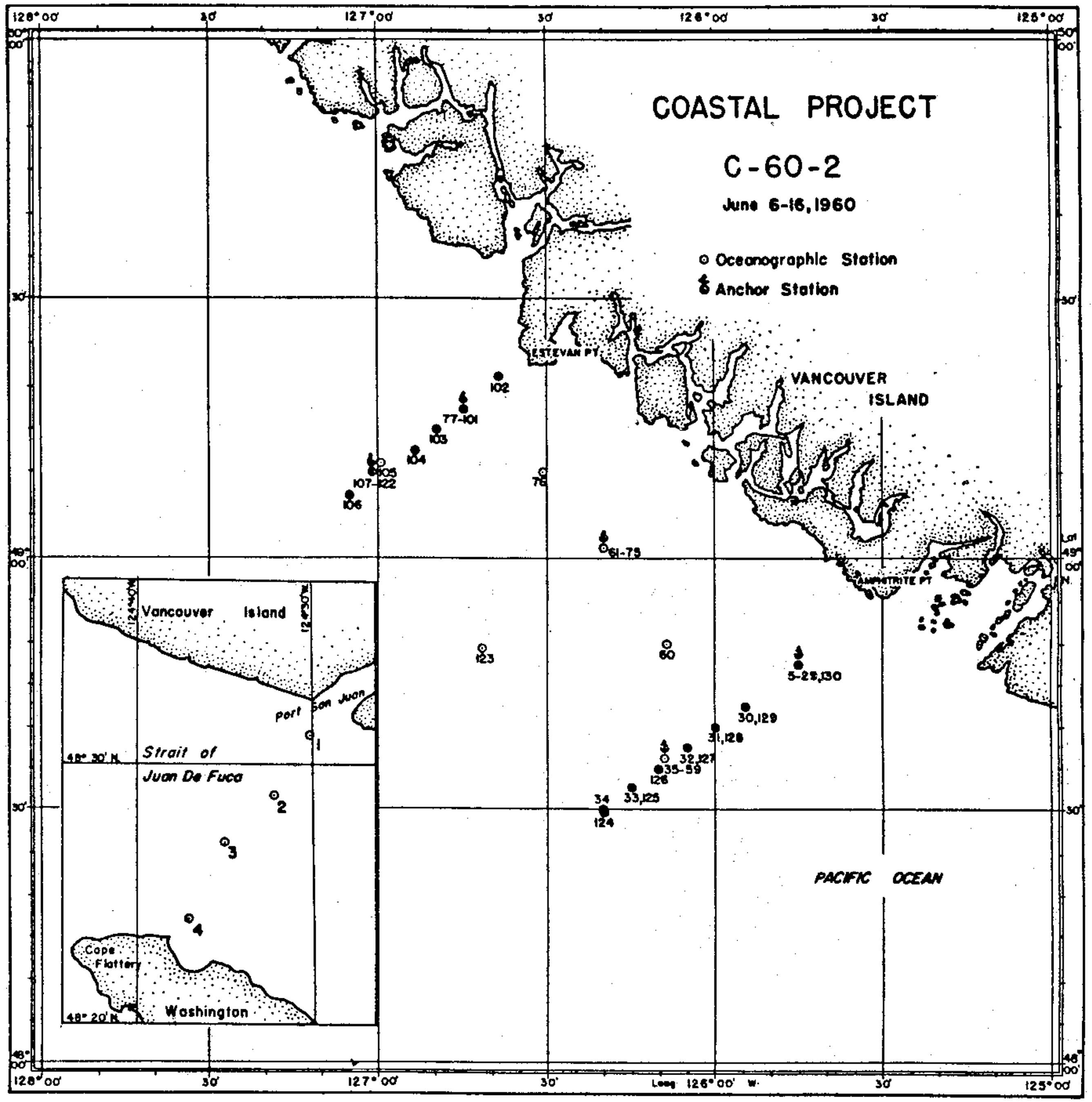

Fig. 61. Coastal Project, June 6-16, 1960. Solid circles indicate stations used in the sections.

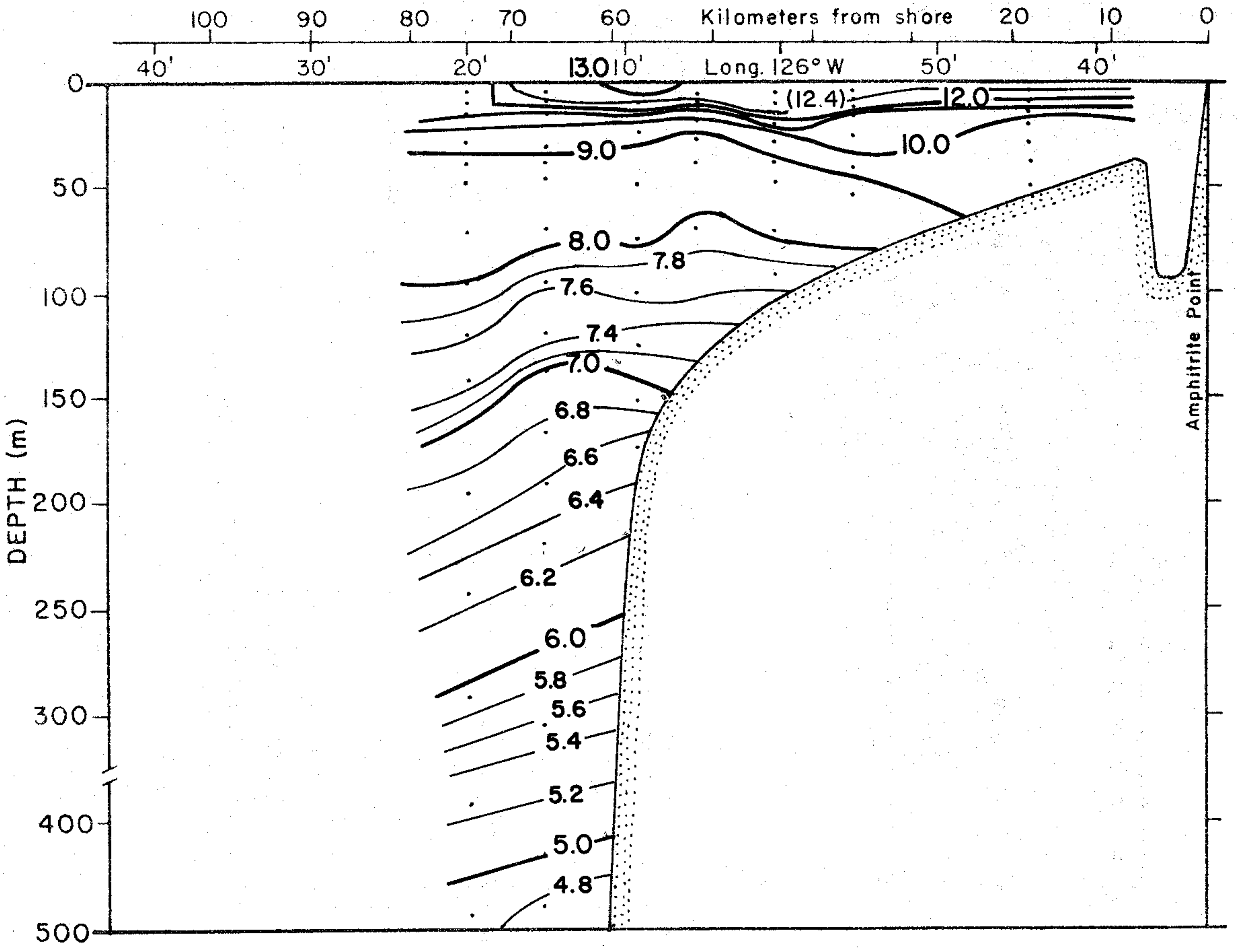

Fig. 62a. Temperature (°C) seaward of Amphitrite Point, June 8-9, 1960.

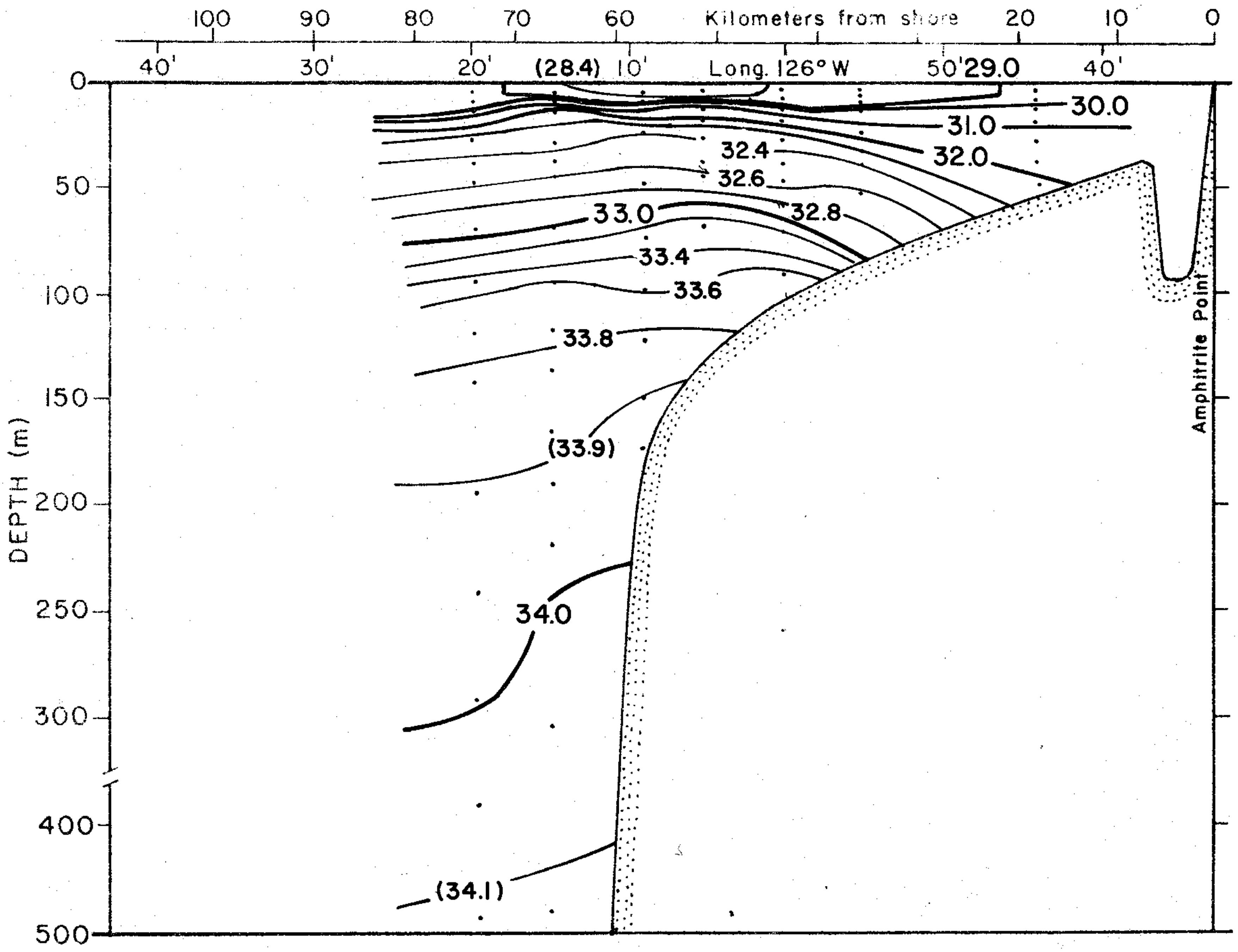

Fig. 62b. Salinity ($^{o}/_{oo}$) seaward of Amphitrite Point, June 8-9, 1960.

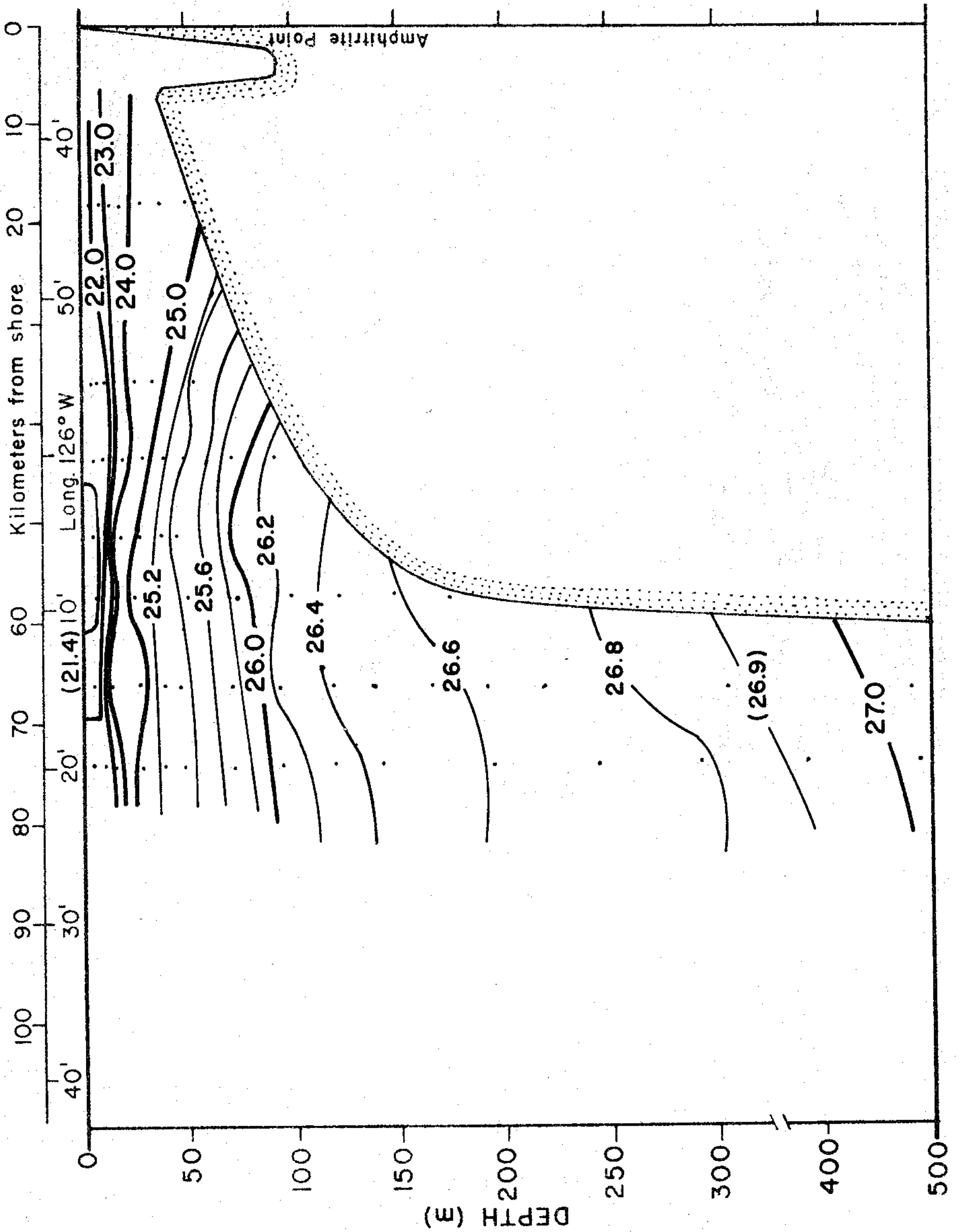

Fig. 62c. Density (σ_t) seaward of Amphitrite Point, June 8-9, 1960.

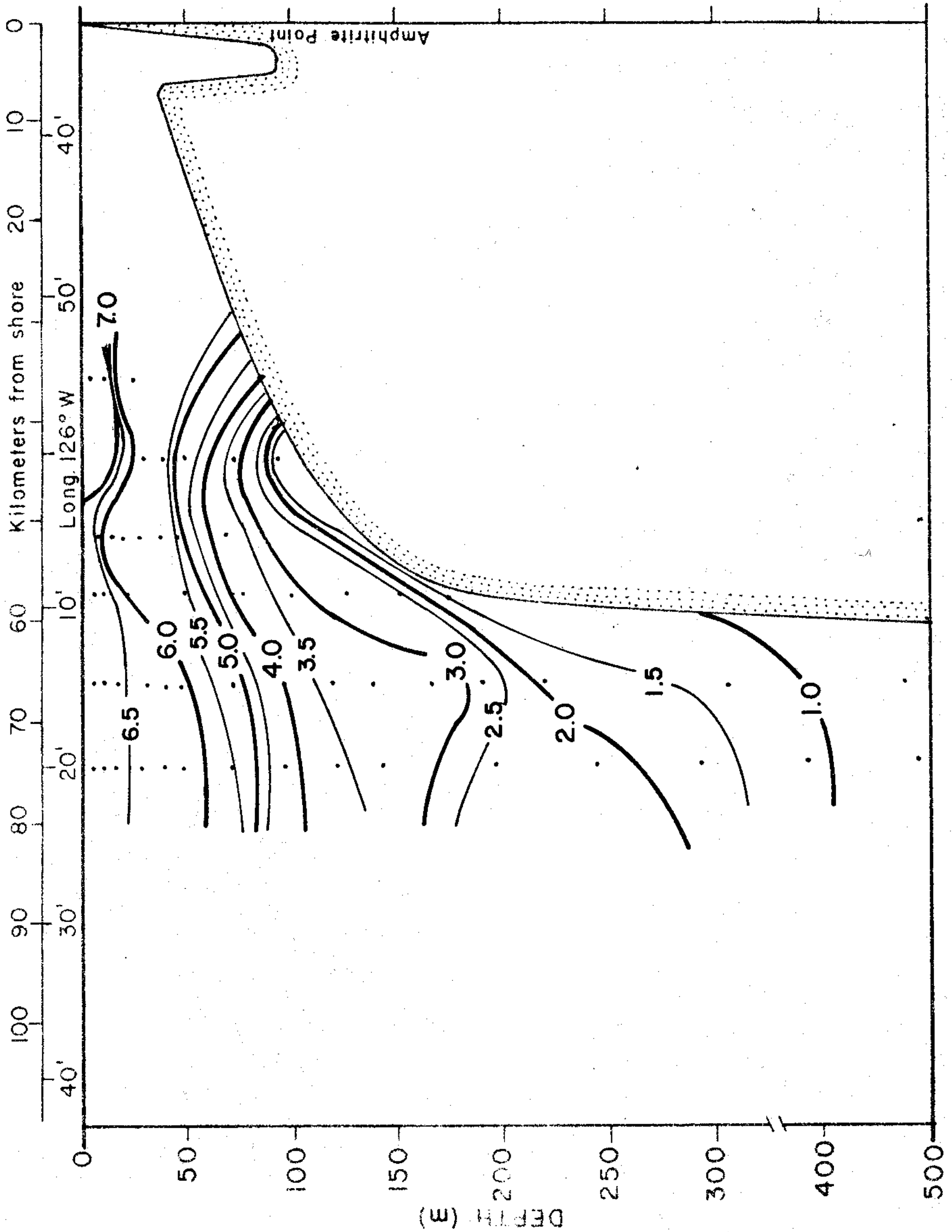

Fig. 62d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, June 8-9, 1960.

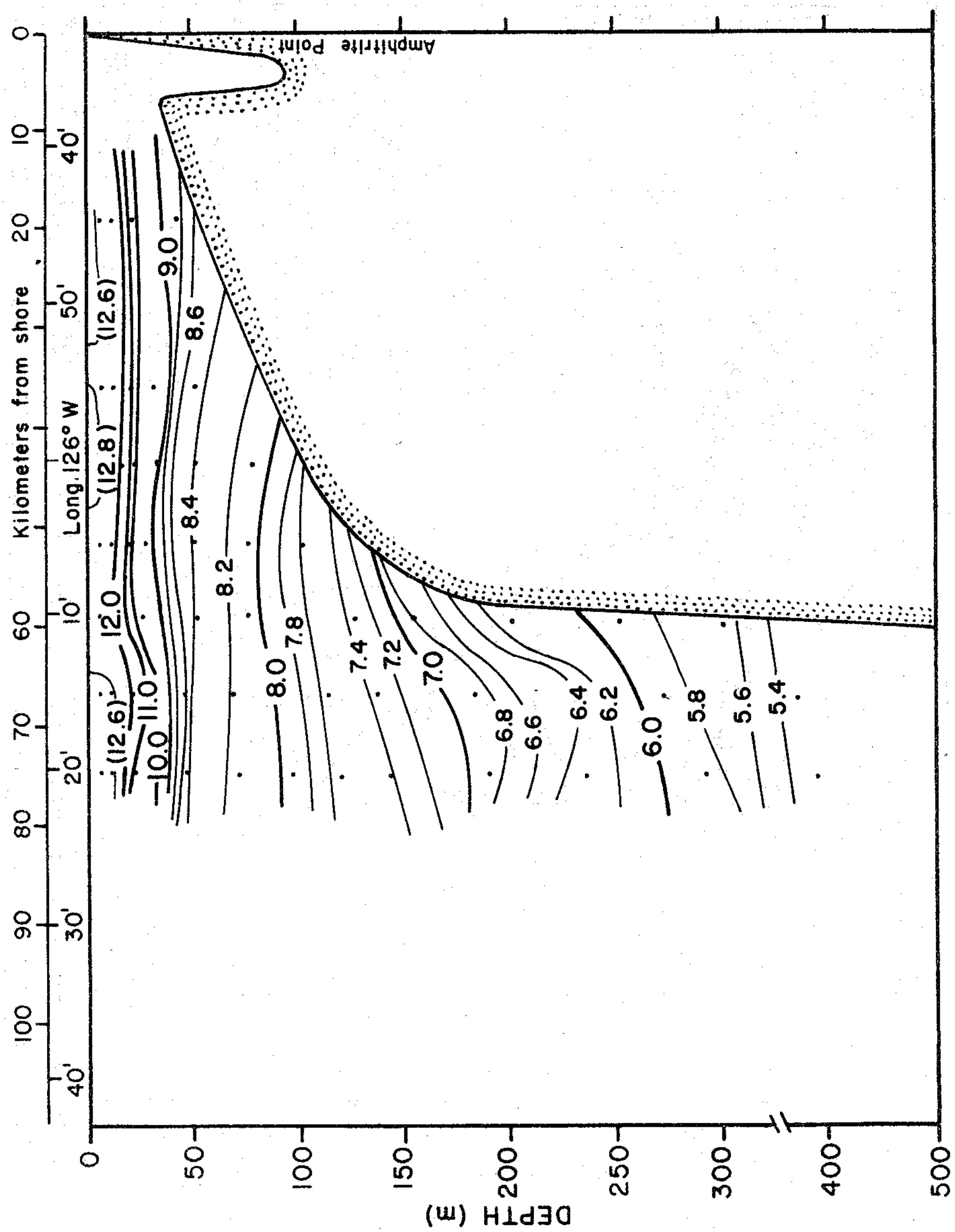

Fig. 63a. Temperature (°C) seaward of Amphitrite Point, June 16, 1960.

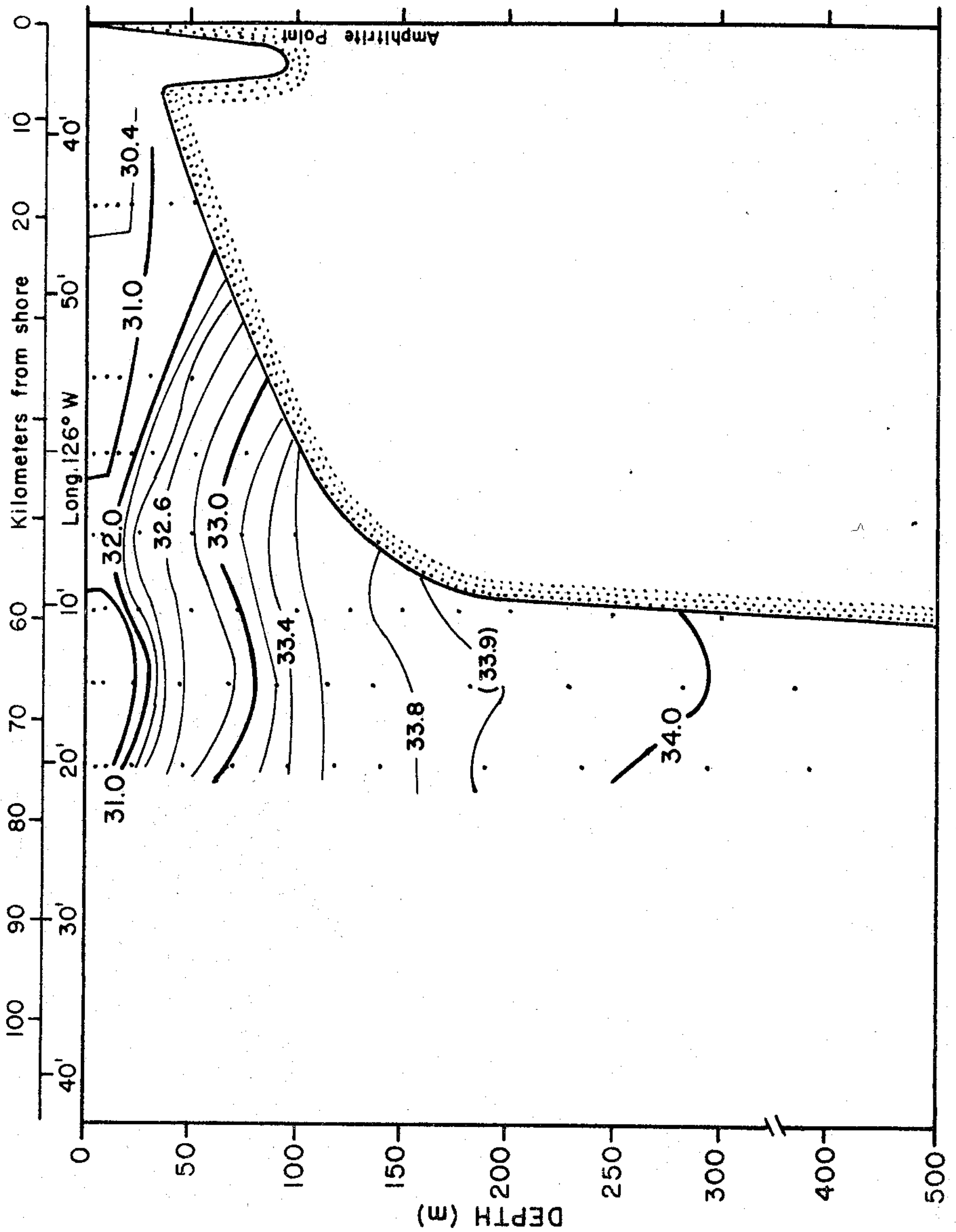

Fig. 63b. Salinity (°/oo) seaward of Amphitrite Point, June 16, 1960.

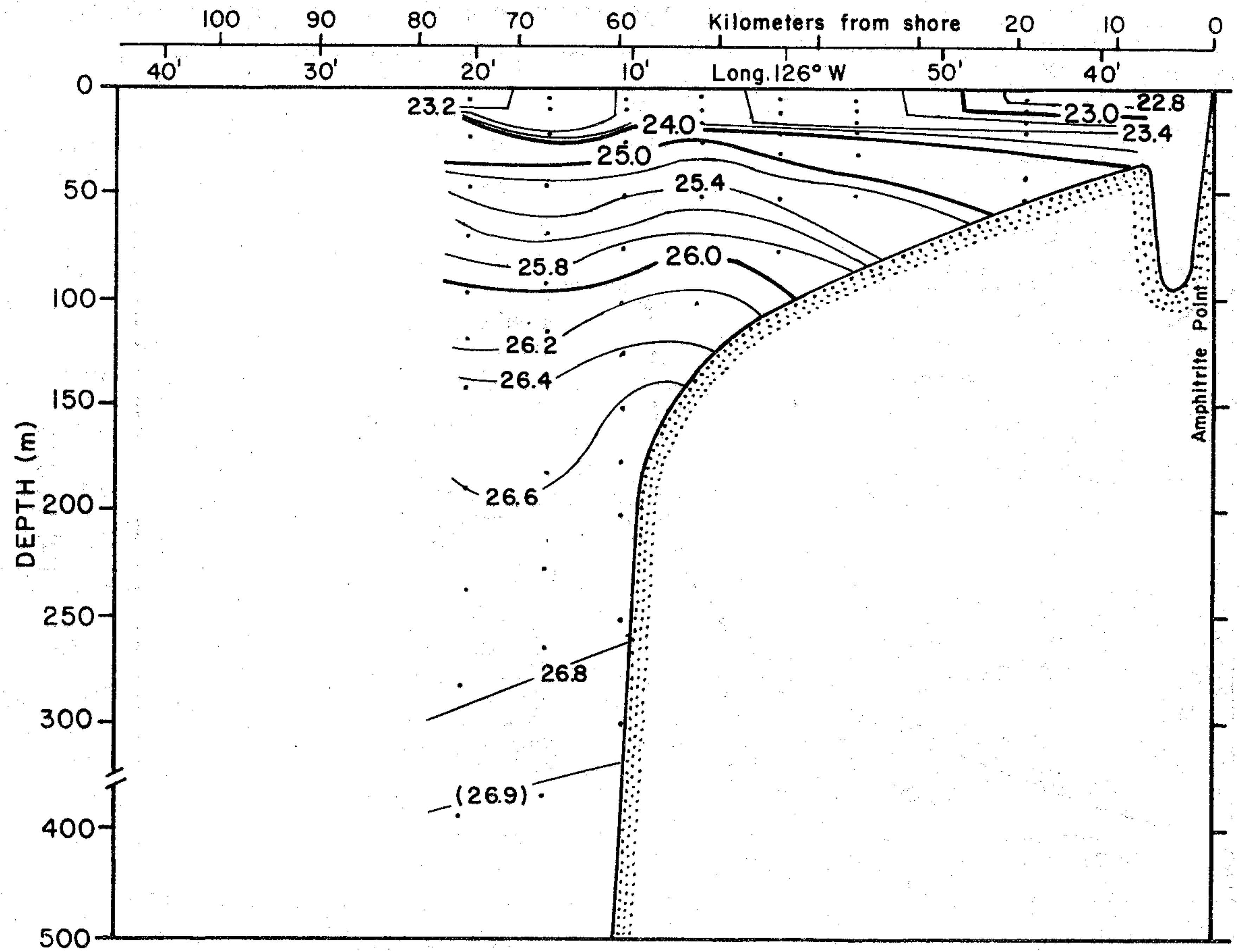

Fig. 63c. Density (σ_t) seaward of Amphitrite Point, June 16, 1960.

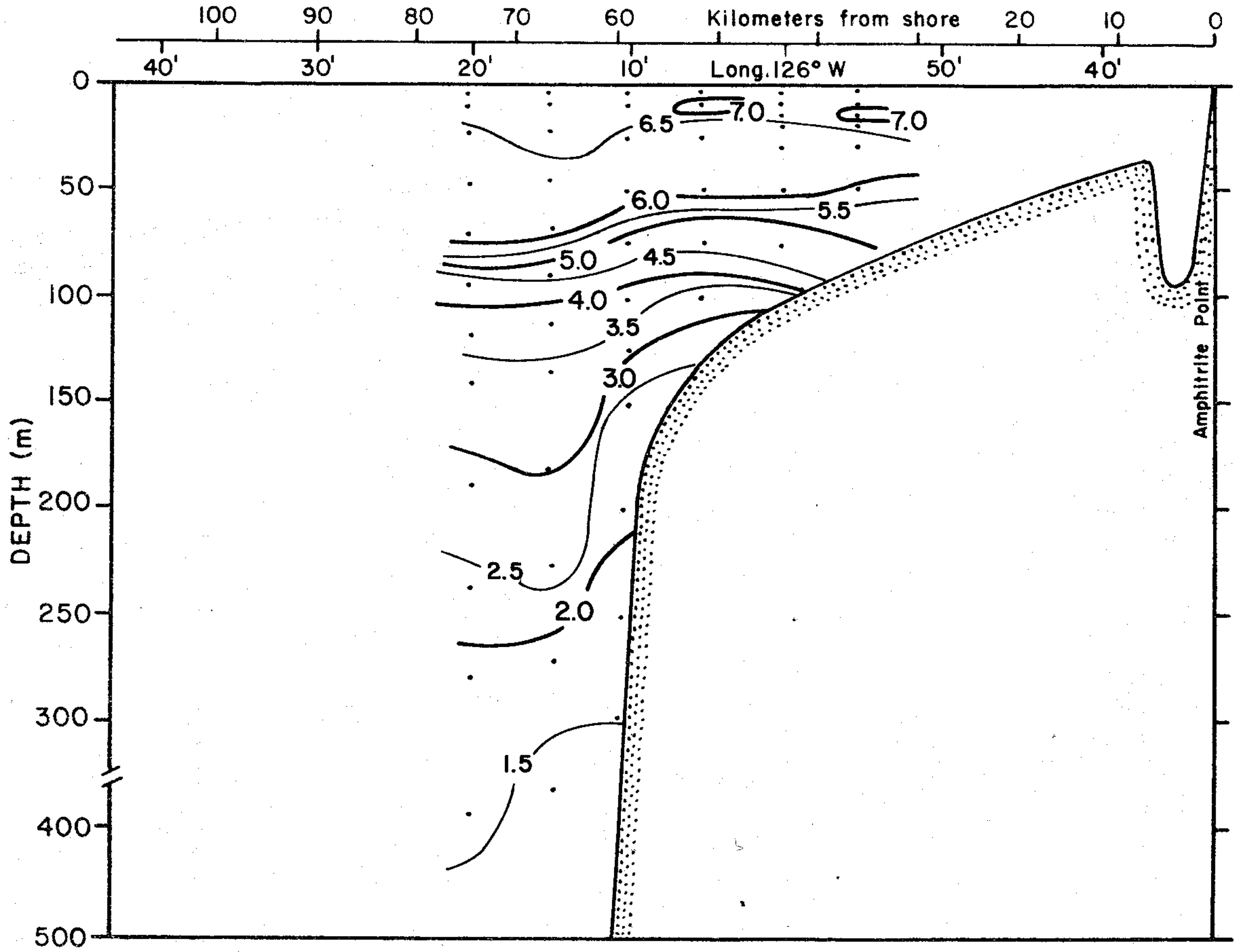

Fig. 63d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, June 16, 1960.

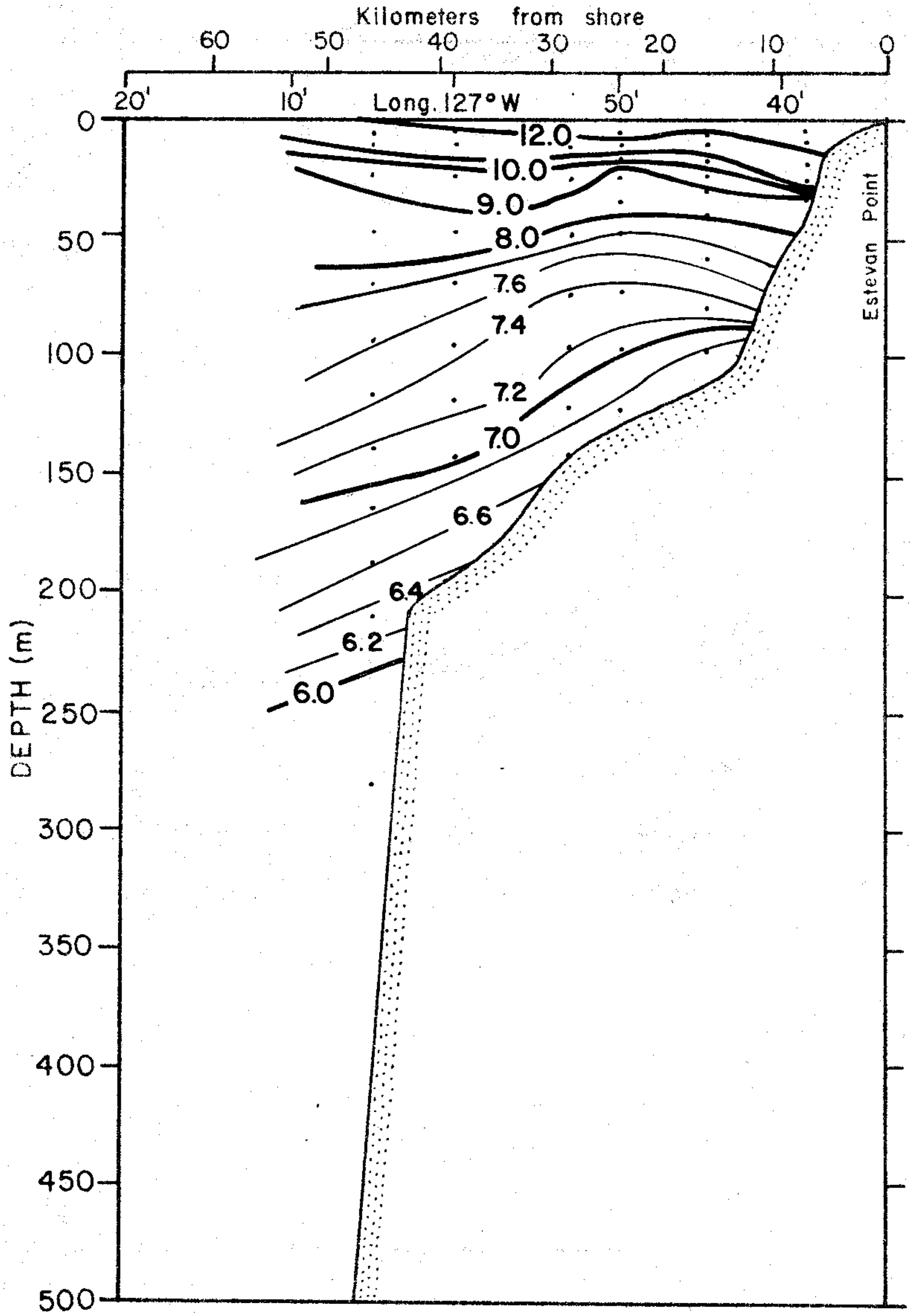

Fig. 64a. Temperature (°C) seaward of Estevan Point, June 14-15, 1960.

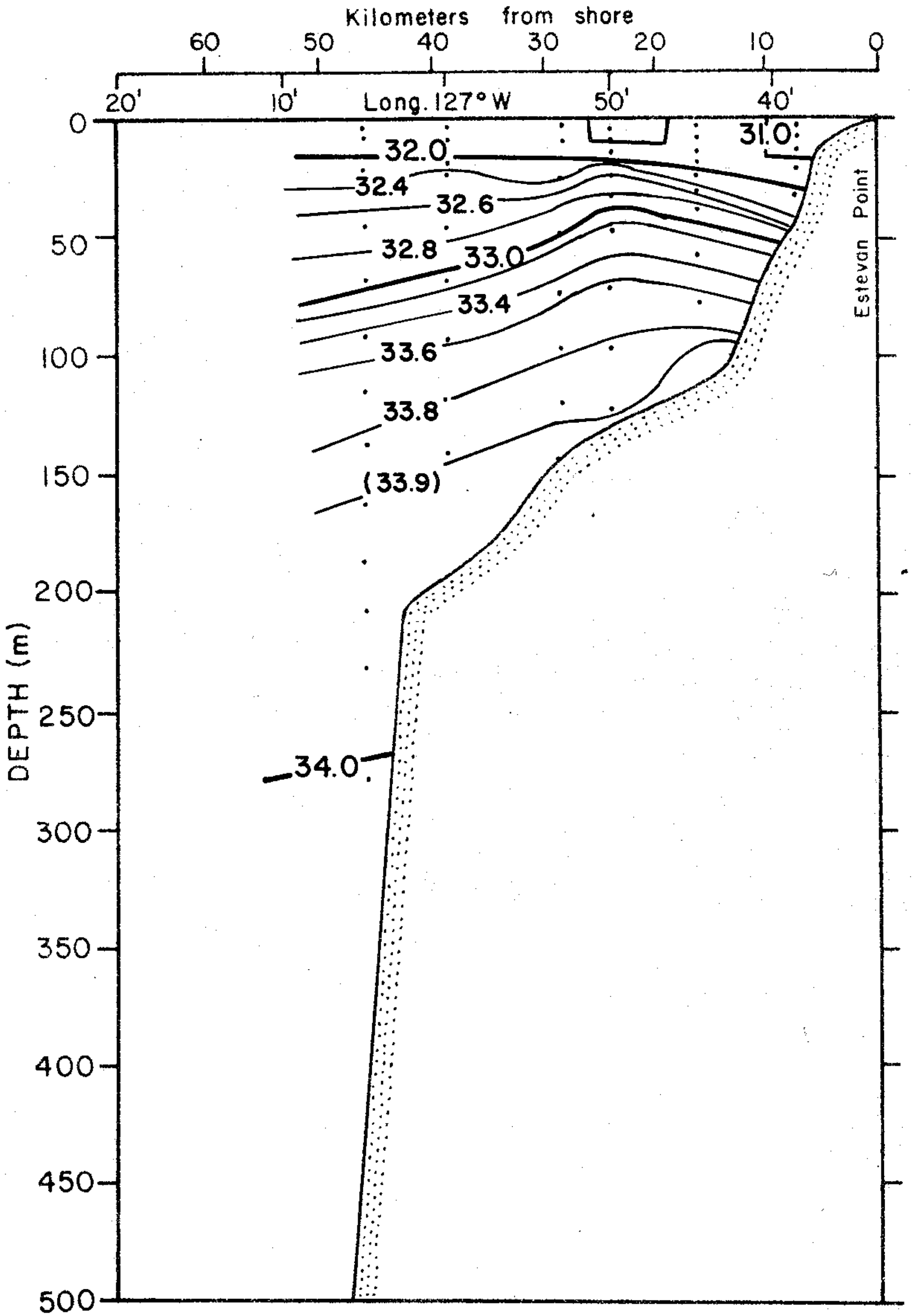

Fig. 64b. Salinity (°/oo) seaward of Estevan Point, June 14-15, 1960.

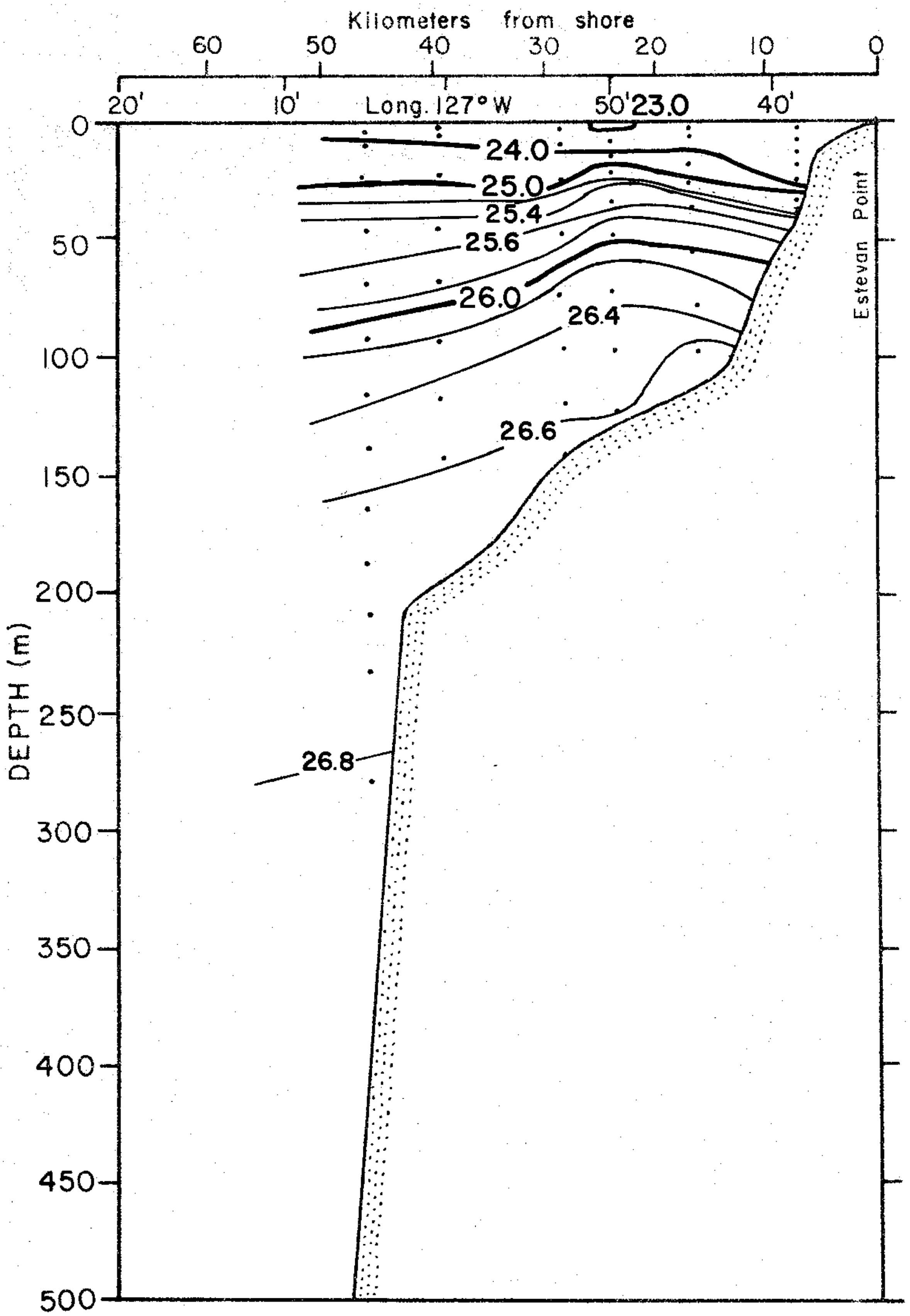

Fig. 64c. Density (σ_t) seaward of Estevan Point, June 14-15, 1960.

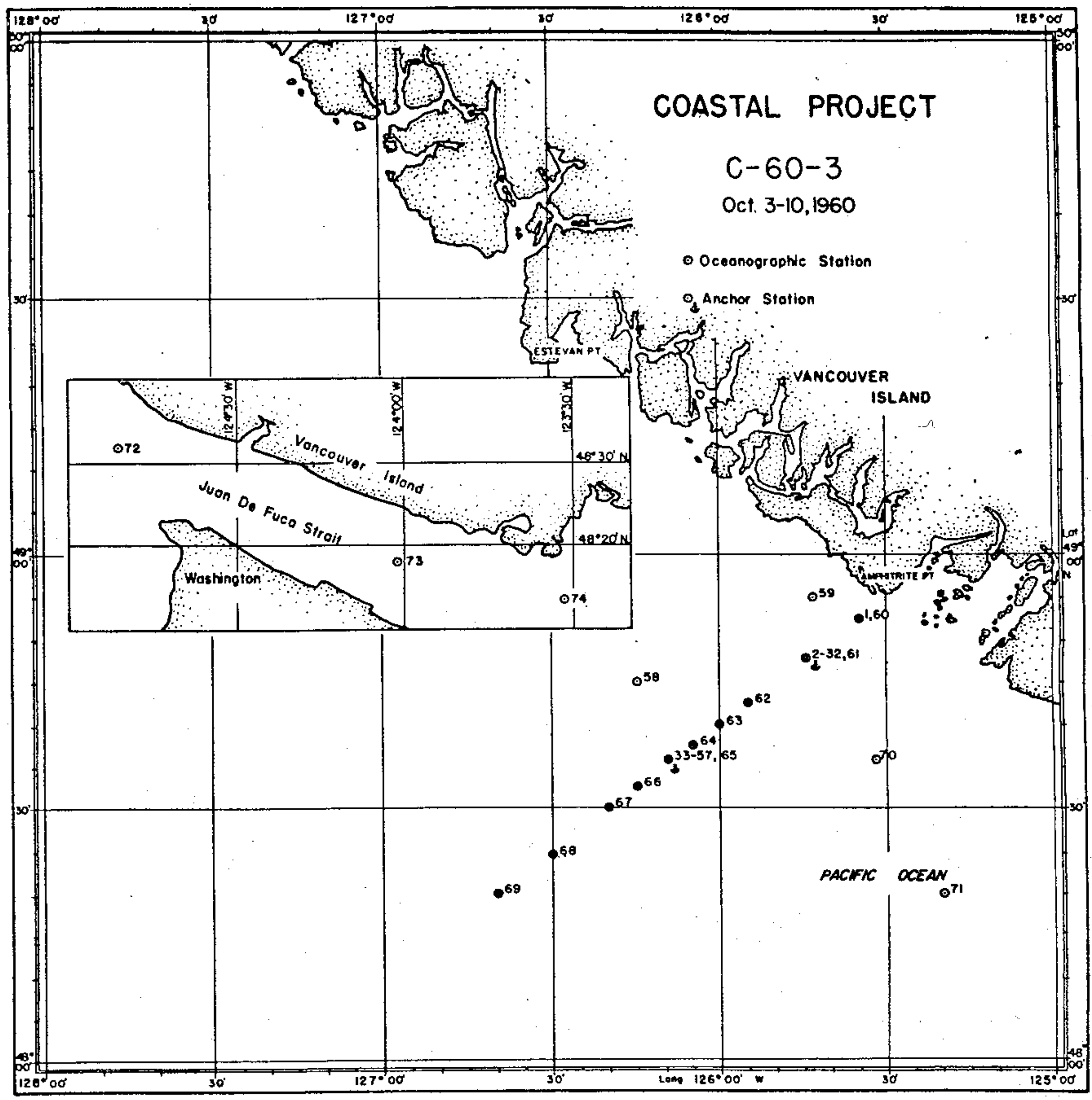

Fig. 65. Coastal project, October 3-10, 1960. Solid circles indicate stations used in the sections.

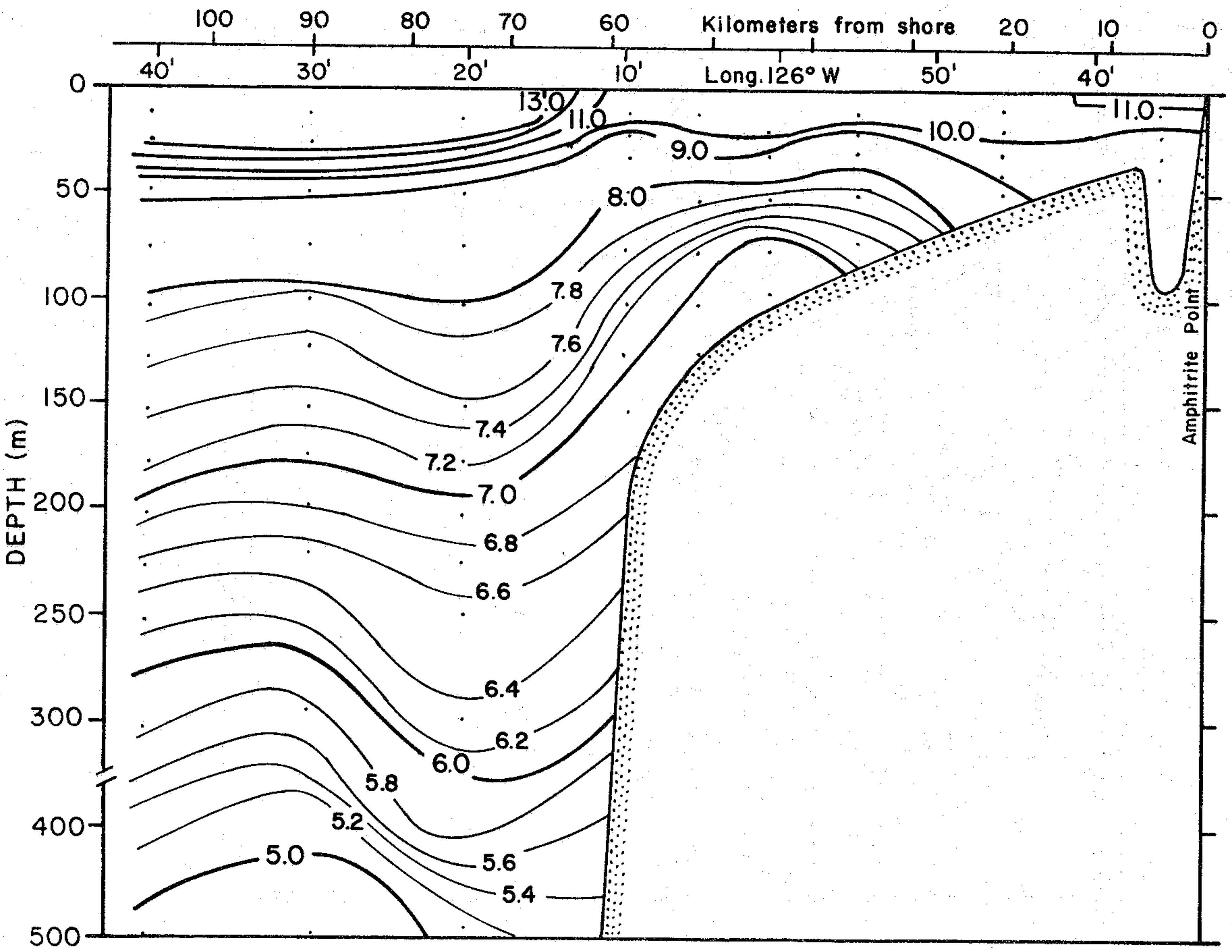

Fig. 66a. Temperature (°C) seaward of Amphitrite Point, October 9-10, 1960.

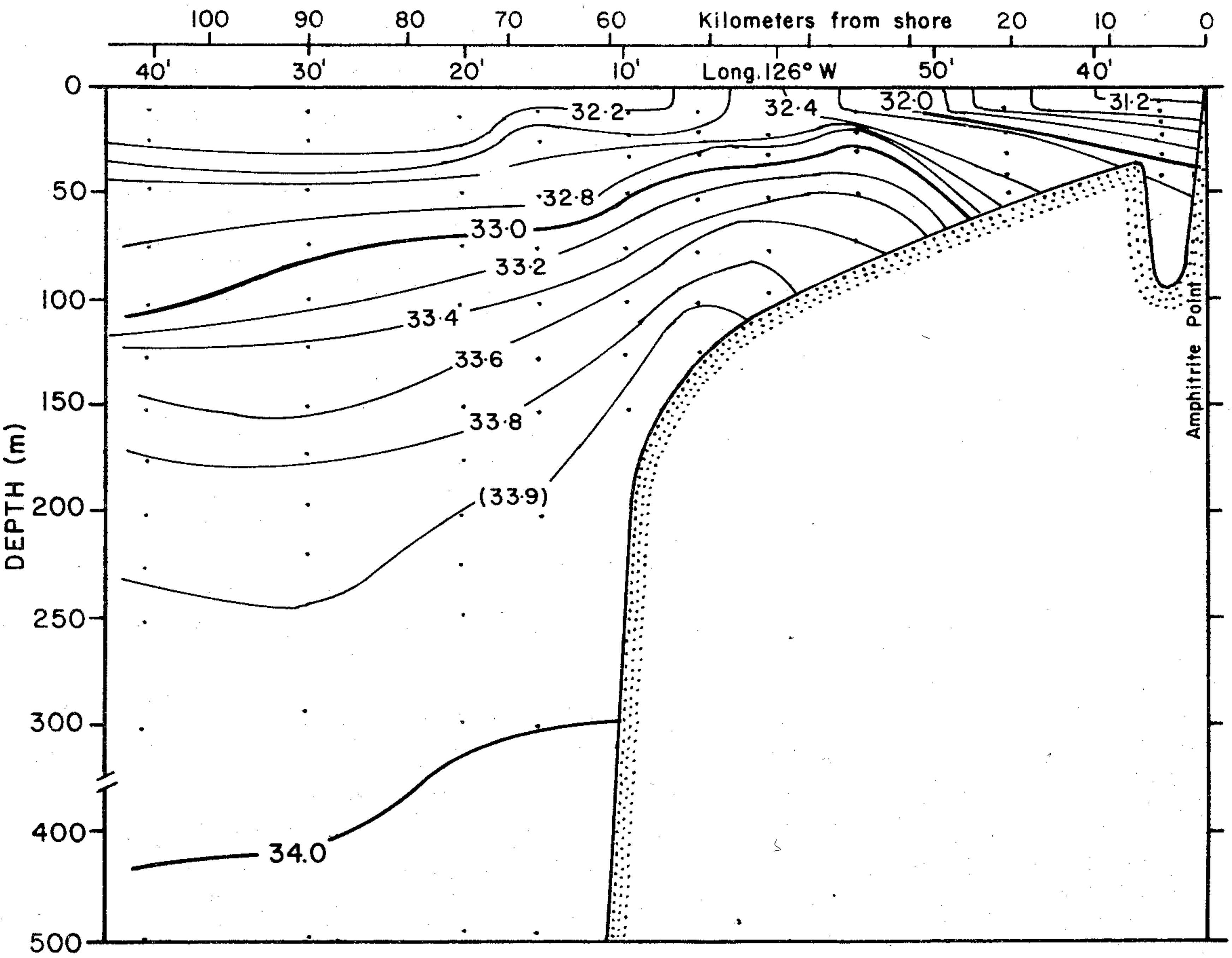

Fig. 66b. Salinity (o/oo) seaward of Amphitrite Point, October 9-10, 1960.

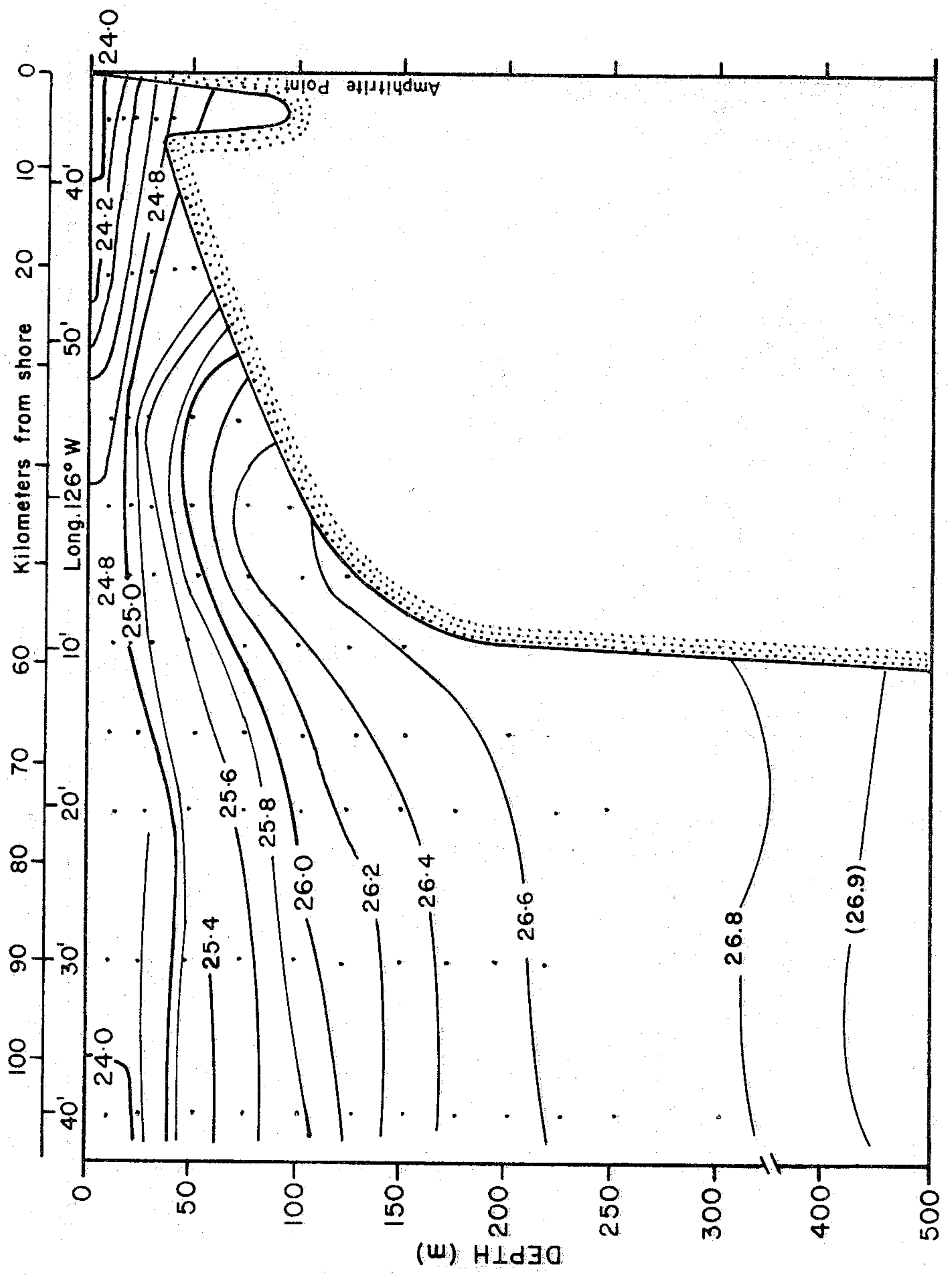

Fig. 66c. Density (σ_t) seaward of Amphitrite Point, October 9-10, 1960.

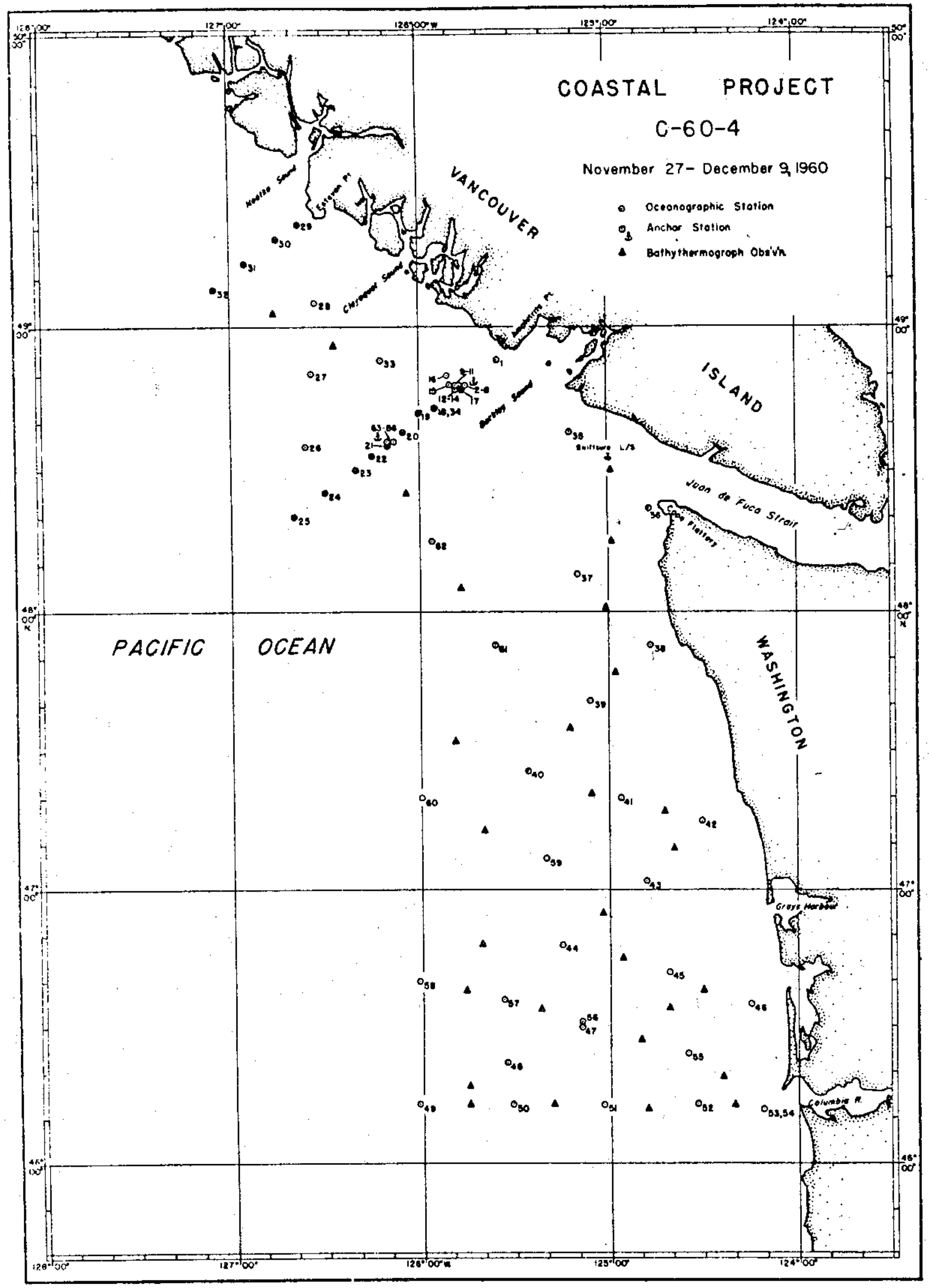

Fig. 67. Coastal project, November 27 - December 9, 1960. Solid circles indicate stations used in the sections.

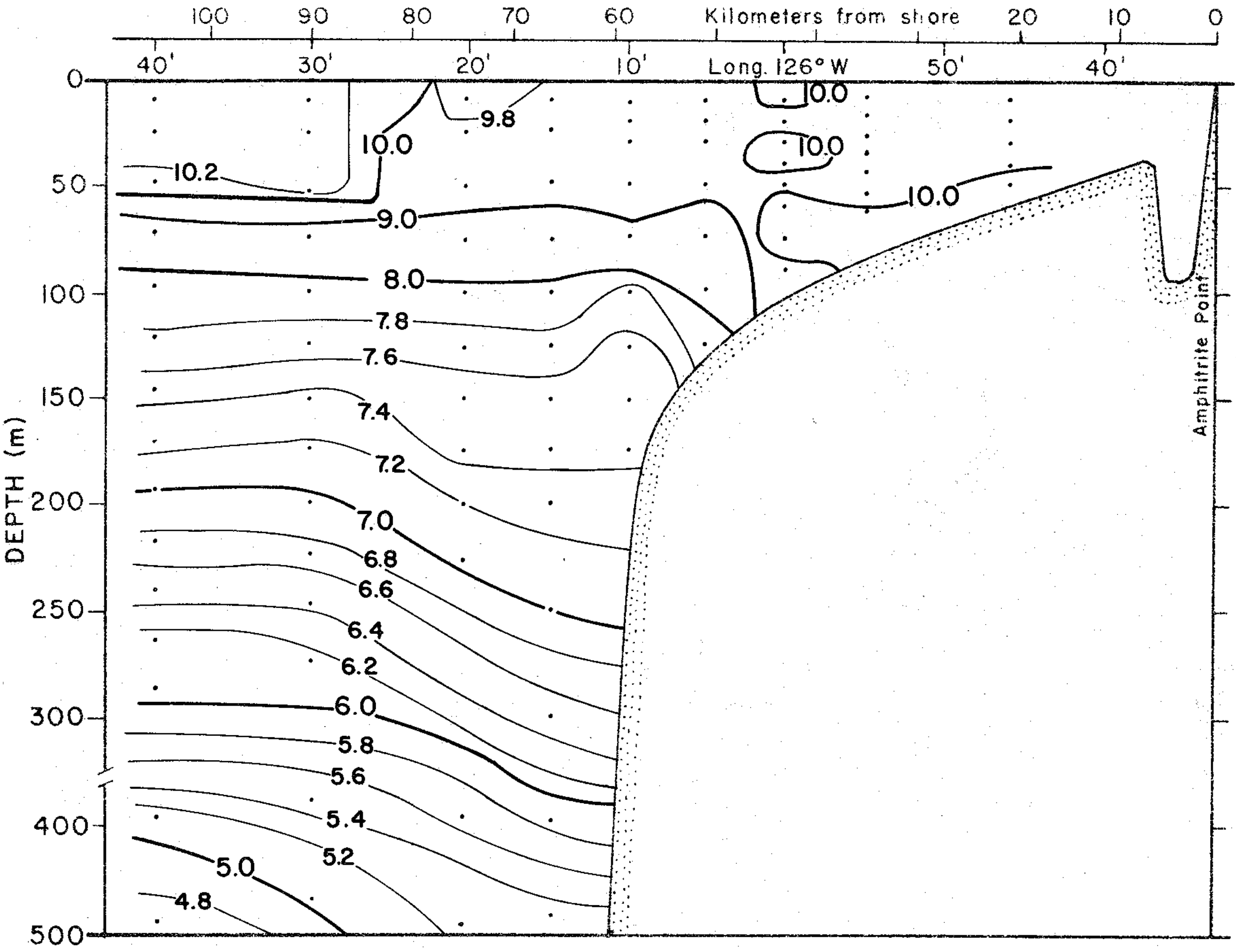

Fig. 68a. Temperature (°C) seaward of Amphitrite Point, December 1, 1960.

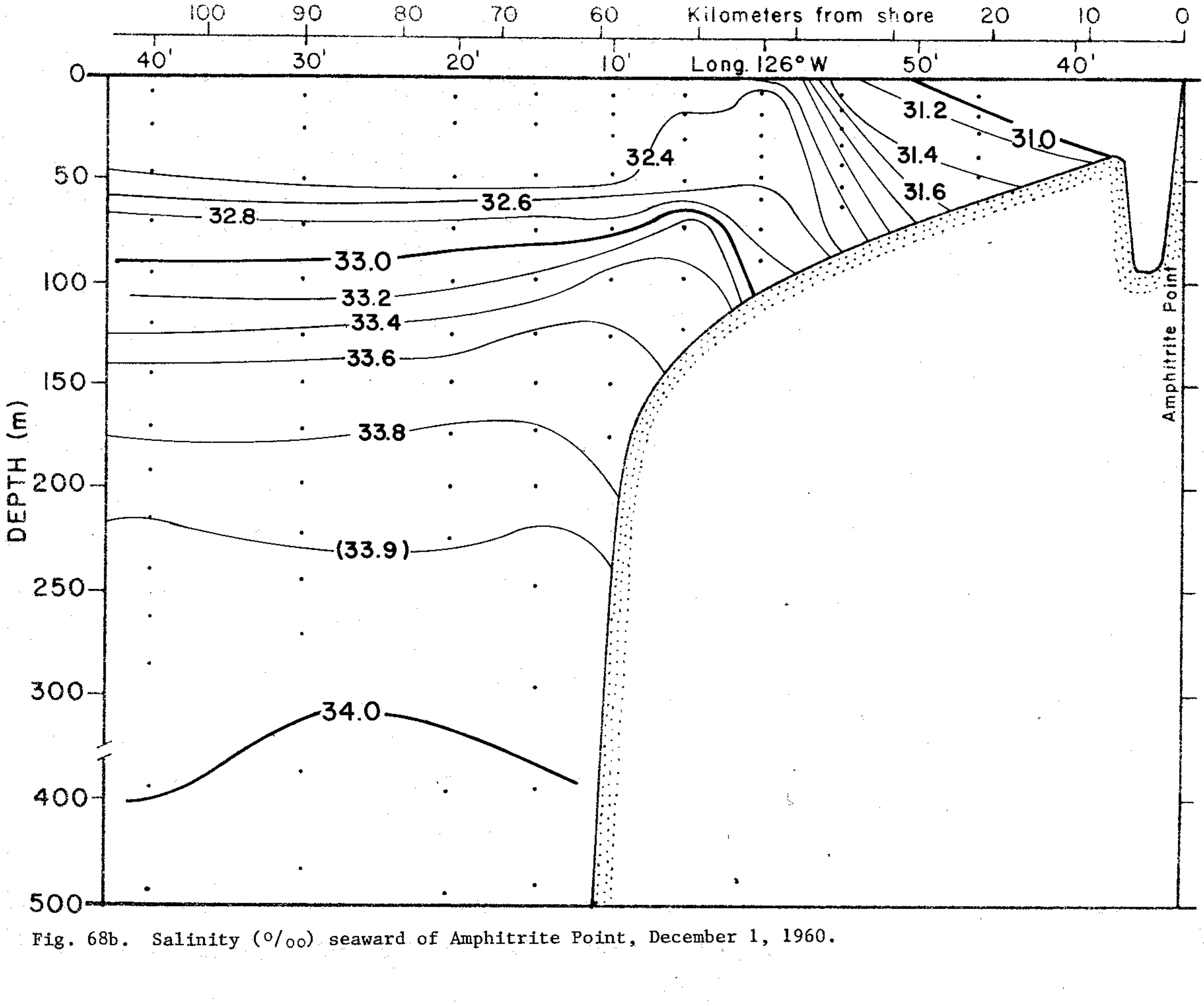

Fig. 68b. Salinity (°/₀₀) seaward of Amphitrite Point, December 1, 1960.

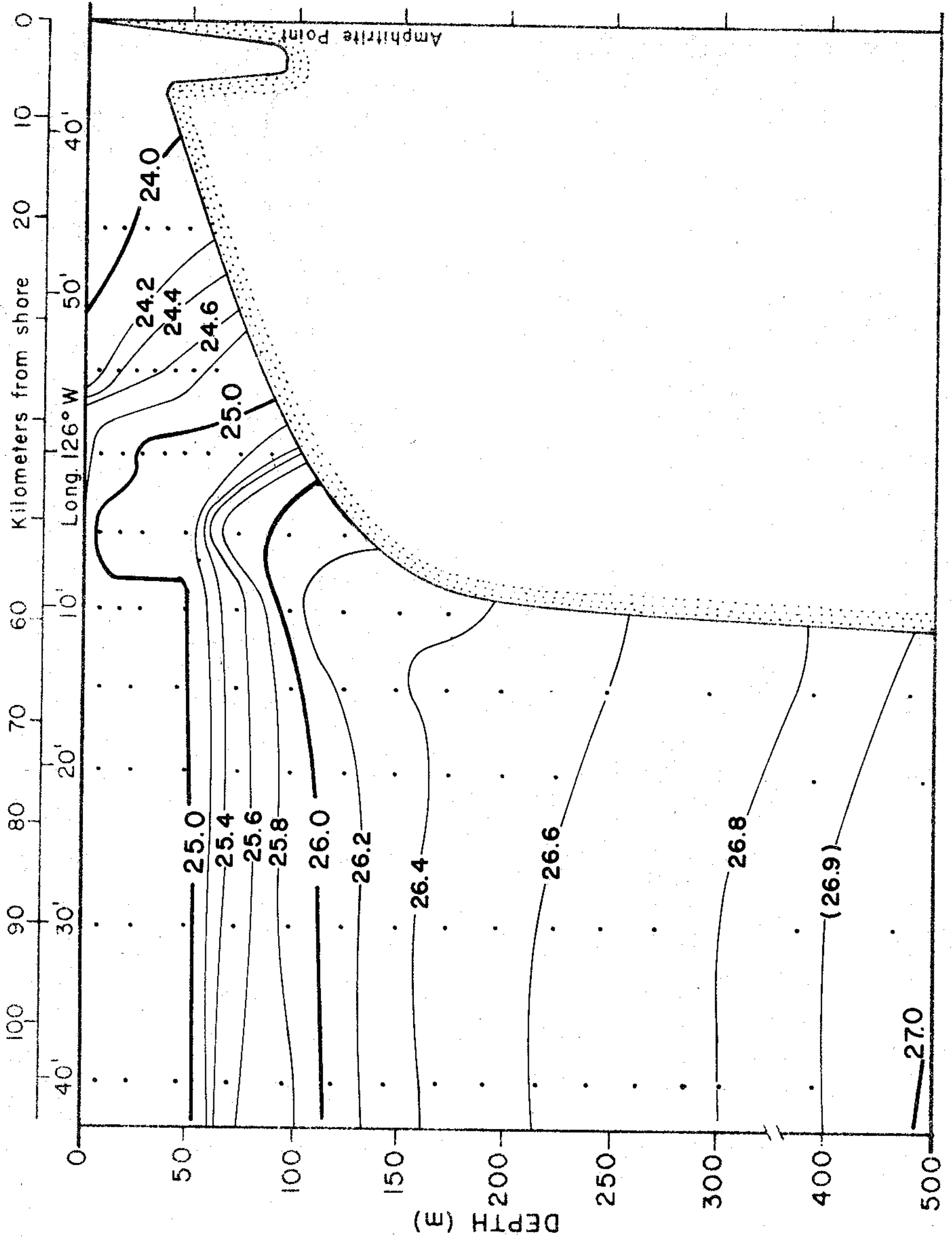

Fig. 68c. Density (σ_t) seaward of Amphitrite Point, December 1, 1960.

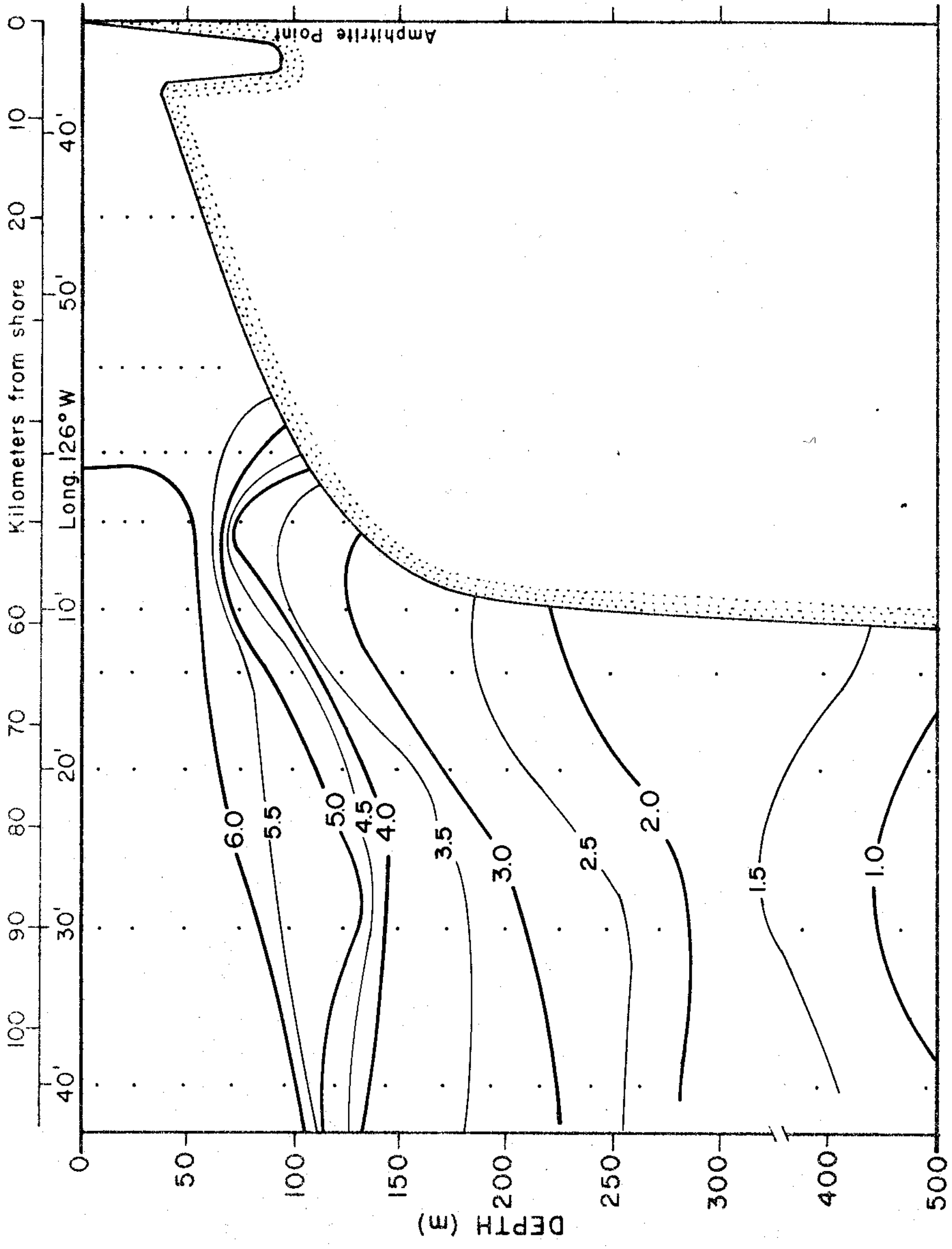

Fig. 68d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, December 1, 1960.

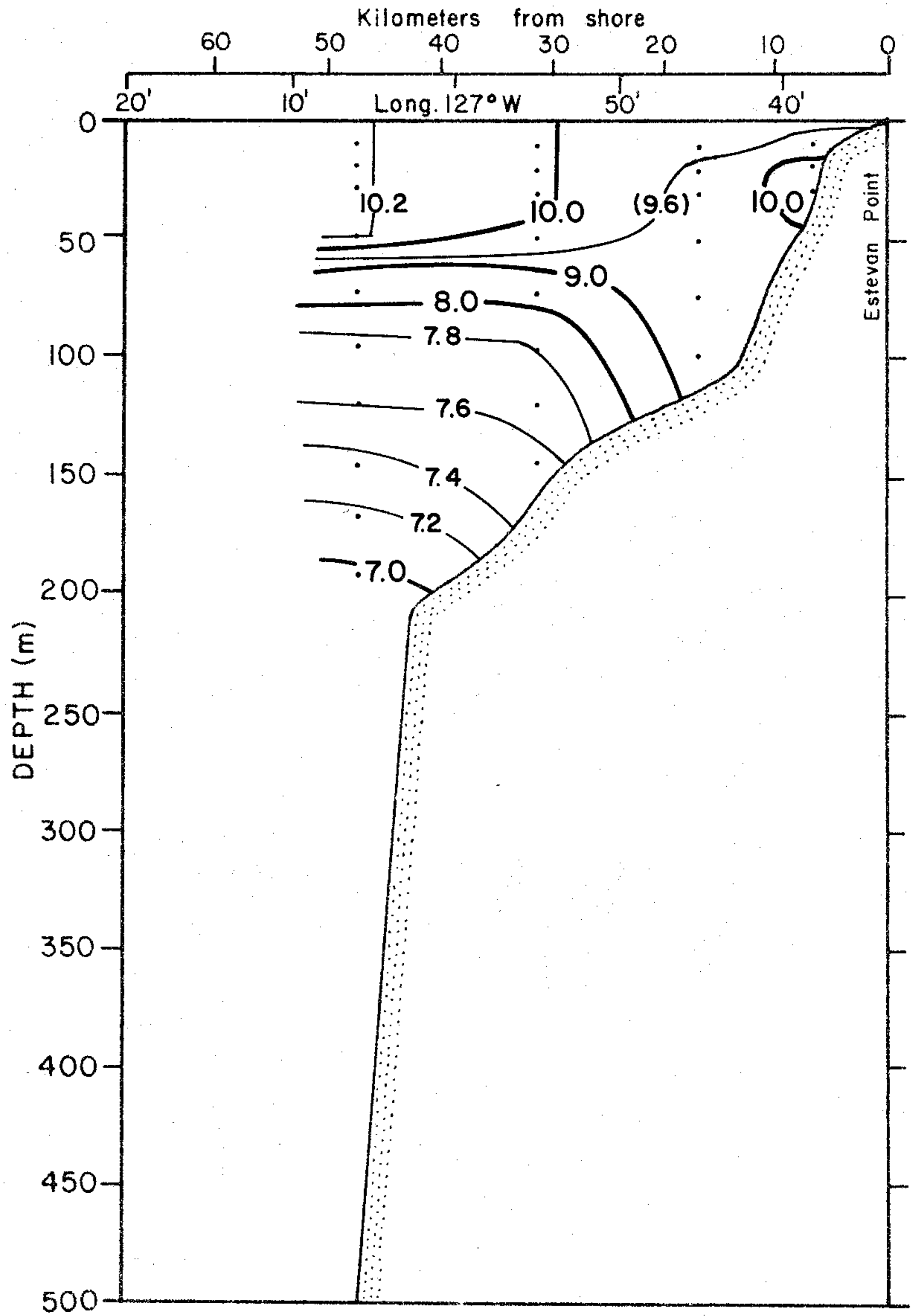

Fig. 69a. Temperature (°C) seaward of Estevan Point, December 2, 1960.

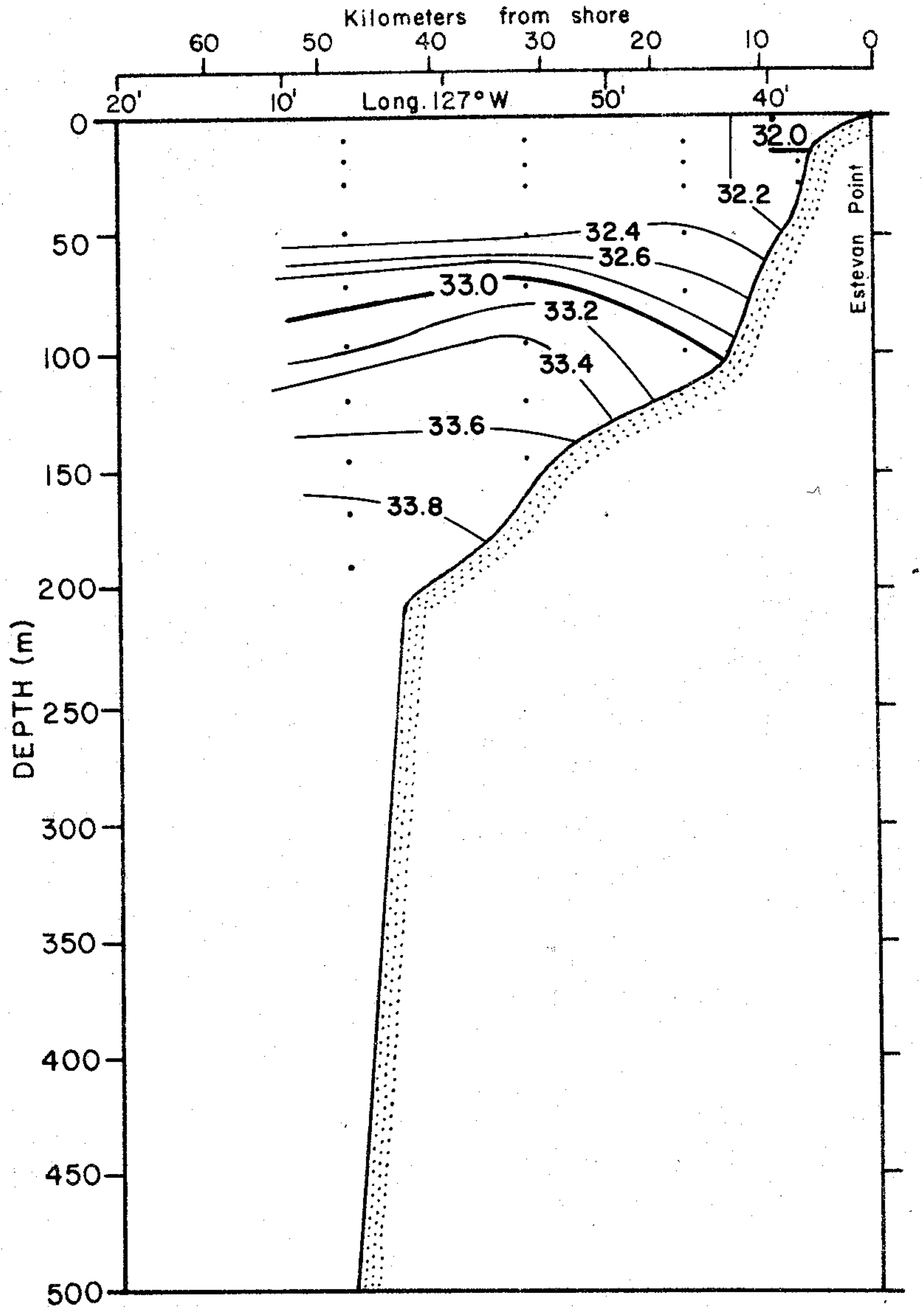

Fig. 69b. Salinity (°/oo) seaward of Estevan Point, December 2, 1960.

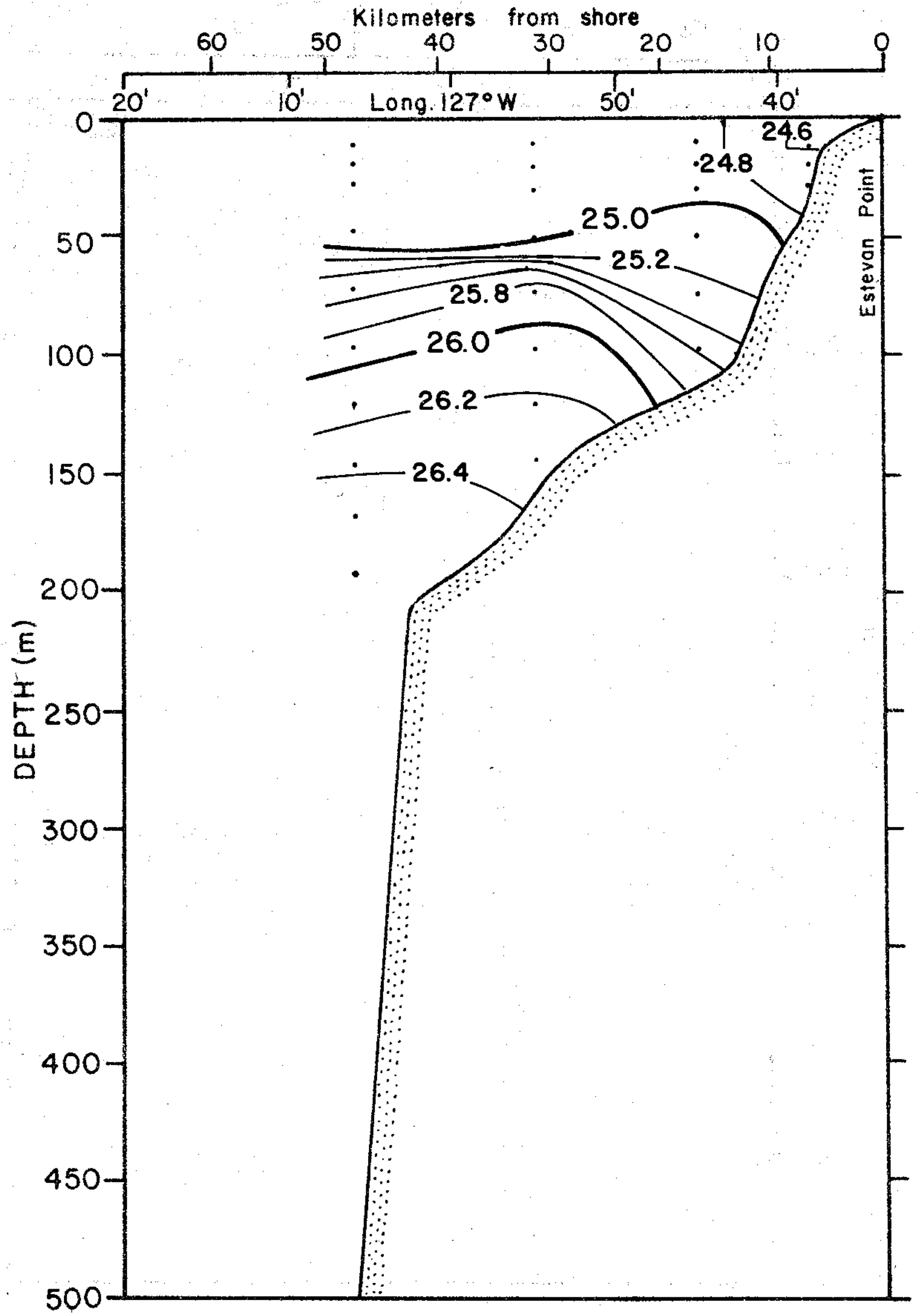

Fig. 69c. Density (σ_t) seaward of Estevan Point, December 2, 1960.

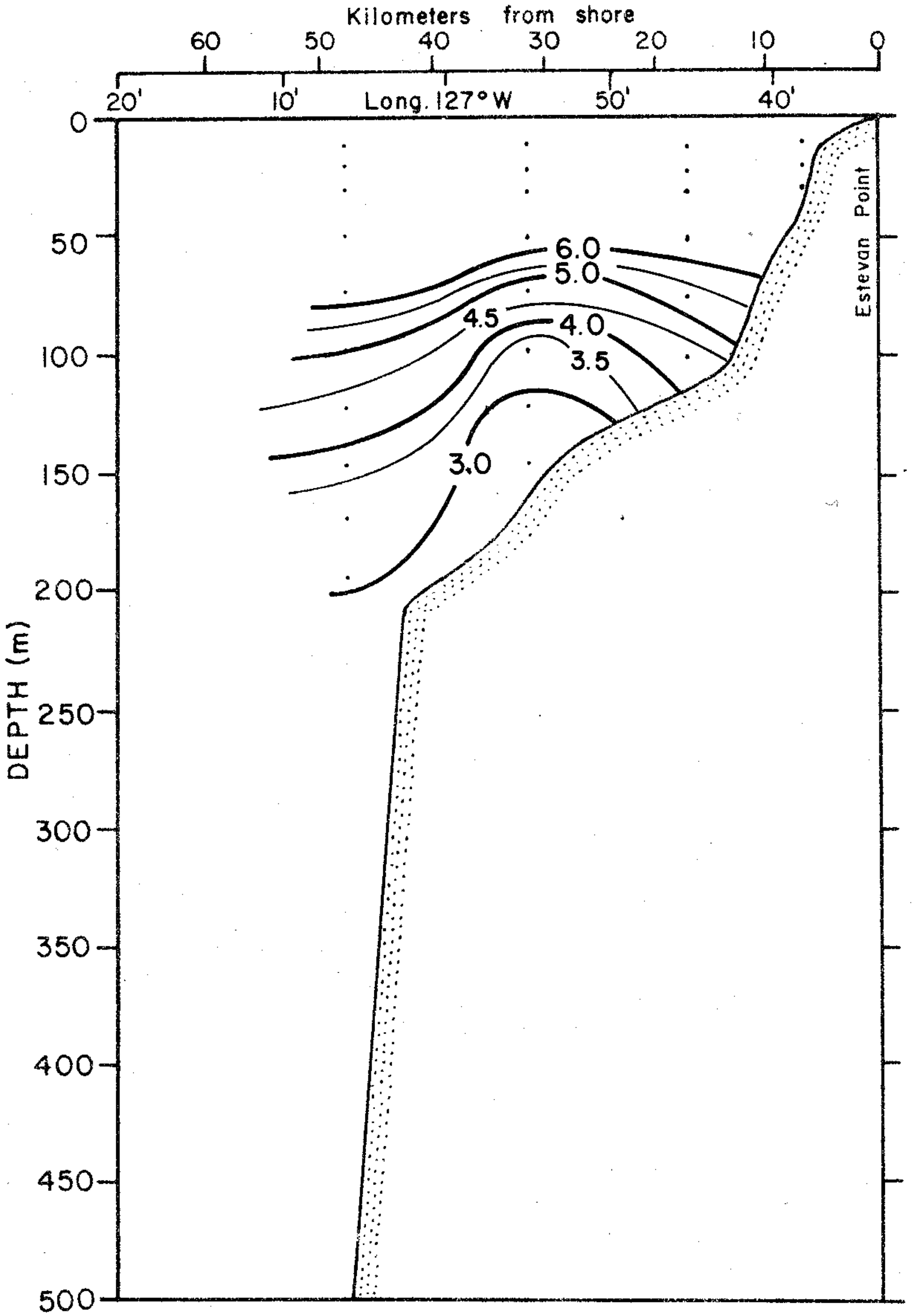

Fig. 69d. Dissolved oxygen (mL/L) seaward of Estevan Point, December 2, 1960.

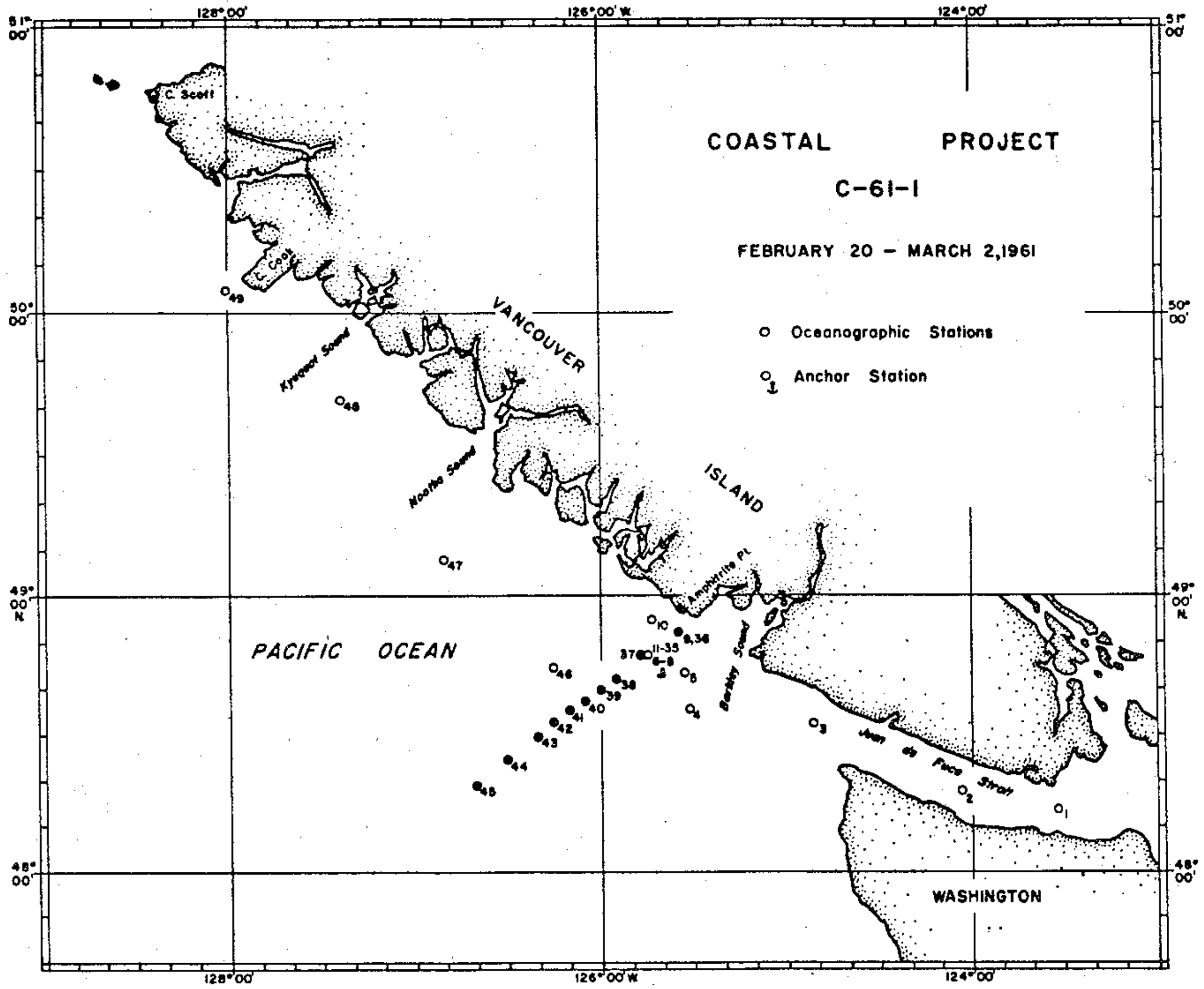

Fig. 70. Coastal project, February 20 - March 2, 1961. Solid circles indicate stations used in the sections.

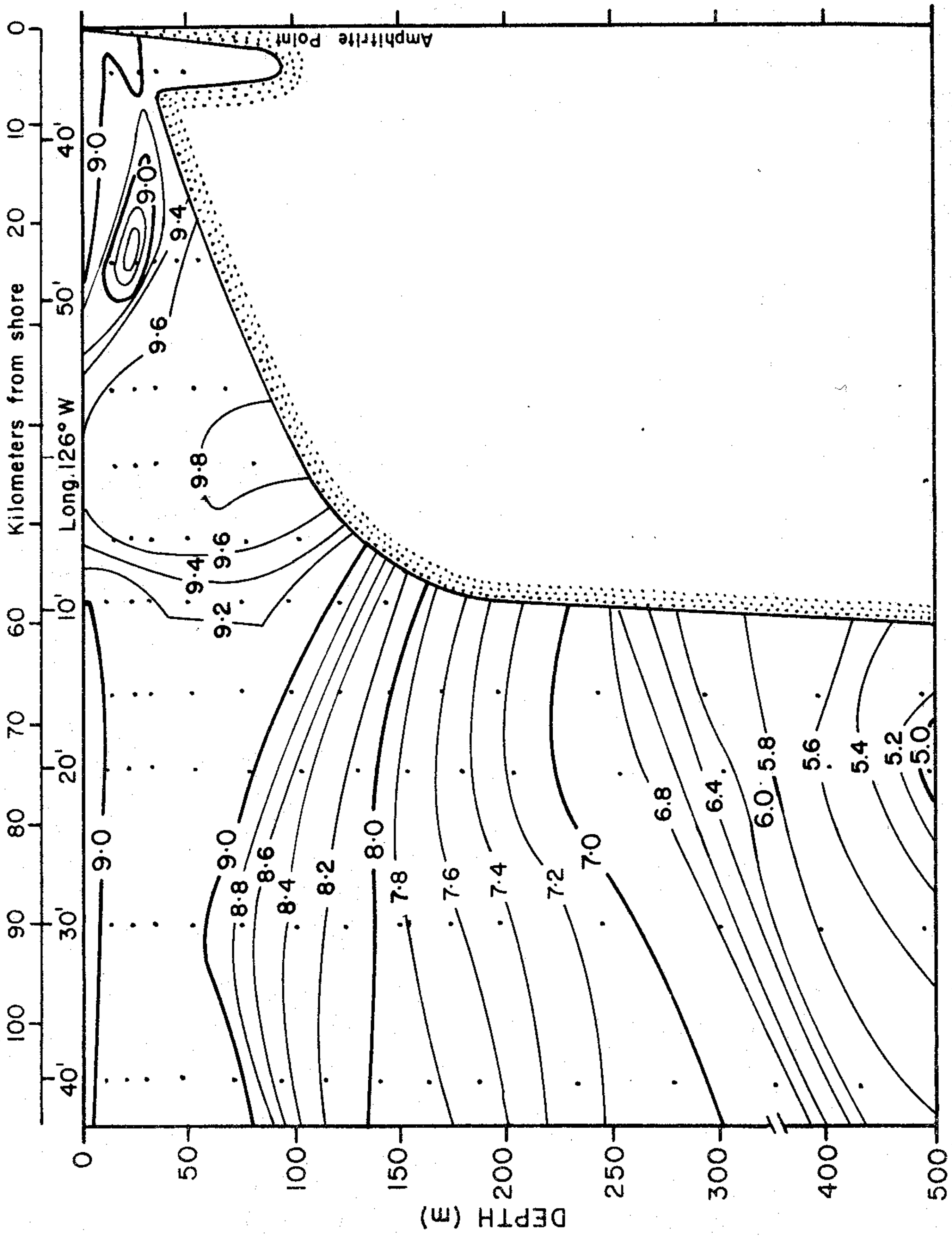

Fig. 71a. Temperature (°C) seaward of Amphitrite Point, February 26-27, 1961.

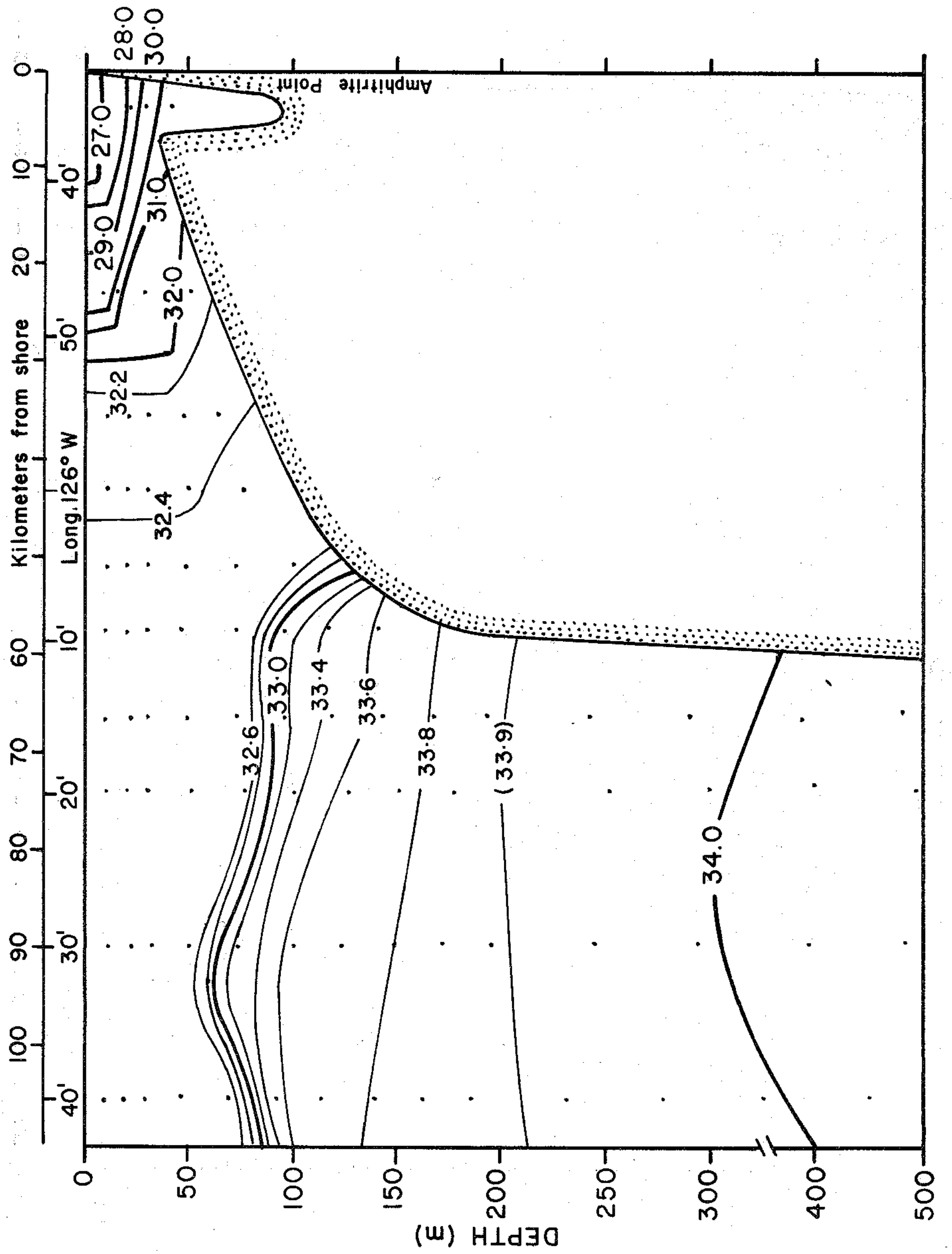

Fig. 71b. Salinity (°/oo) seaward of Amphitrite Point, February 26-27, 1961.

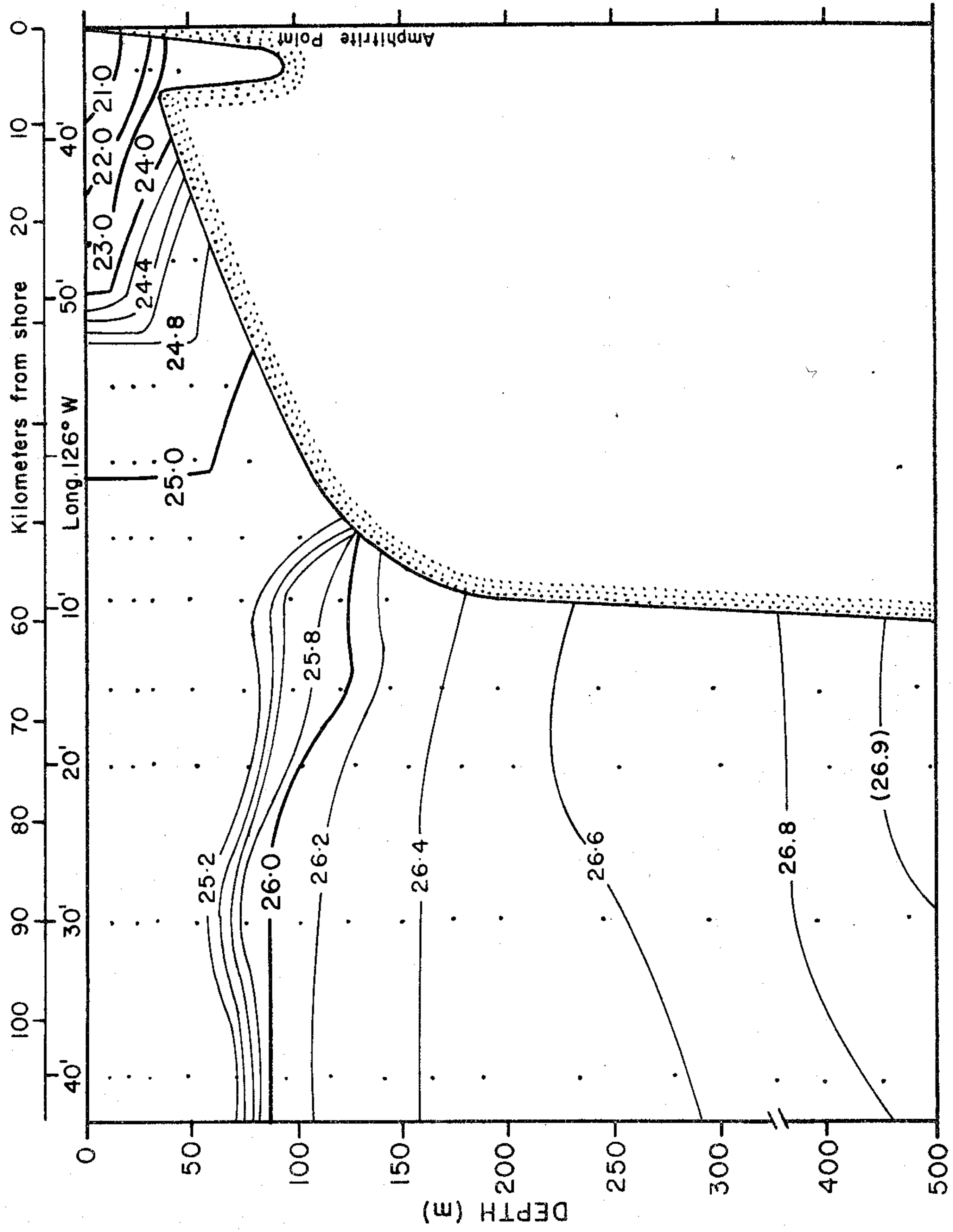

Fig. 71c. Density (σt) seaward of Amphitrite Point, February 26-27, 1961.

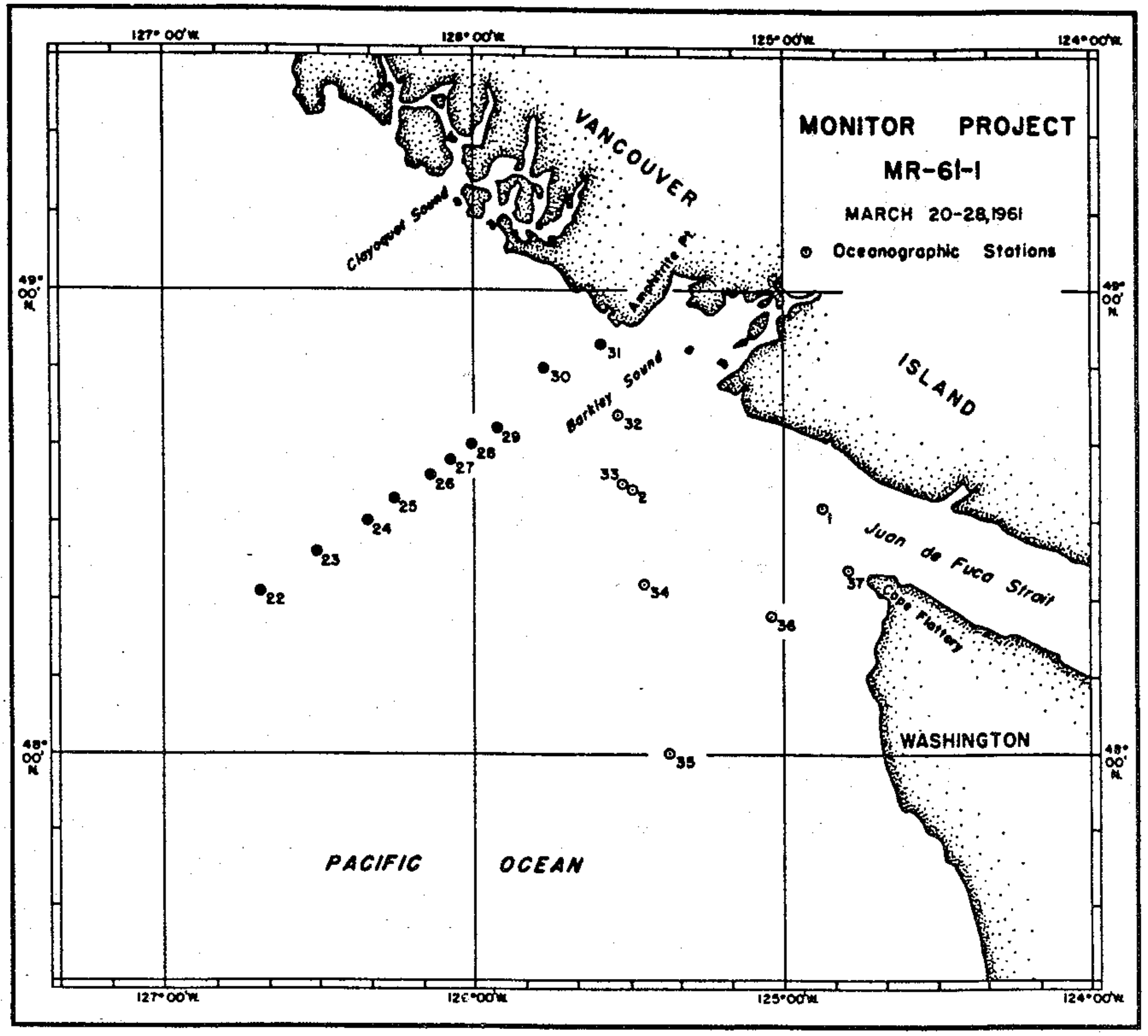

Fig. 72. Monitor project, March 20-28, 1961. Solid circles indicate stations used in the sections.

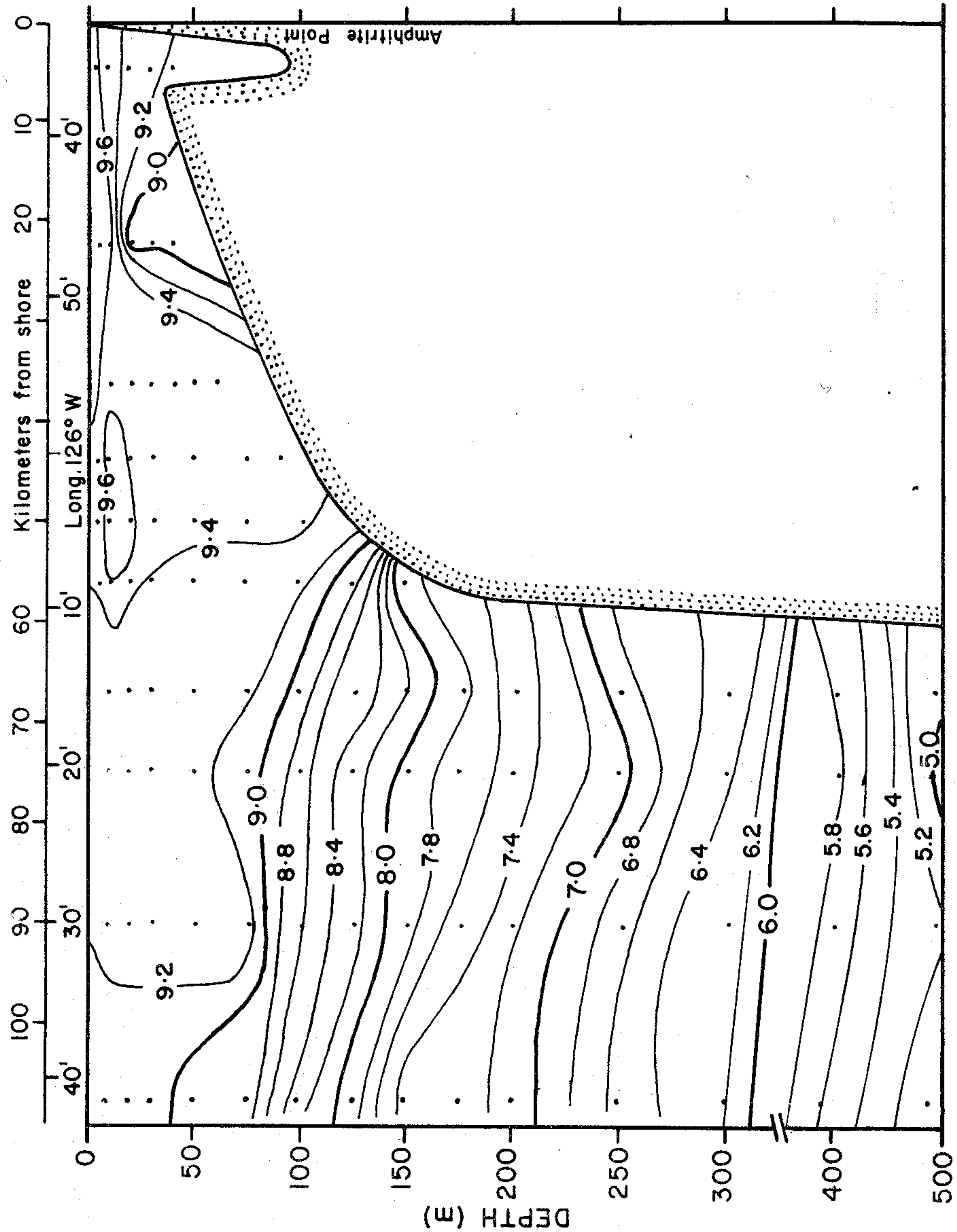

Fig. 73a. Temperature (°C) seaward of Amphitrite Point, March 27-28, 1961.

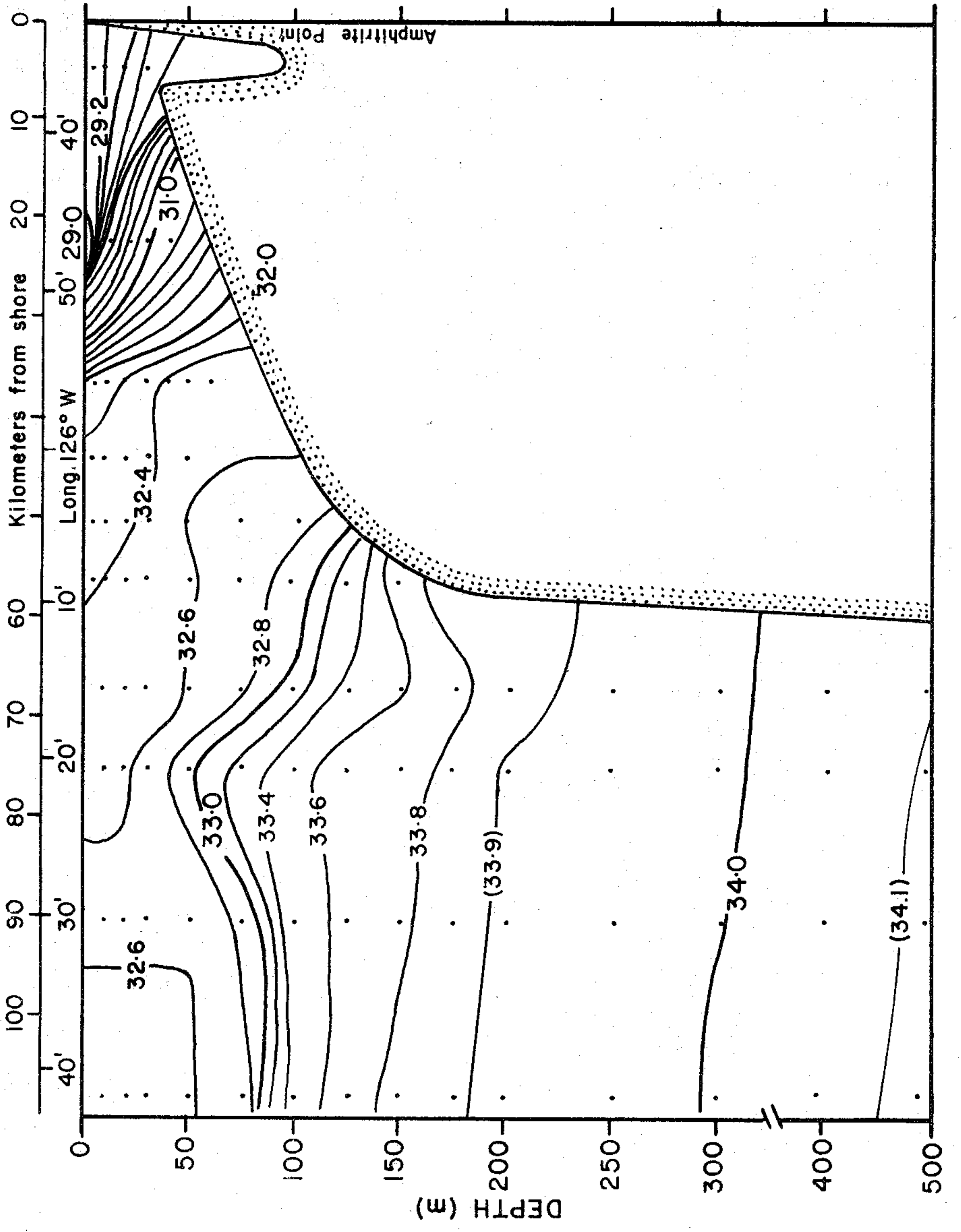

Fig. 73b. Salinity ($^{0}/_{00}$) seaward of Amphitrite Point, March 27-28, 1961.

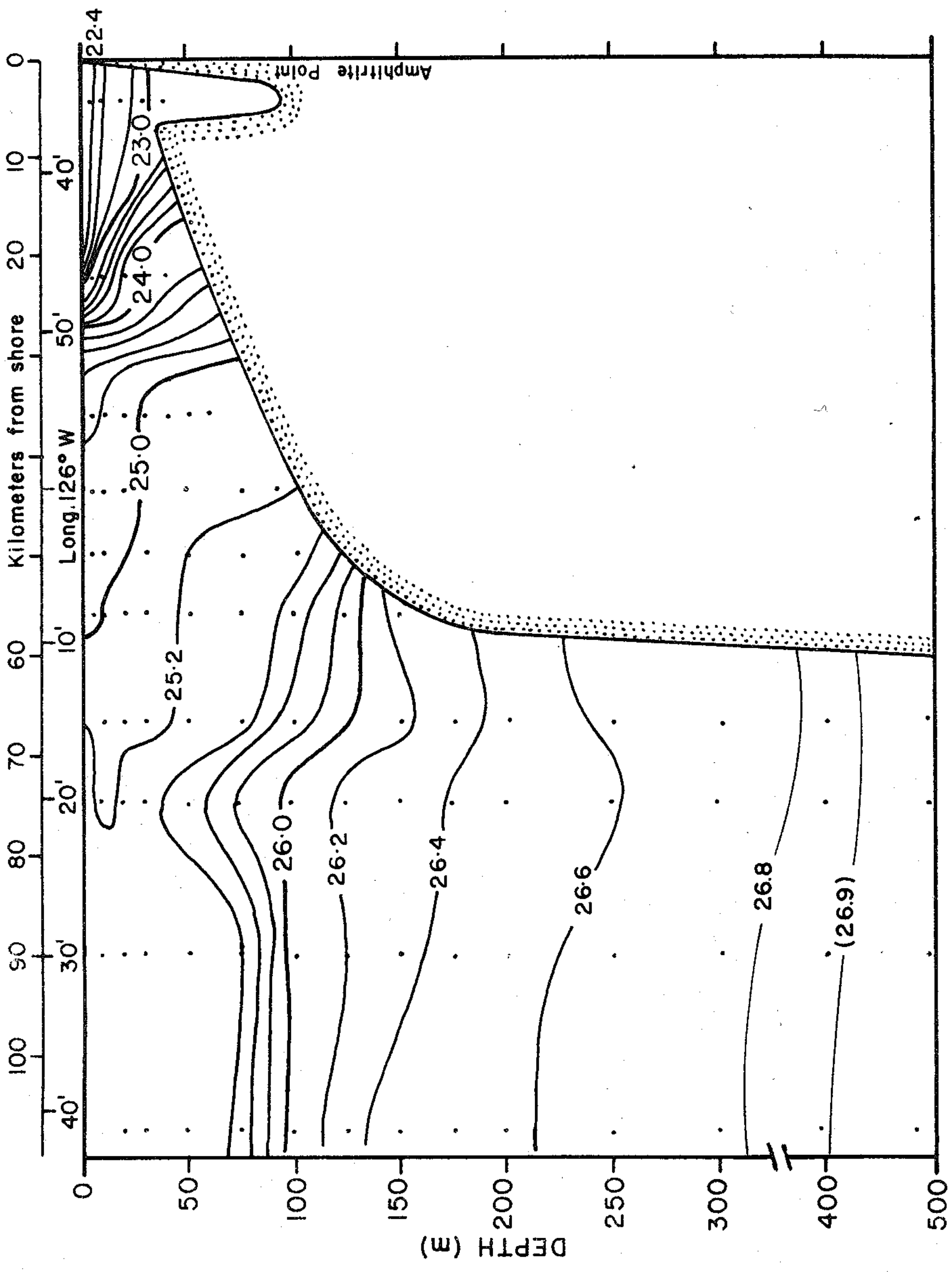

Fig. 73c. Density (σ_t) seaward of Amphitrite Point, March 27-28, 1961.

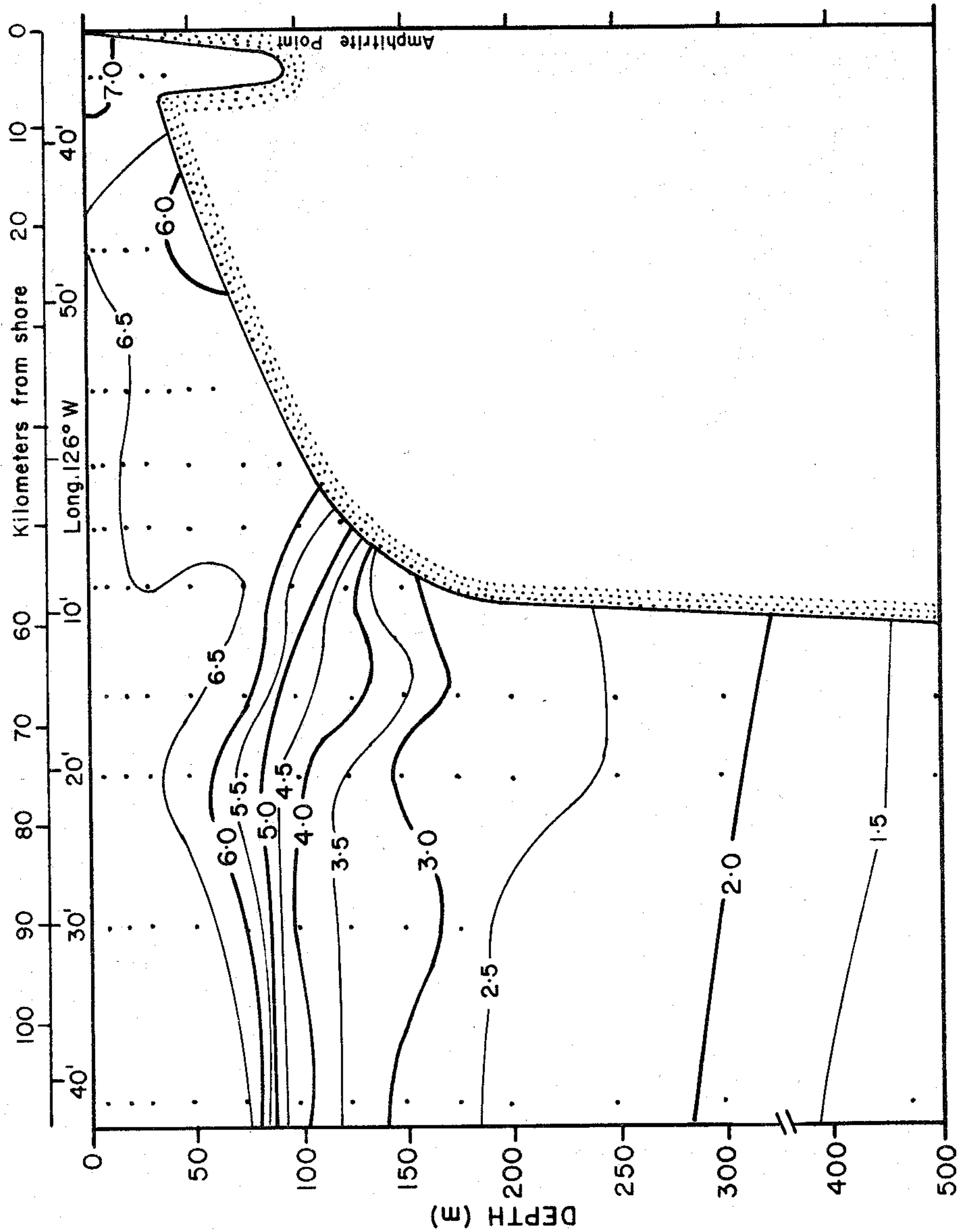

Fig. 73d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, March 27-28, 1961.

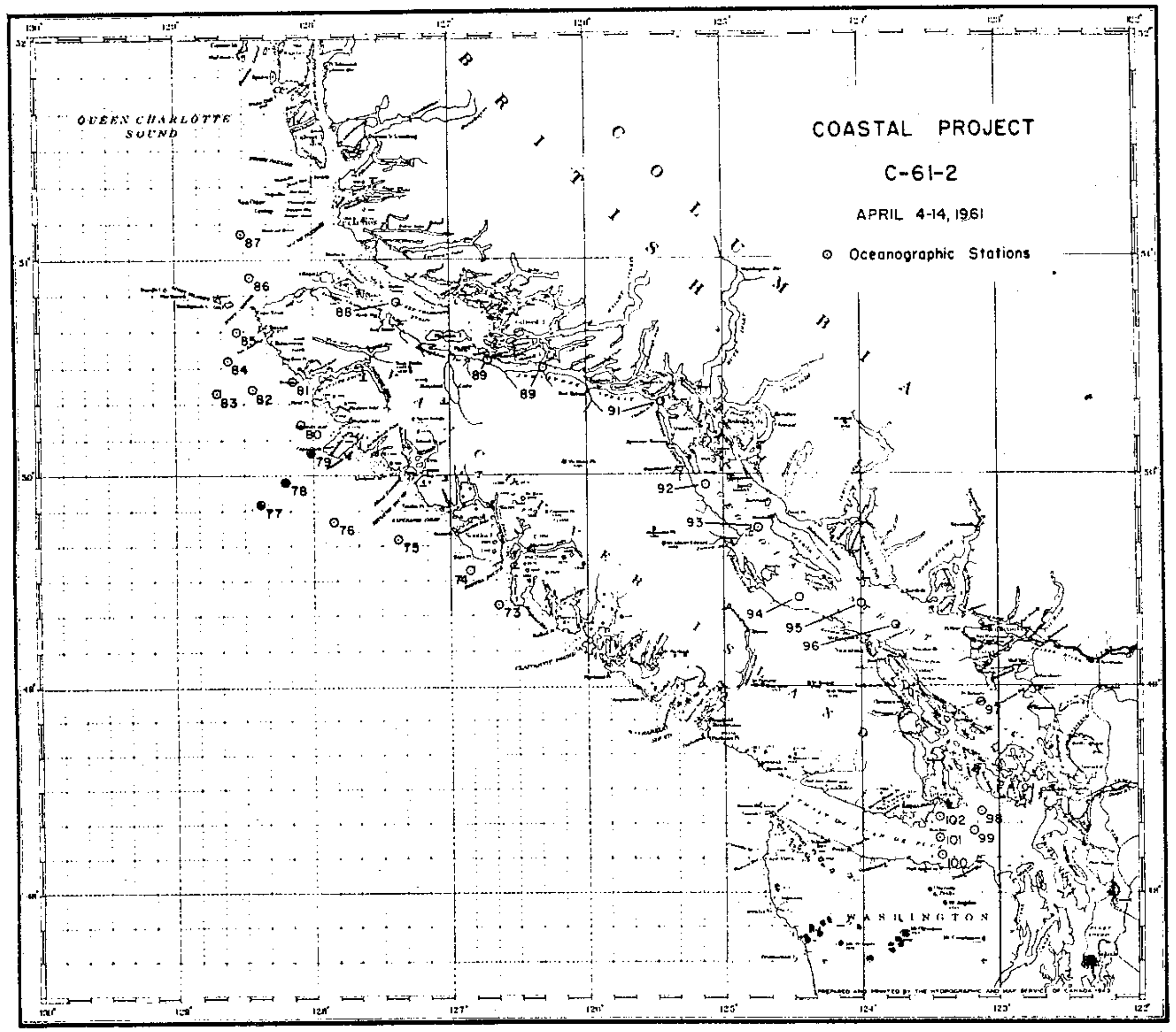

Fig. 74. Coastal project, April 4-14, 1961. Solid circles indicate stations used in the sections.

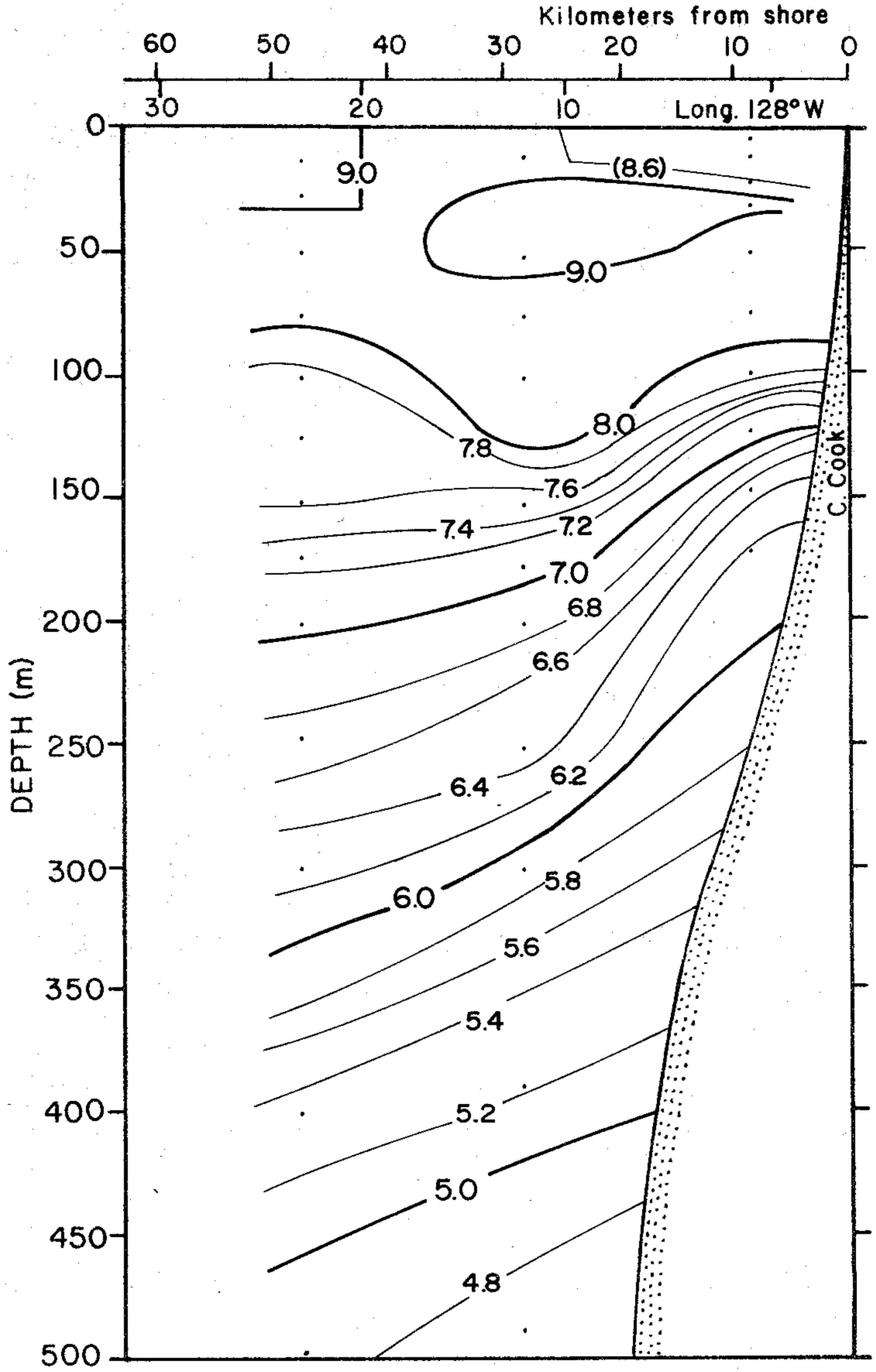

Fig. 75a. Temperature (°C) seaward of Cape Cook, April 11, 1961.

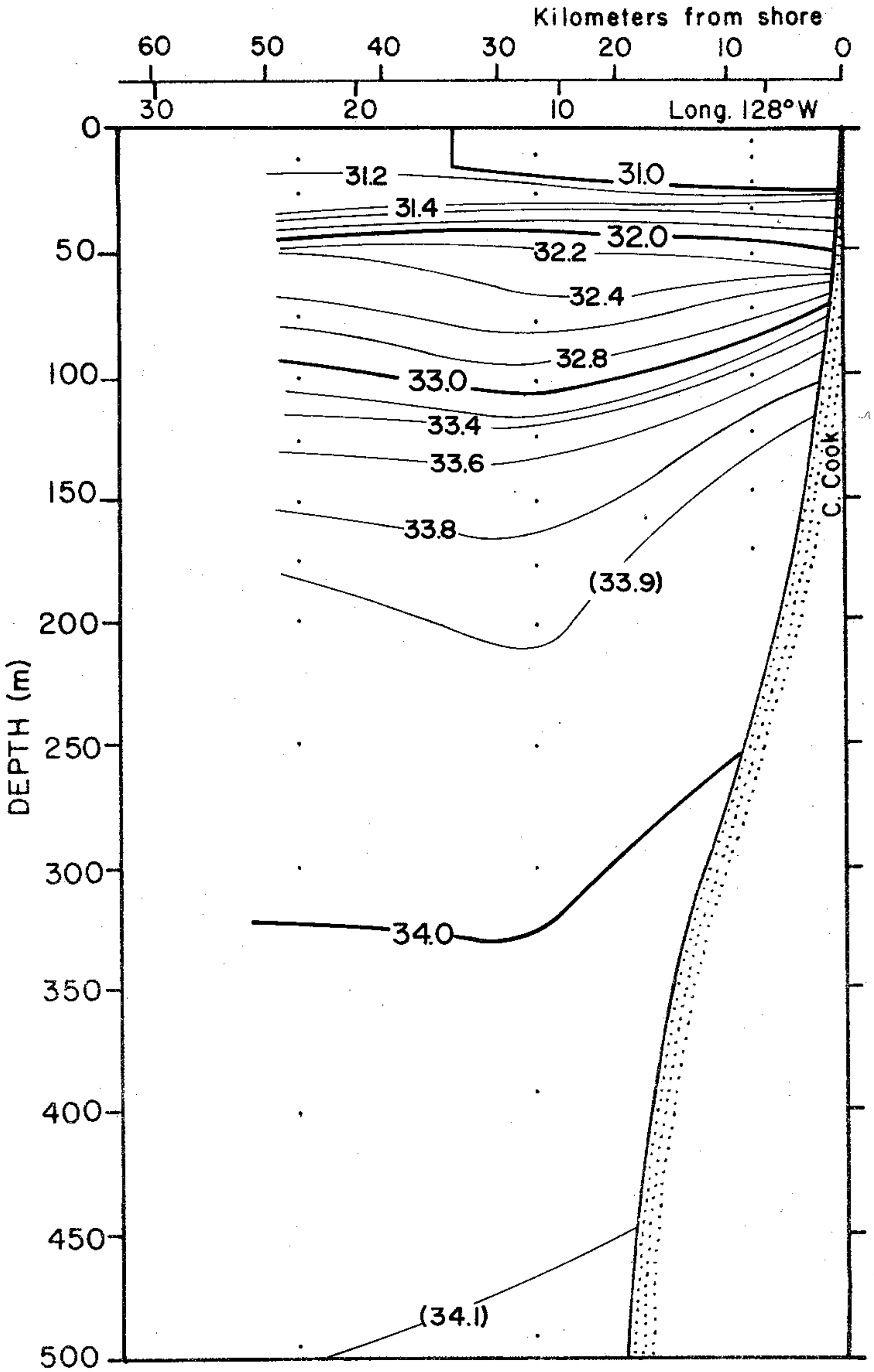

Fig. 75b. Salinity (°/oo) seaward of Cape Cook, April 11, 1961.

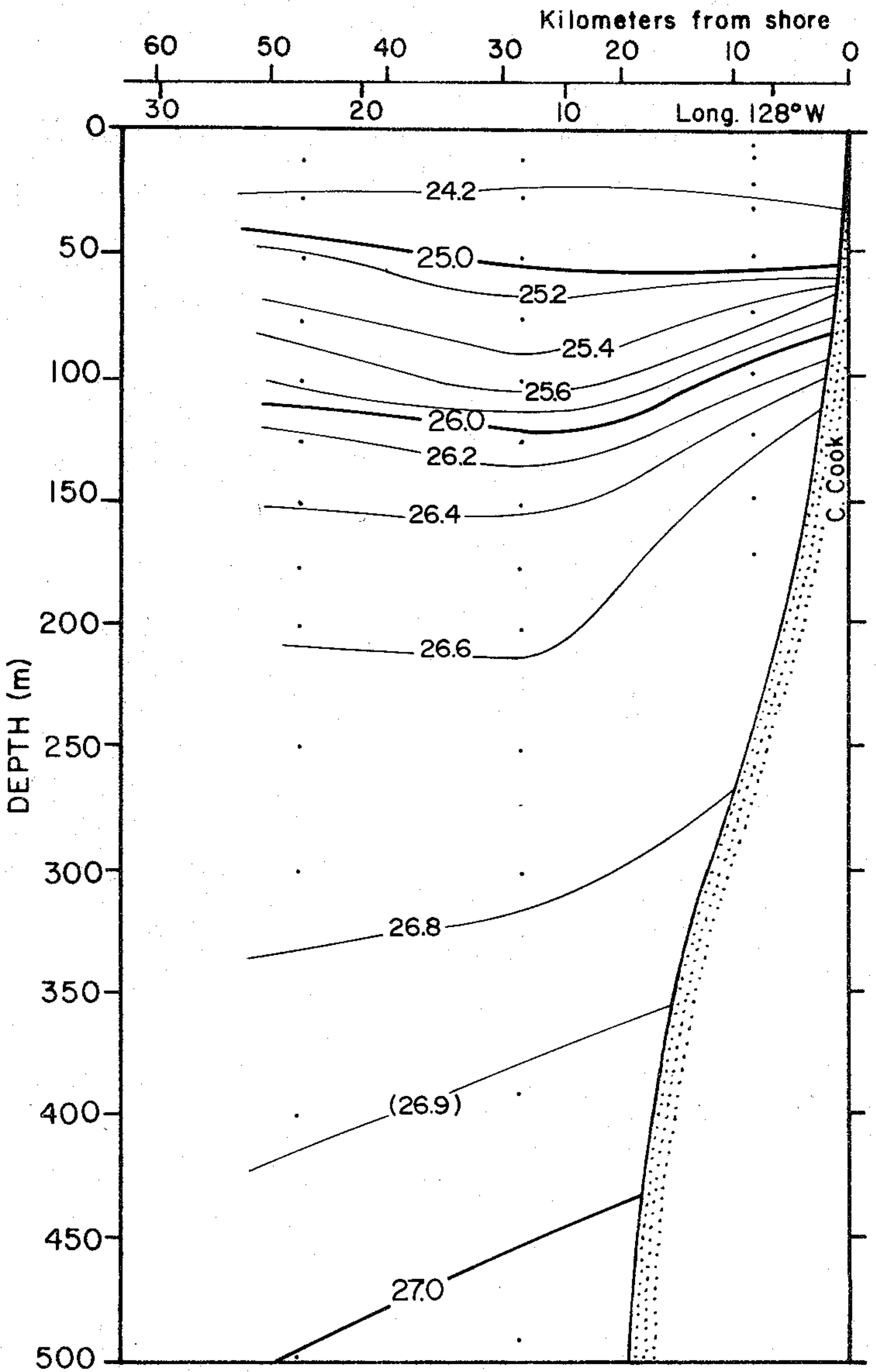

Fig. 75c. Density (σ_t) seaward of Cape Cook, April 11, 1961.

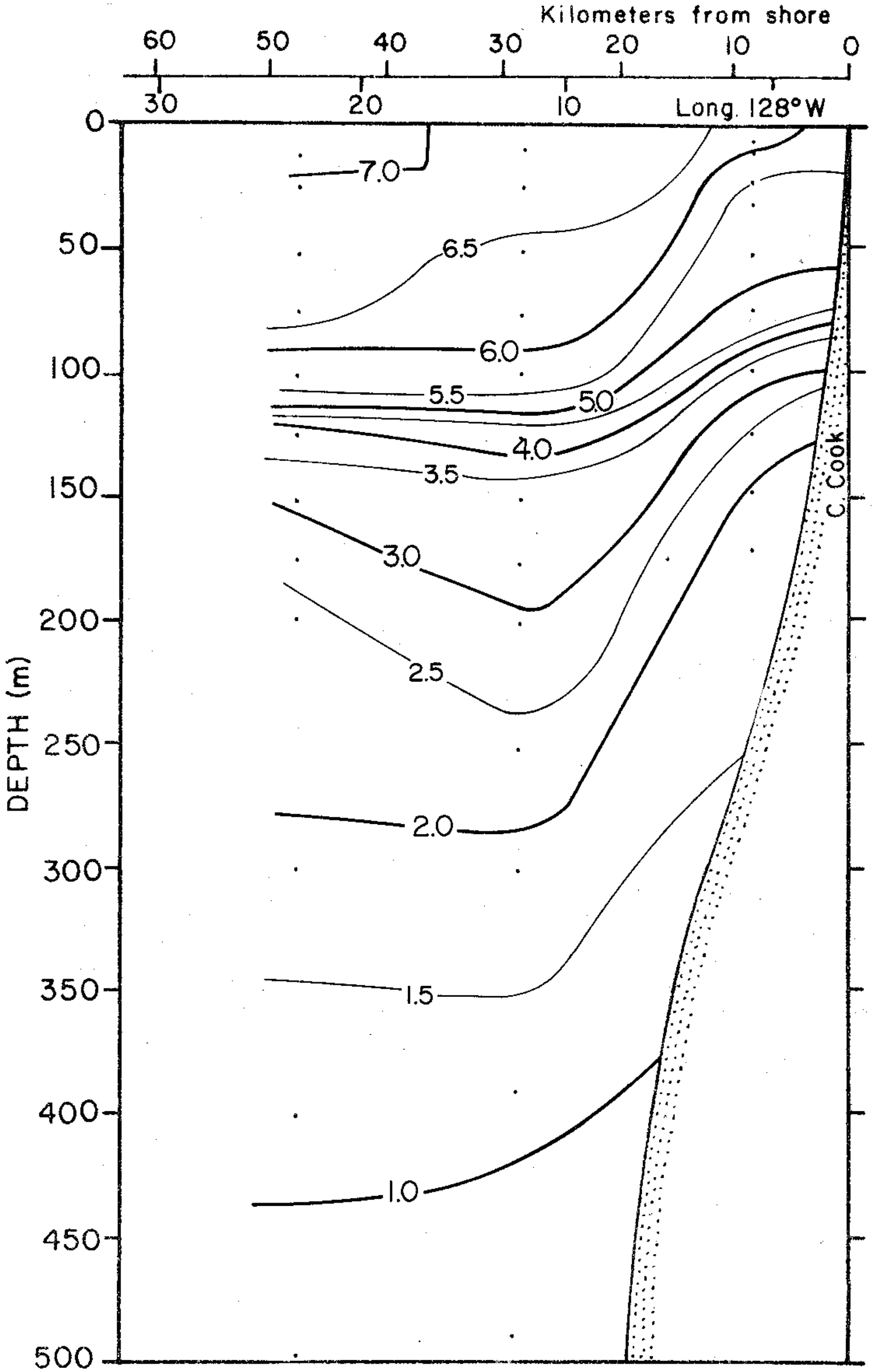

Fig. 75d. Dissolved oxygen (mL/L) seaward of Cape Cook, April 11, 1961.

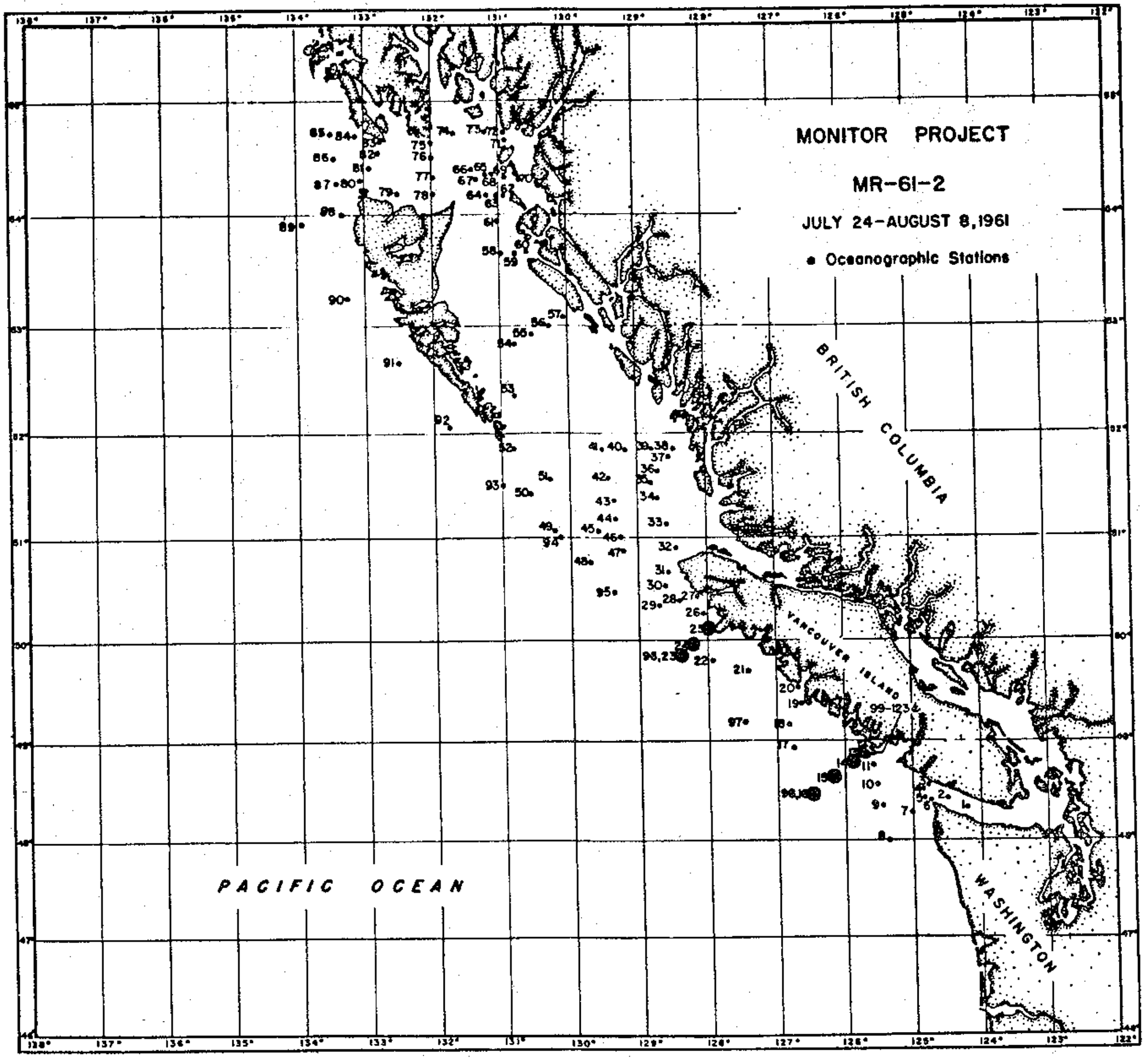

Fig. 76. Monitor project, July 24 - August 8, 1961. Large solid circles indicate stations used in the sections.

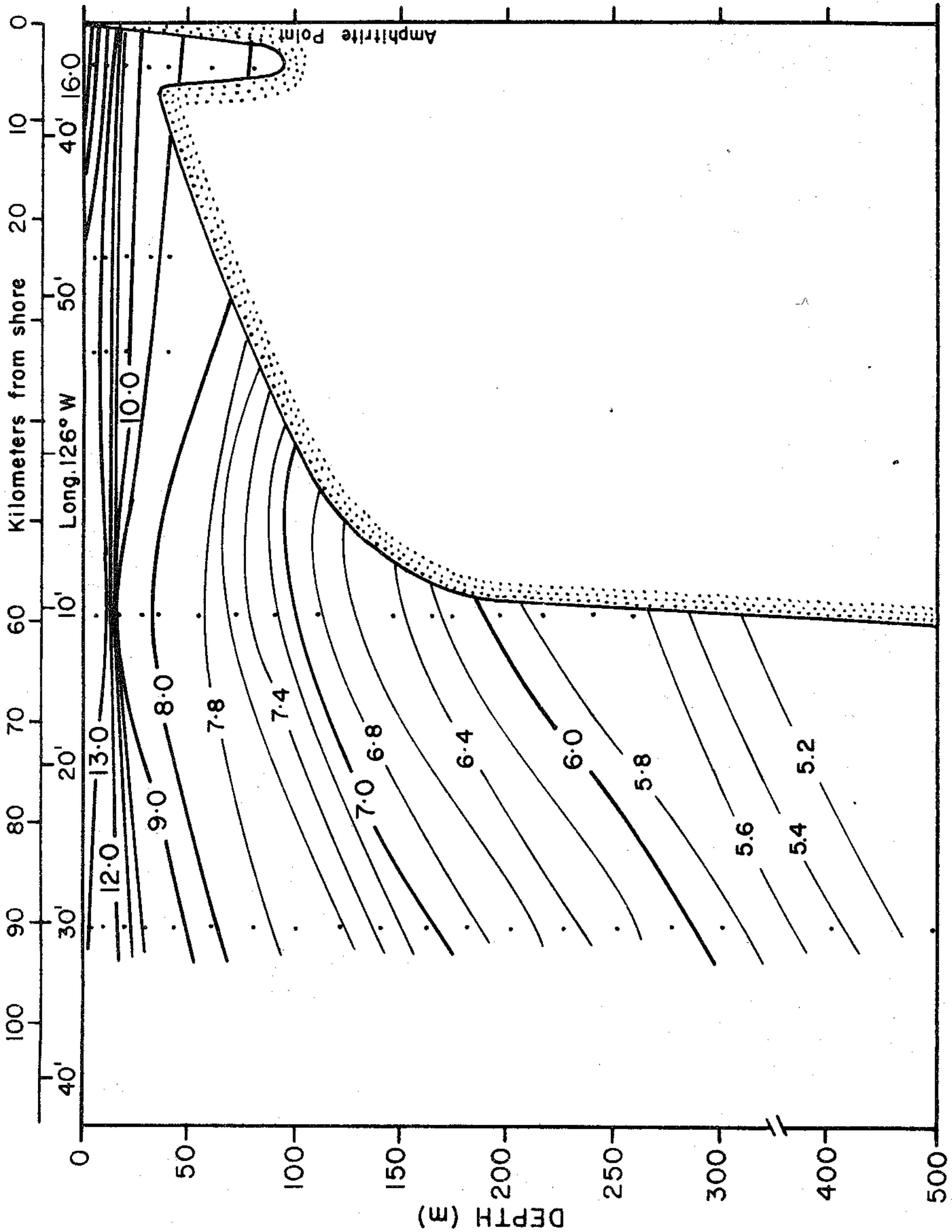

Fig. 77a. Temperature (°C) seaward of Amphitrite Point, July 25, 1961.

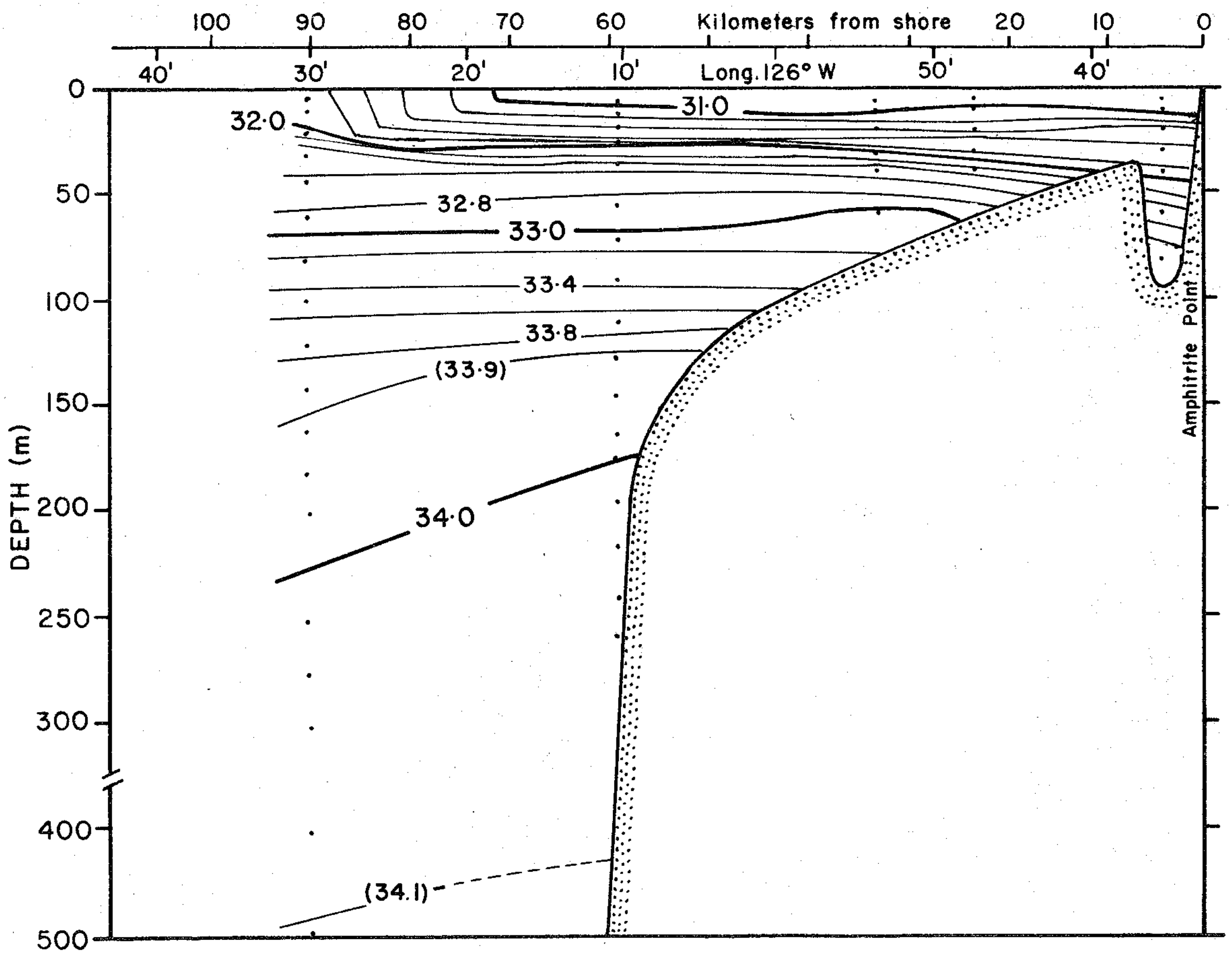

Fig. 77b. Salinity ($^0/_{00}$) seaward of Amphitrite Point, July 25, 1961.

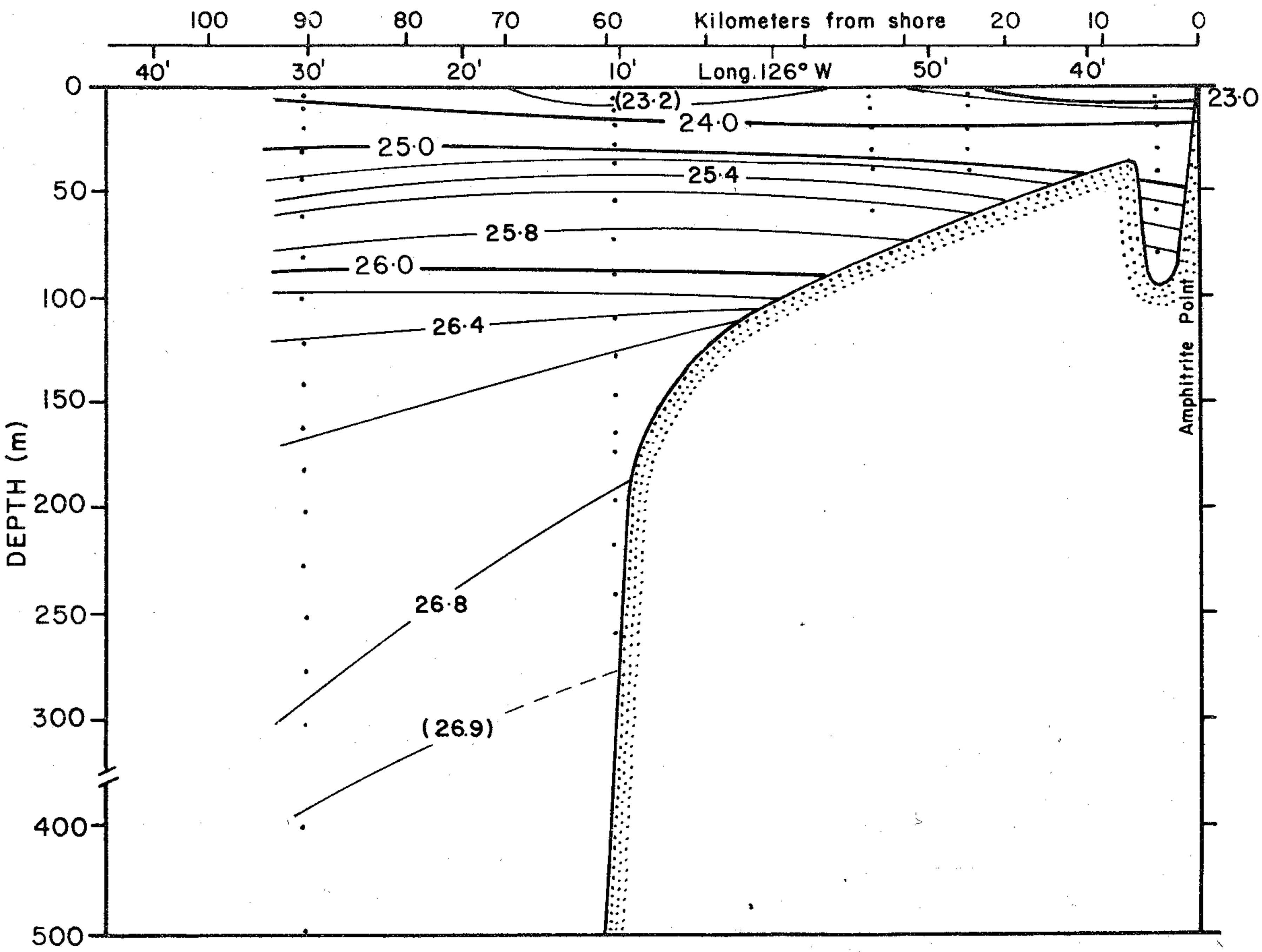

Fig. 77c. Density (σ_t) seaward of Amphitrite Point, July 25, 1961.

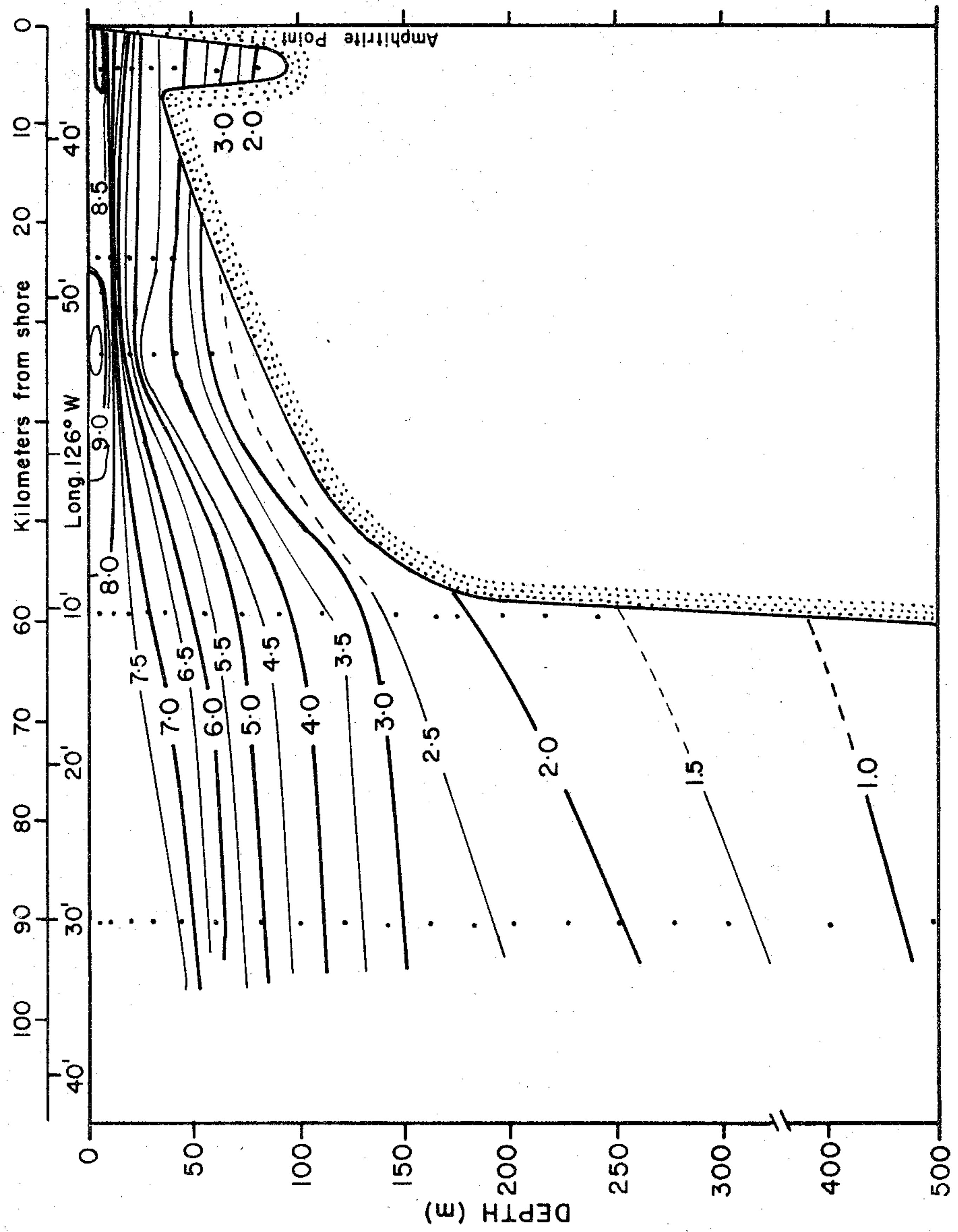

Fig. 77d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, July 25, 1961.

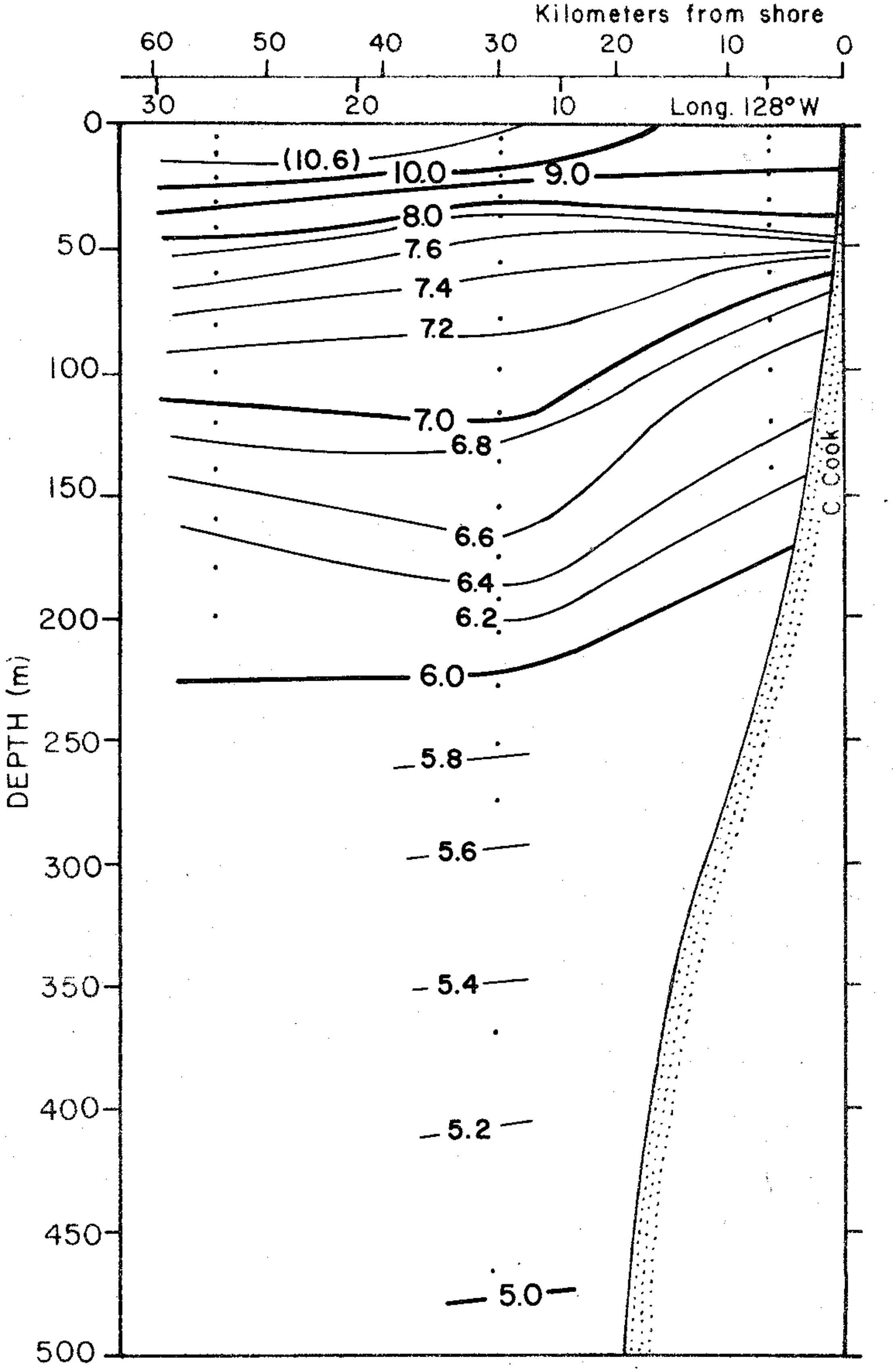

Fig. 78a. Temperature (°C) seaward of Cape Cook, July 26-27, 1961.

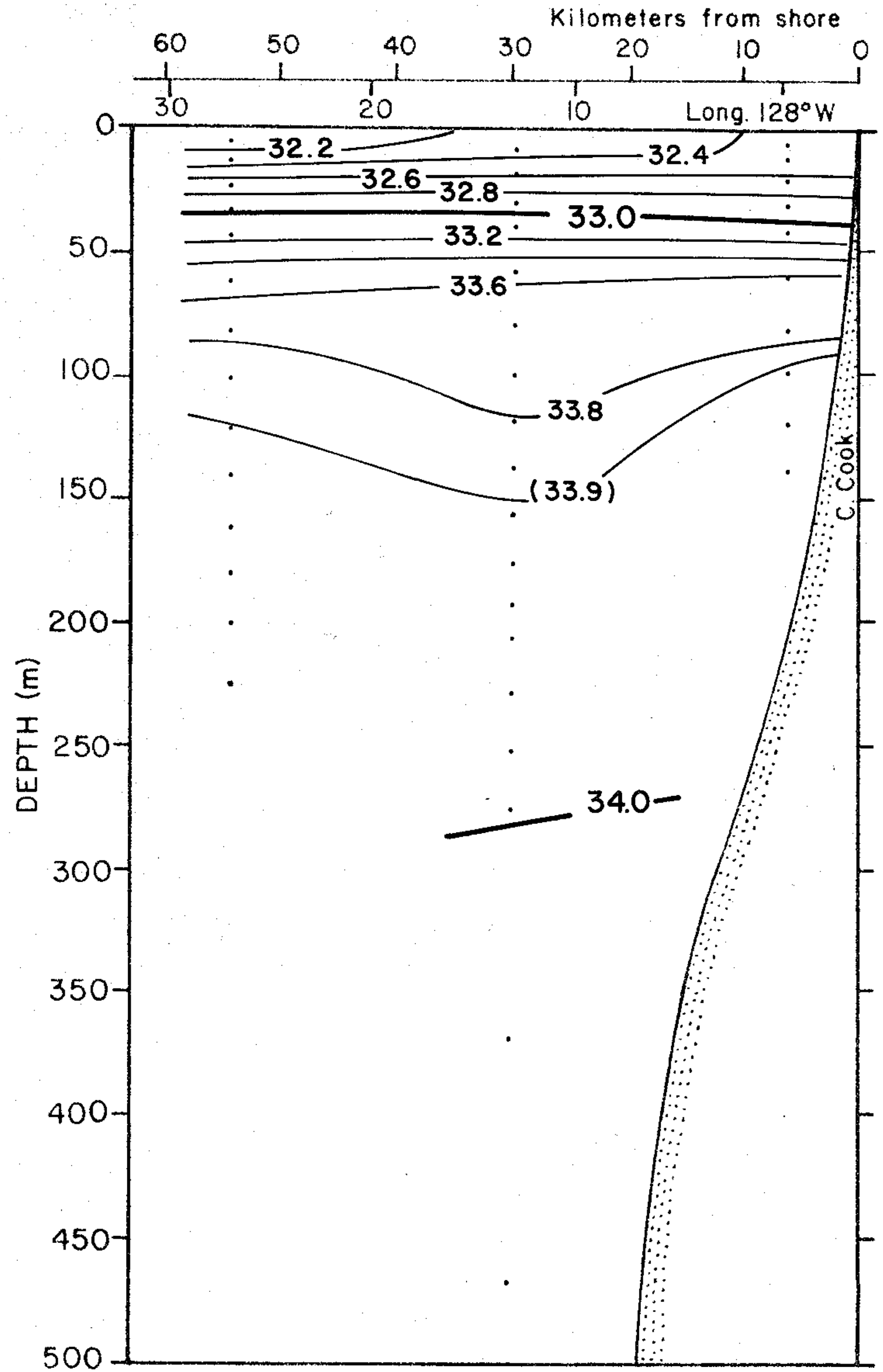

Fig. 78b. Salinity (°/oo) seaward of Cape Cook, July 26-27, 1961.

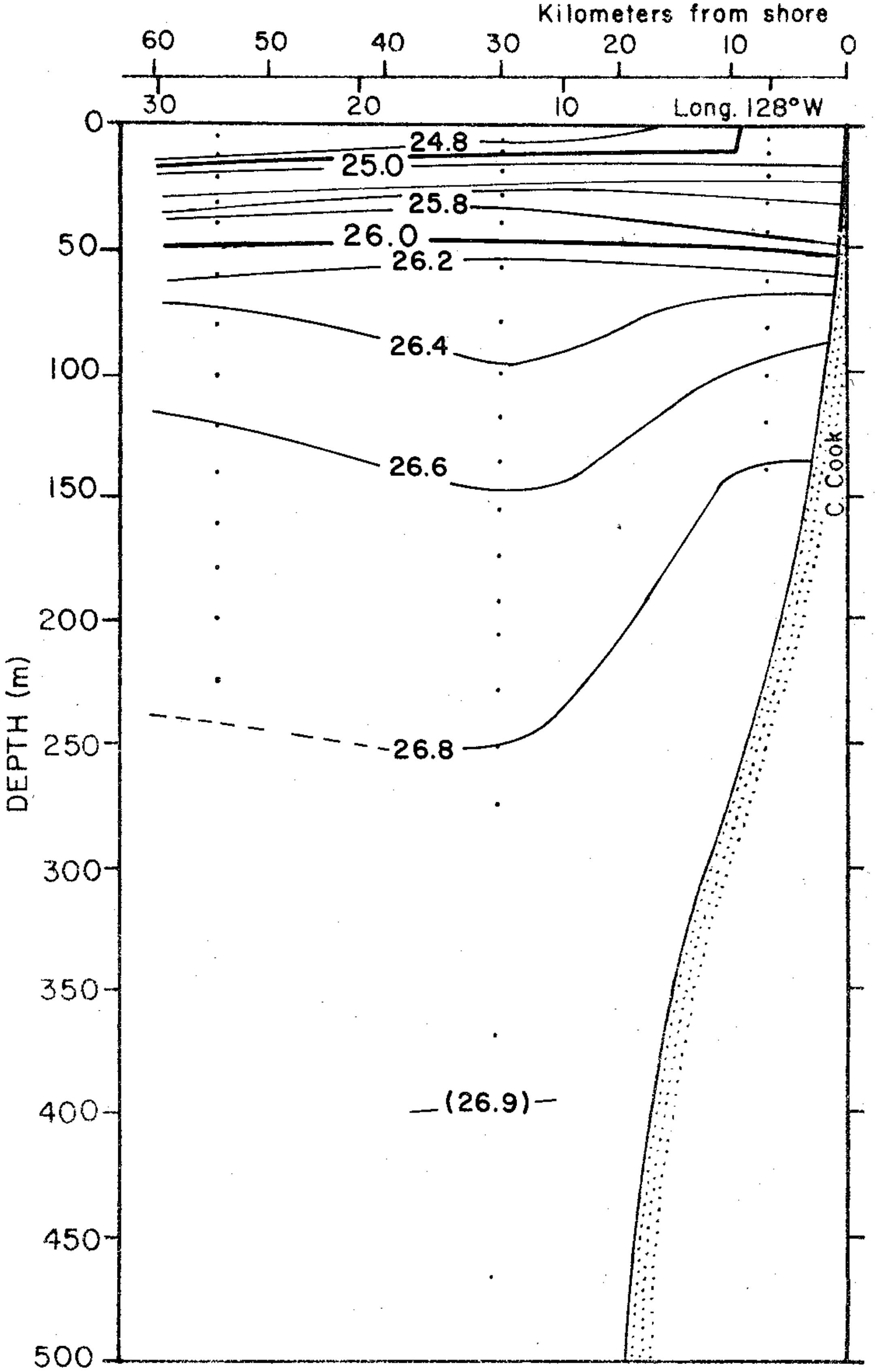

Fig. 78c. Density (σ_t) seaward of Cape Cook, July 26-27, 1961.

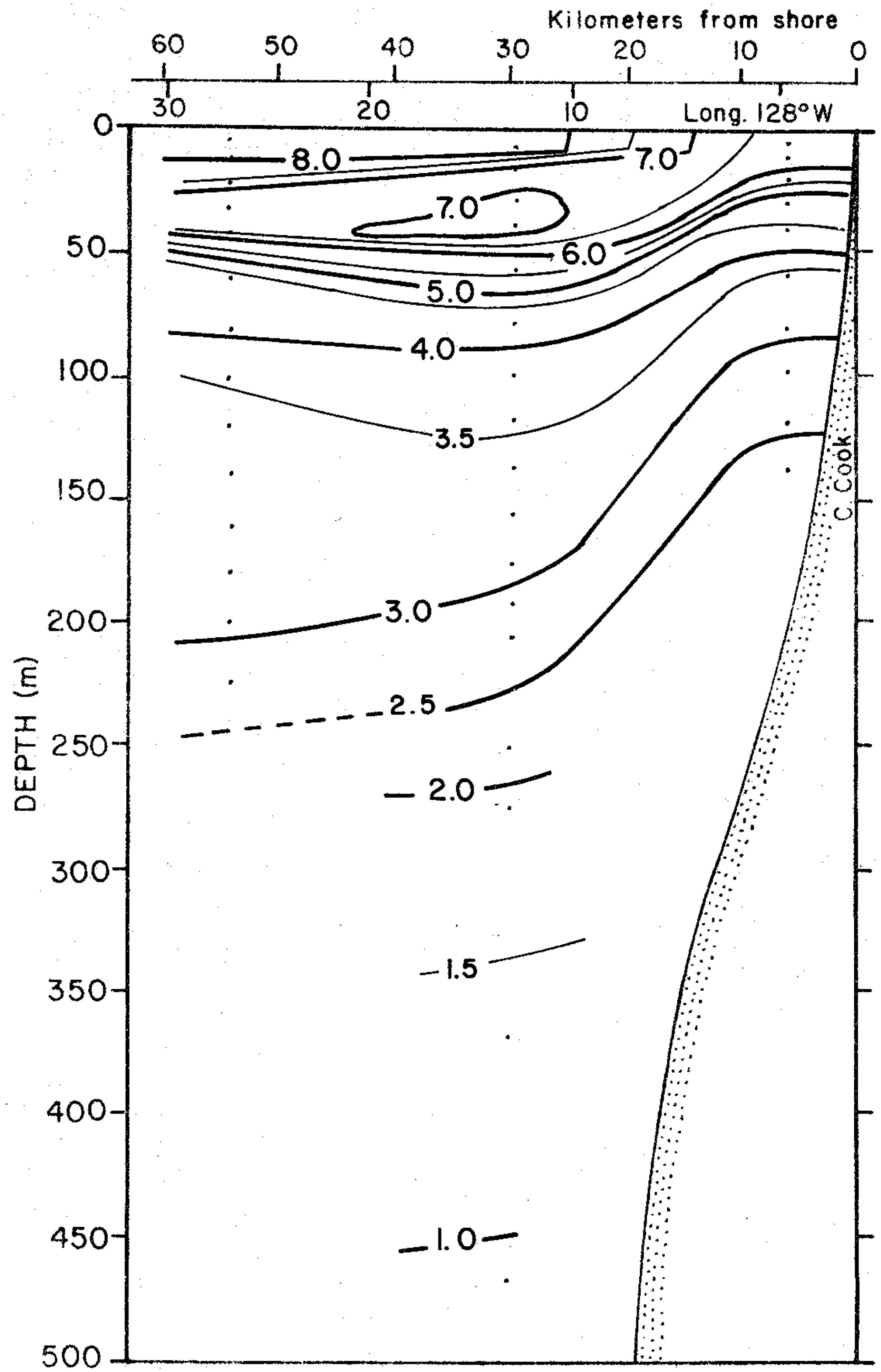

Fig. 78d. Dissolved oxygen (mL/L) seaward of Cape Cook, July 26-27, 1961.

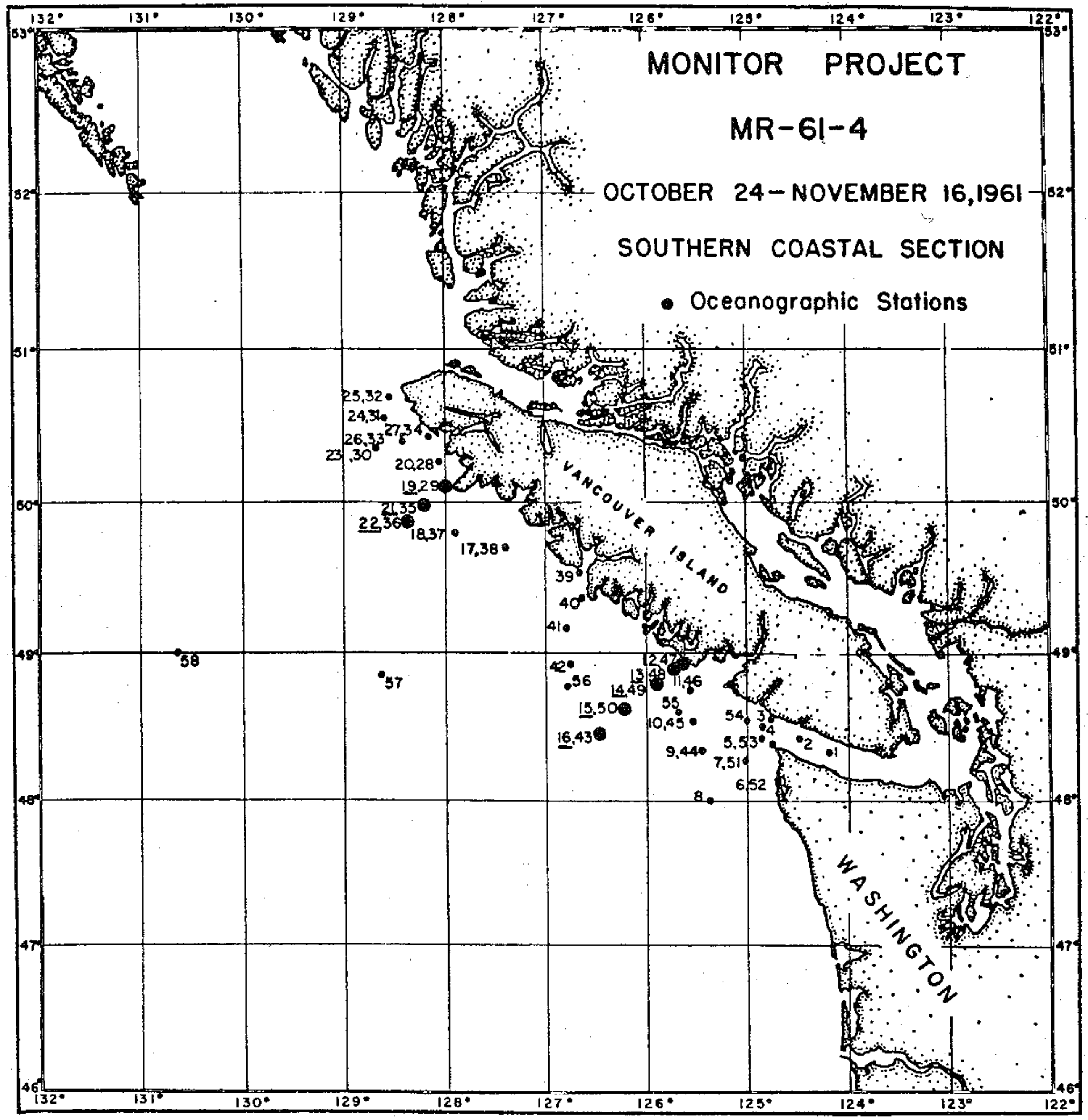

Fig. 79. Monitor project, October 24 - November 16, 1961. Large solid circles and underlined numbers indicate stations used in the sections.

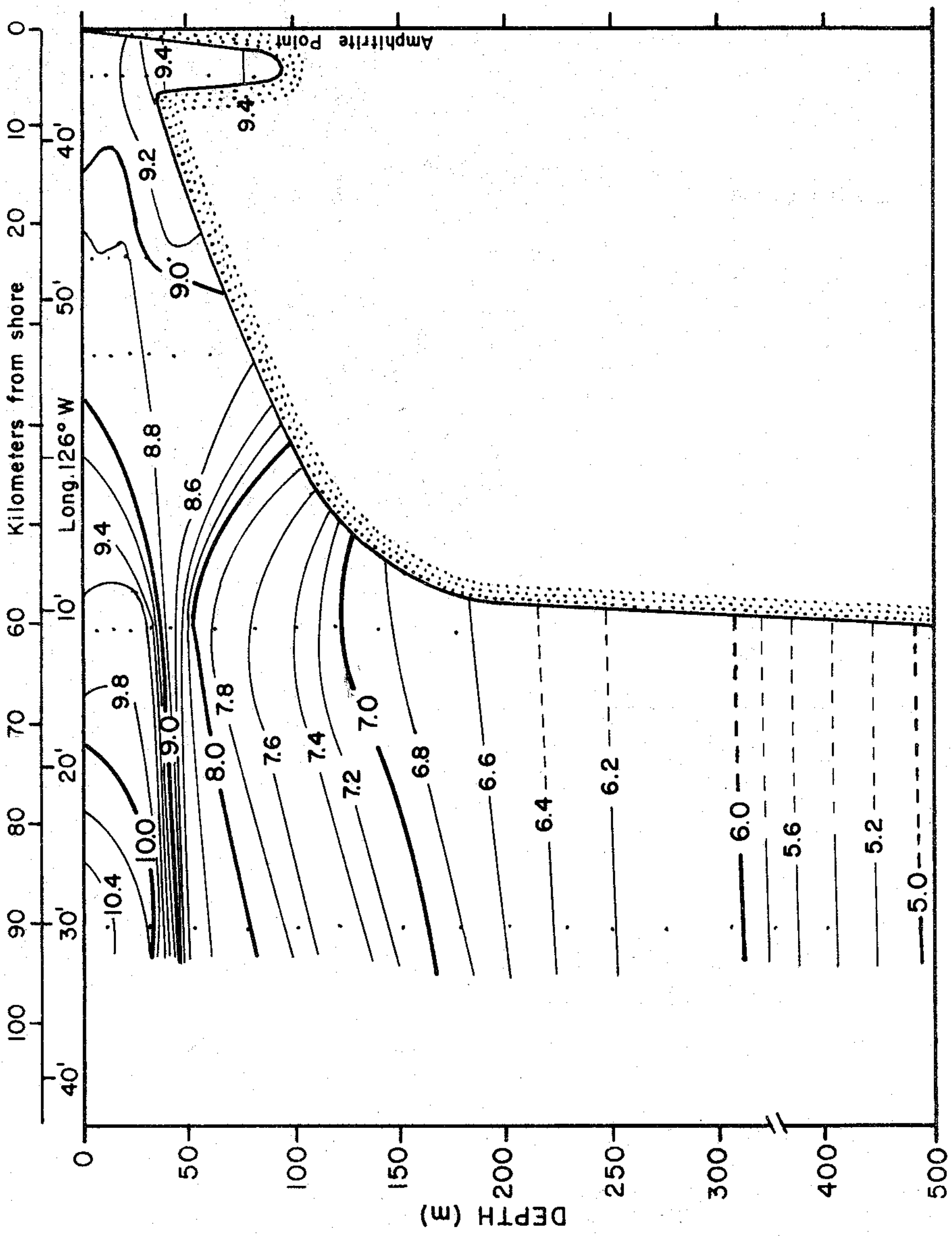

Fig. 80a. Temperature (°C) seaward of Amphitrite Point, October 26, 1961.

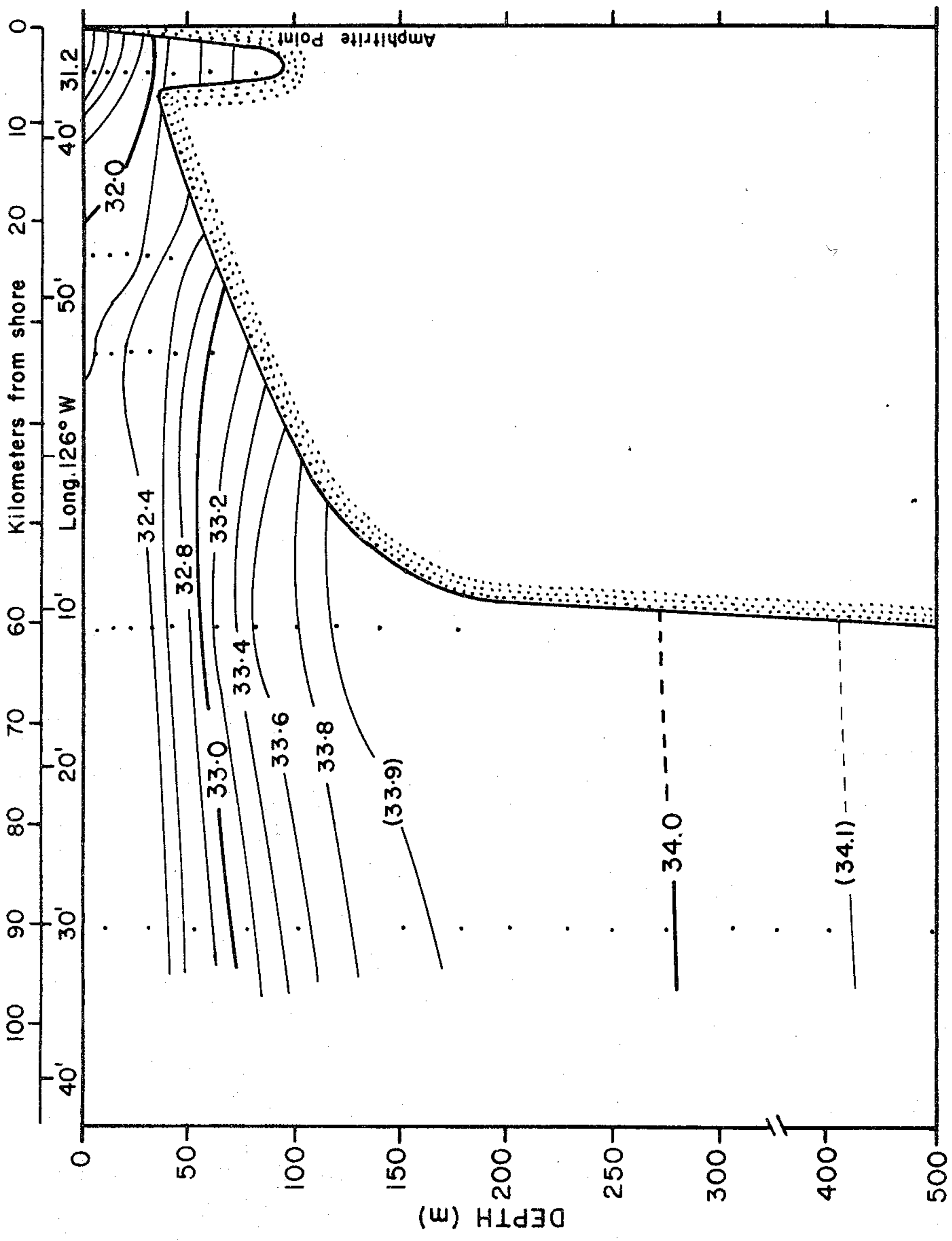

Fig. 80b. Salinity (°/oo) seaward of Amphitrite Point, October 26, 1961.

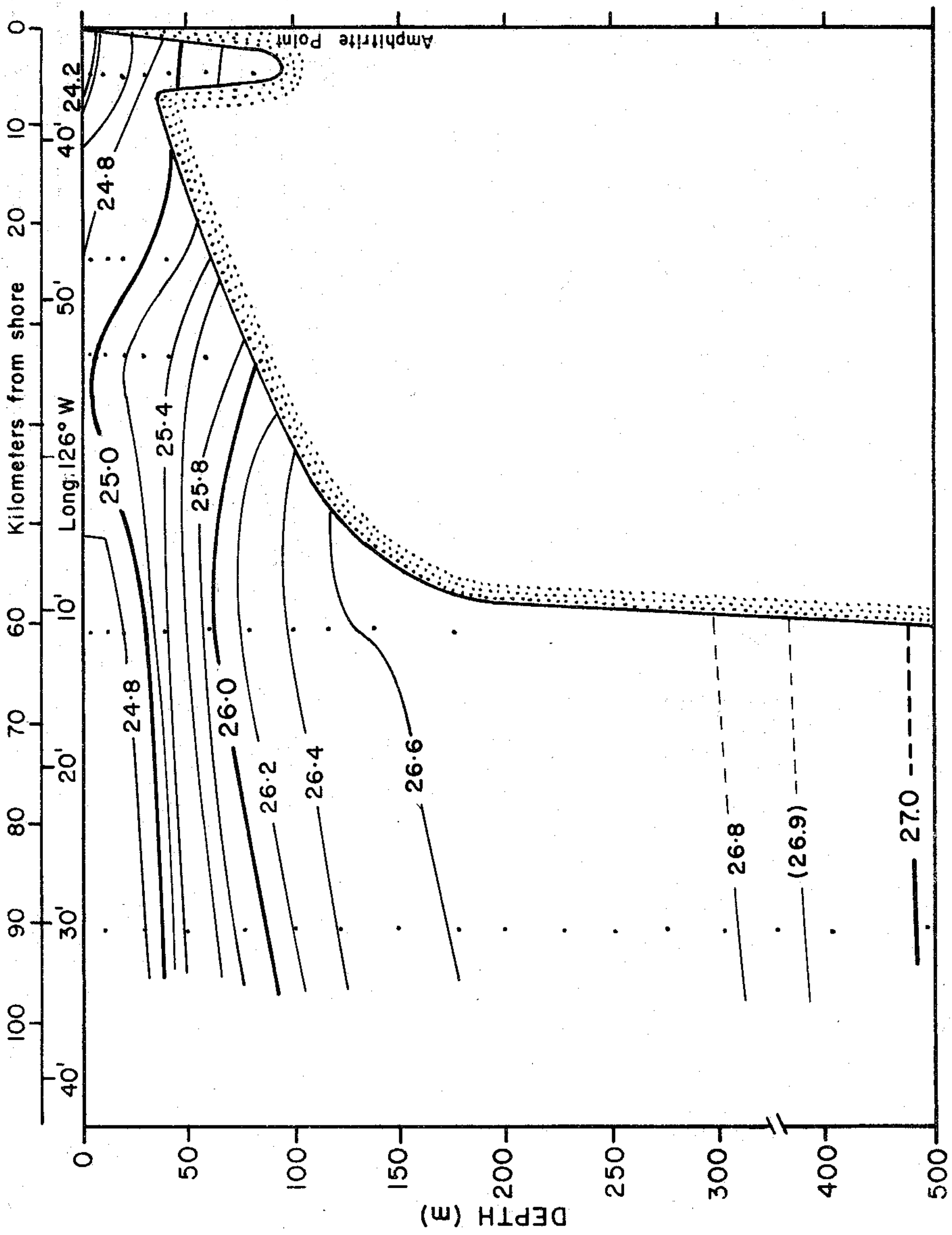

Fig. 80c. Density (σ_t) seaward of Amphitrite Point, October 26, 1961.

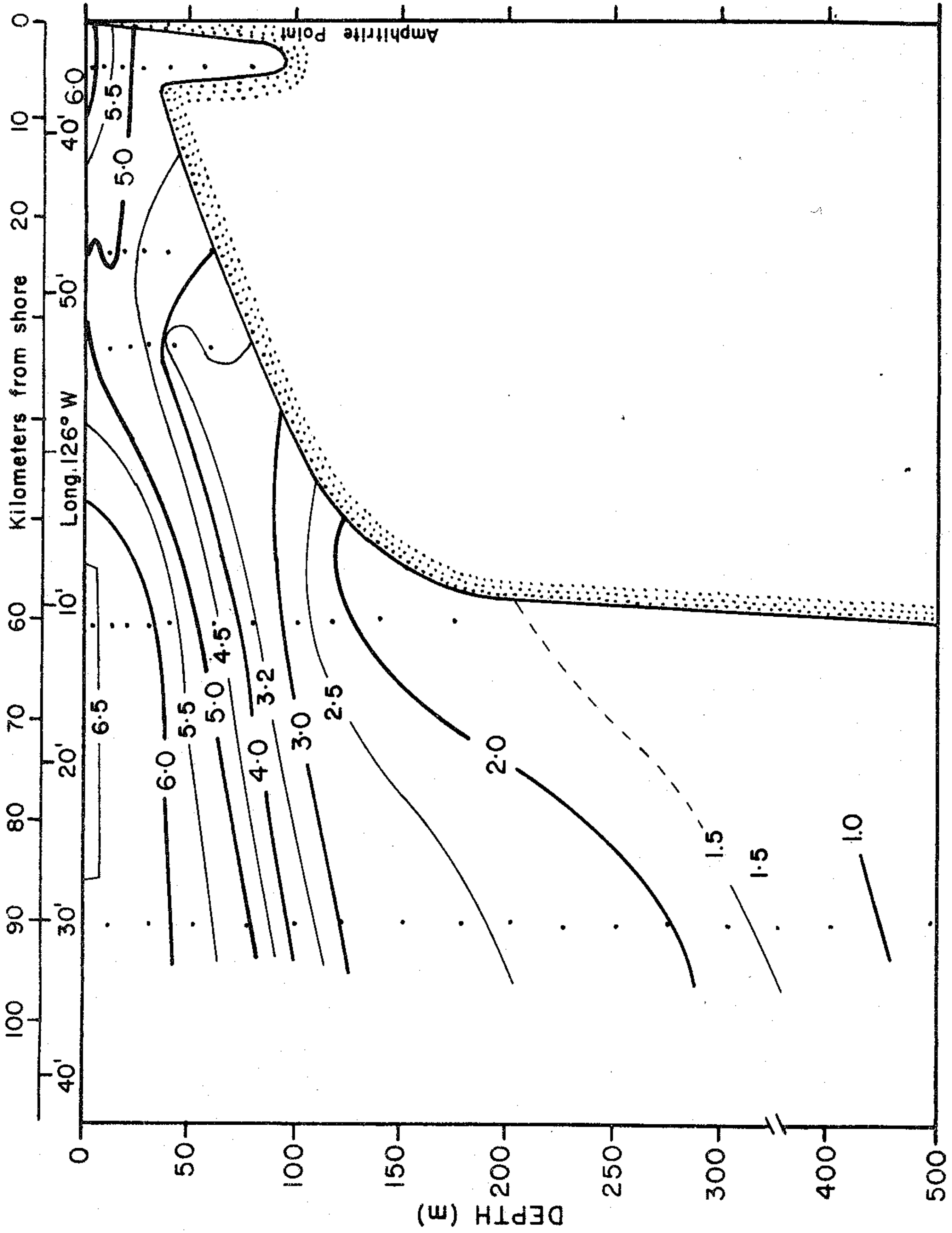

Fig. 80d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, October 26, 1961.

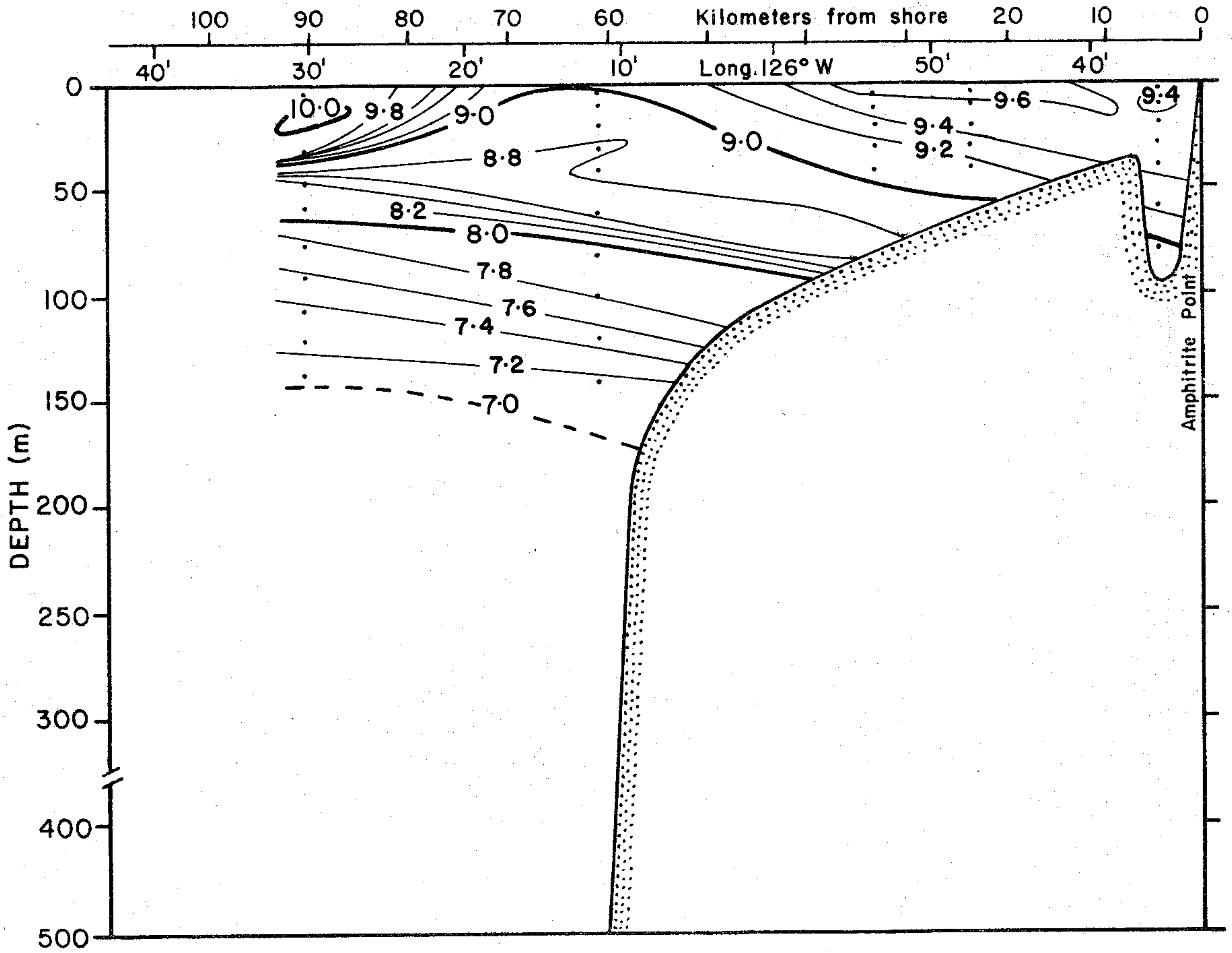

Fig. 81a. Temperature (°C) seaward of Amphitrite Point, November 2, 1961.

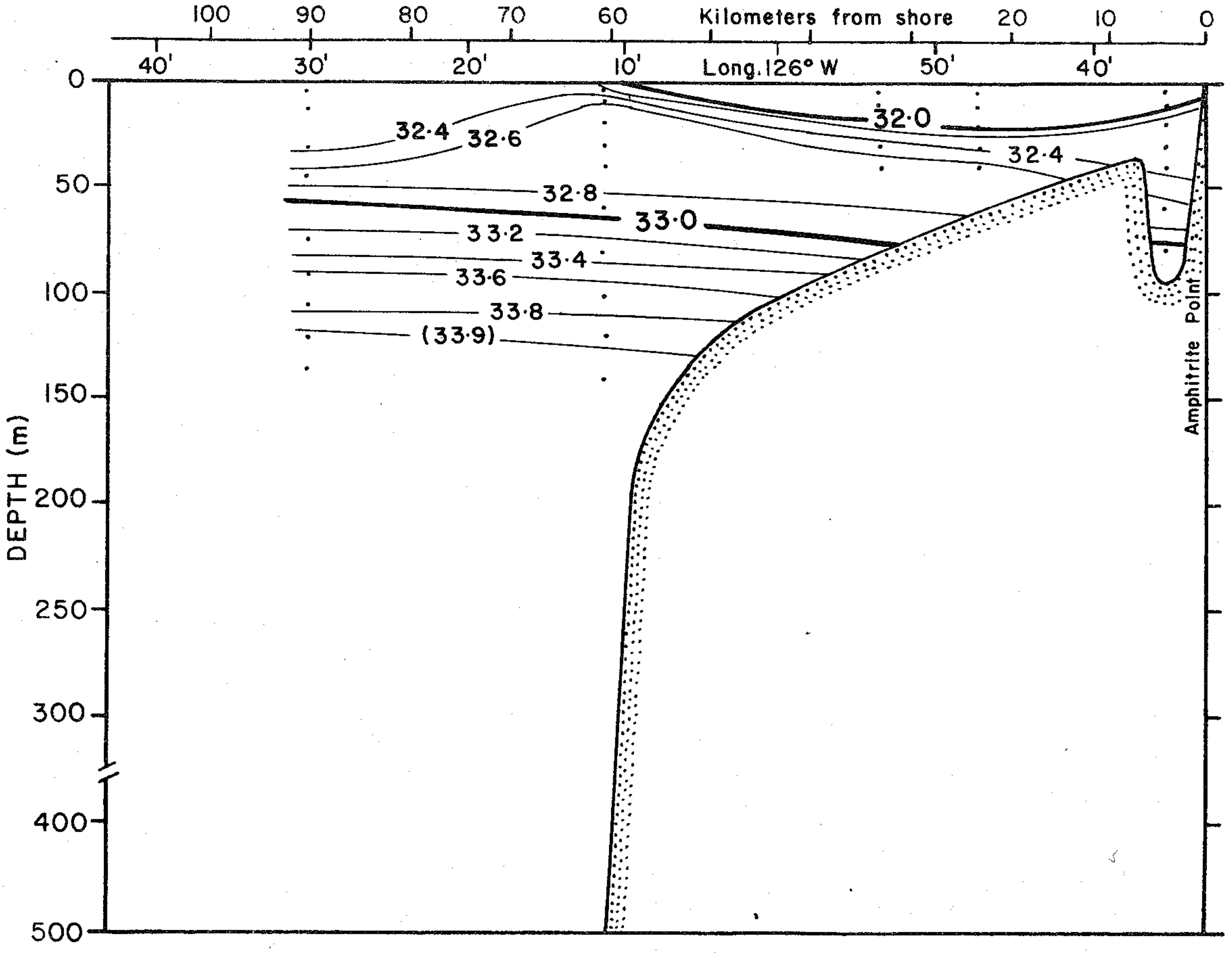

Fig. 81b. Salinity (°/oo) seaward of Amphitrite Point, November 2, 1961.

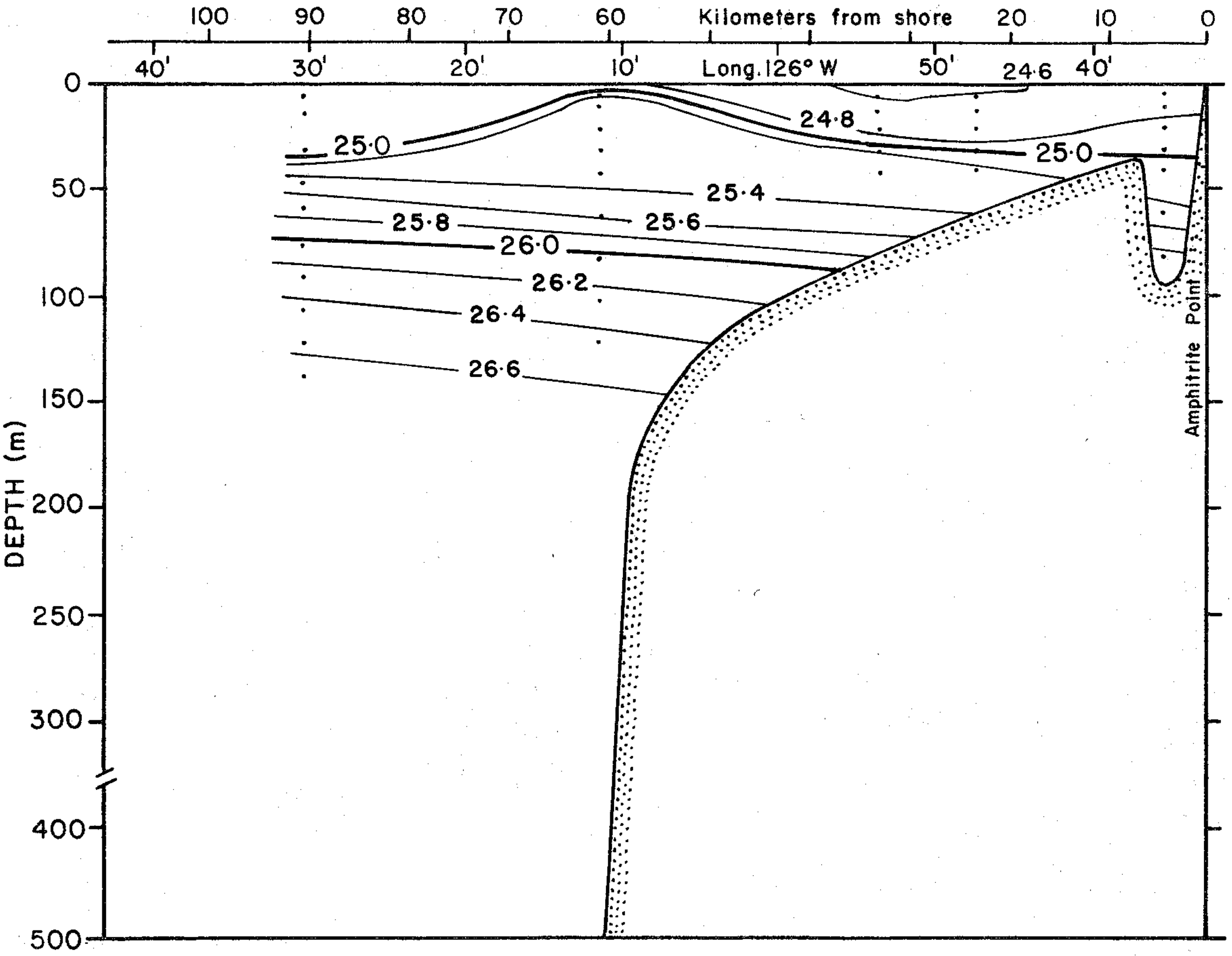

Fig. 81c. Density (σ_t) seaward of Amphitrite Point, November 2, 1961.

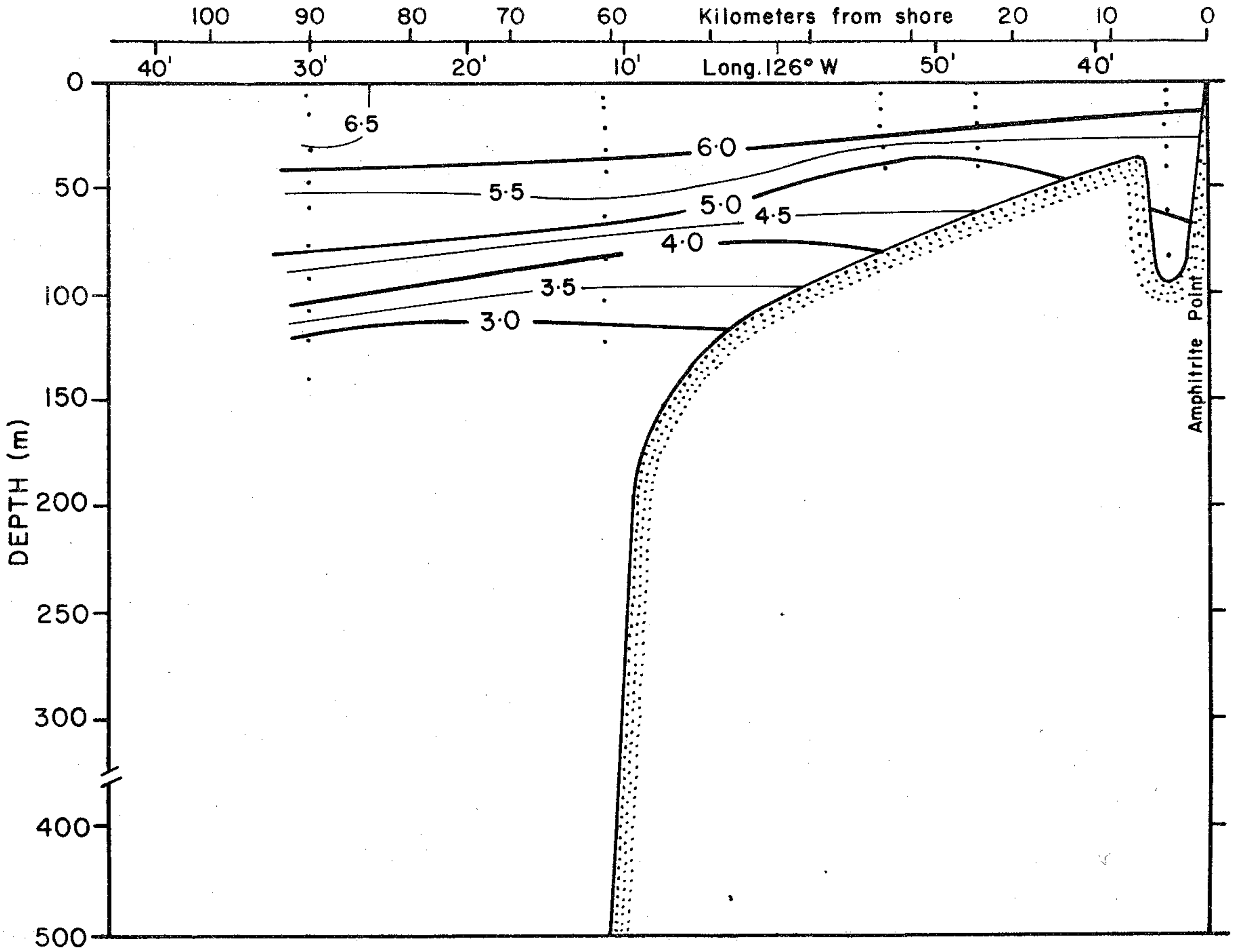

Fig. 81d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, November 2, 1961.

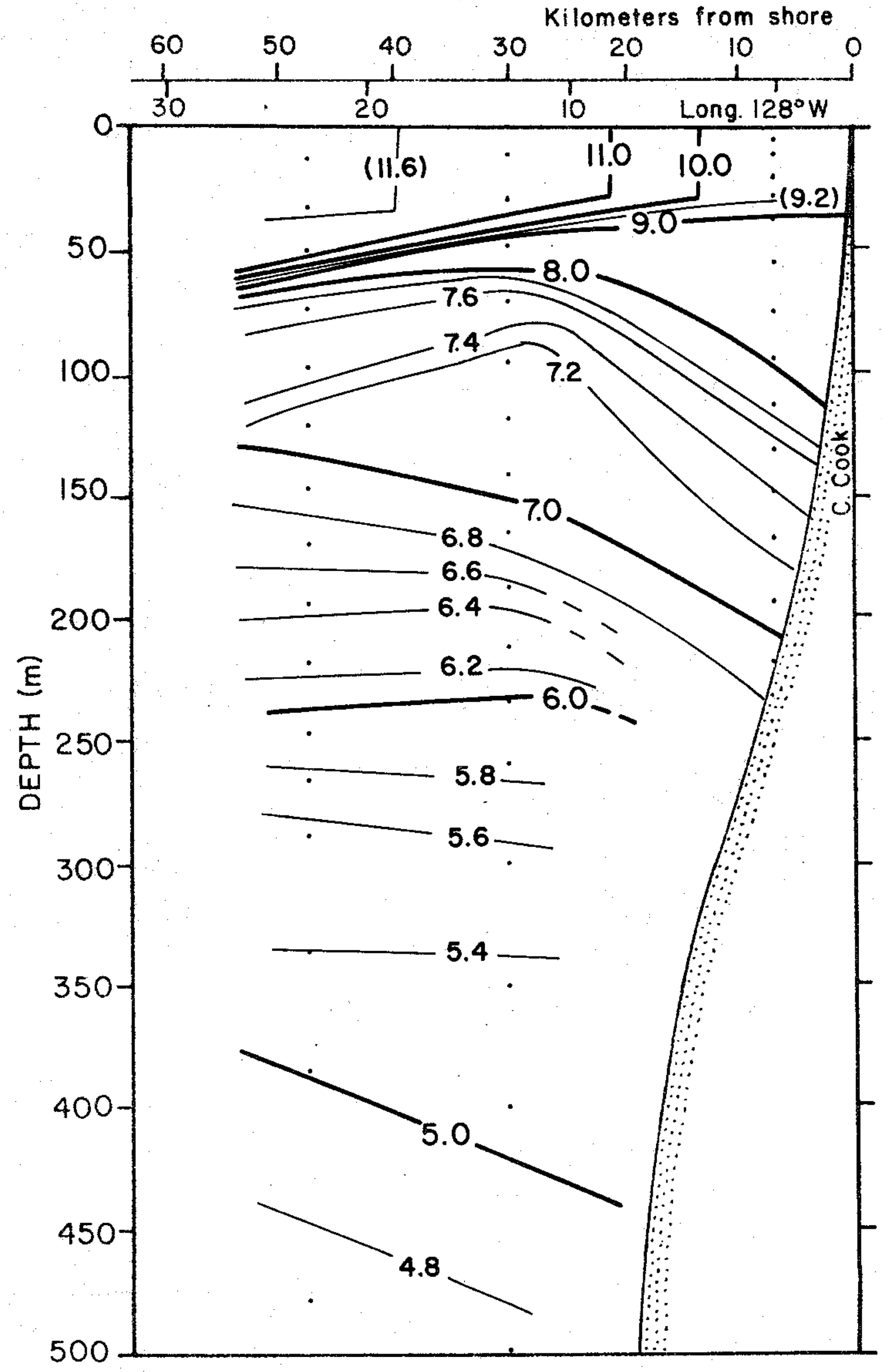

Fig. 82a. Temperature (°C) seaward of Cape Cook, October 28, 1961.

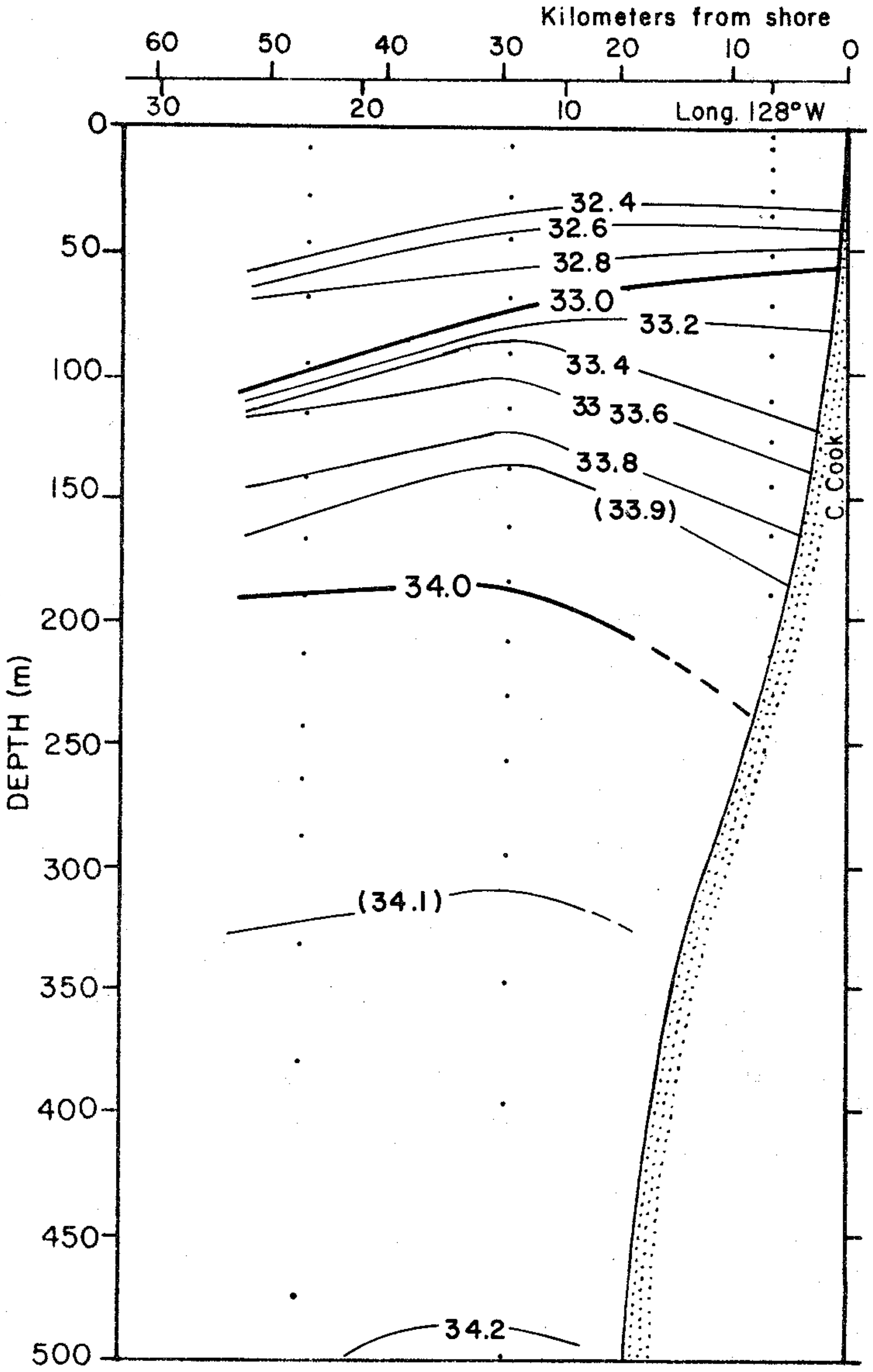

Fig. 82b. Salinity (°/oo) seaward of Cape Cook, October 28, 1961.

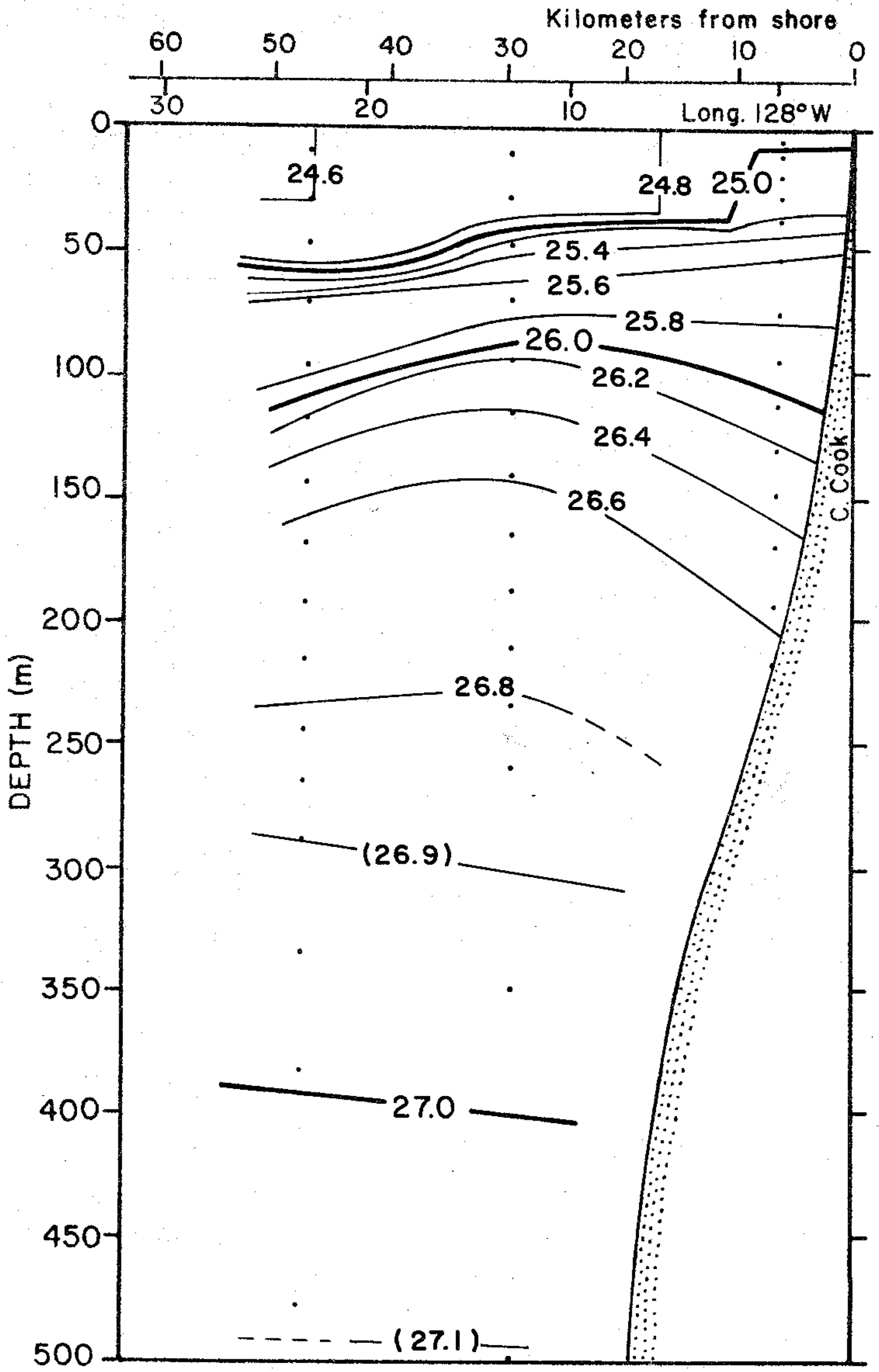

Fig. 82c. Density (σ_t) seaward of Cape Cook, October 28, 1961.

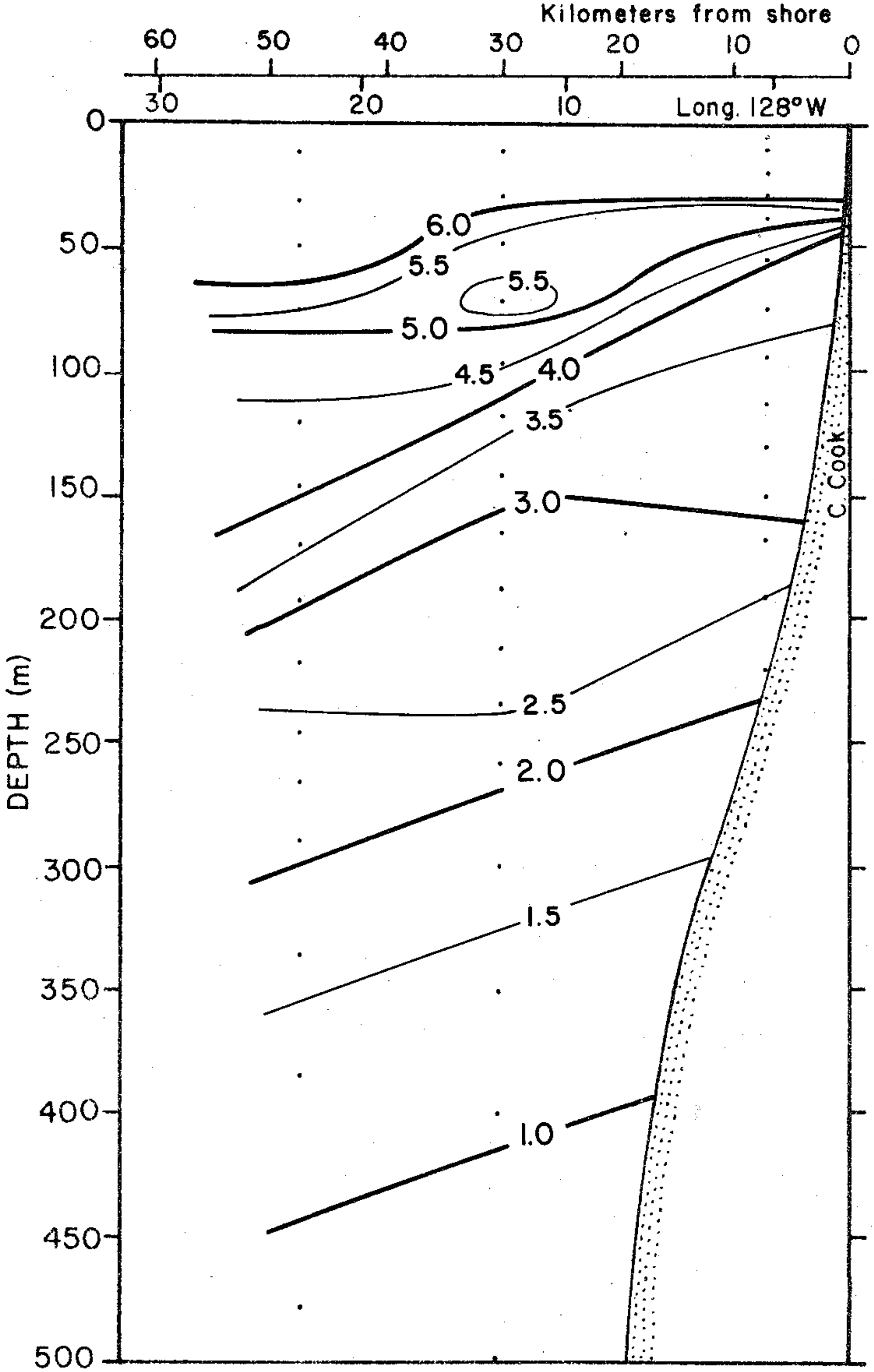

Fig. 82d. Dissolved oxygen (mL/L) seaward of Cape Cook, October 28, 1961.

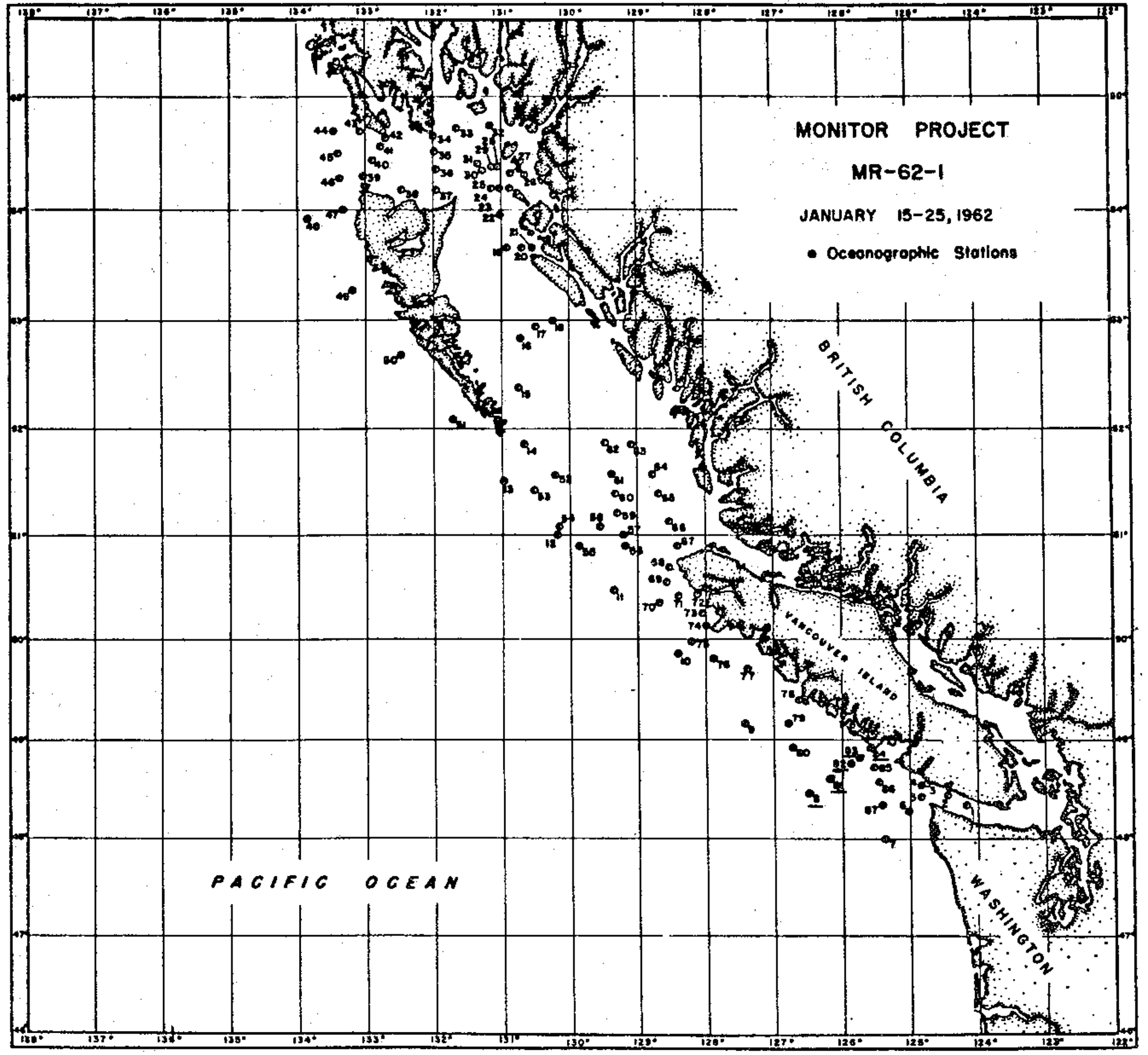

Fig. 83. Monitor project, January 15-25, 1962. Underlined numbers indicate stations used in the sections.

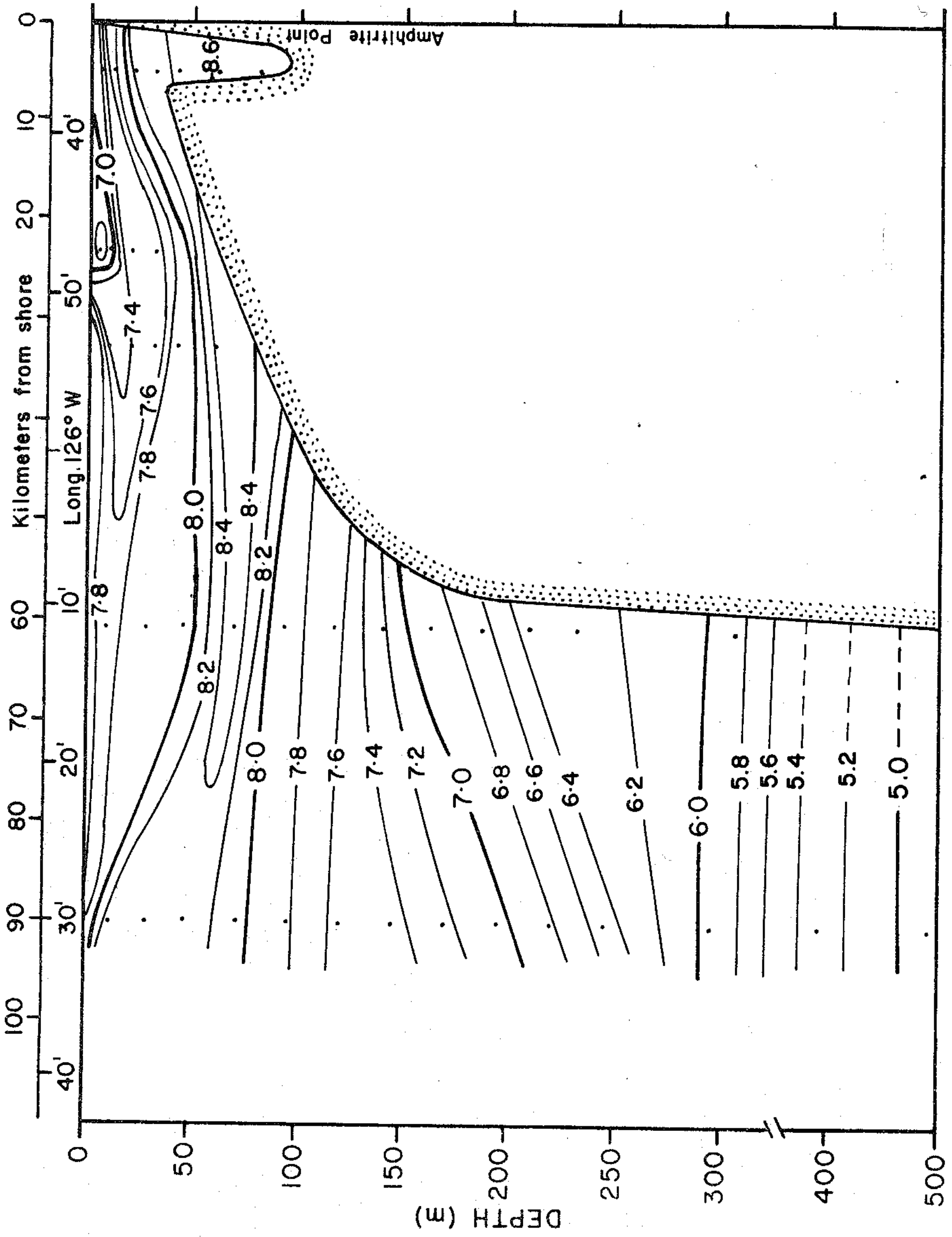

Fig. 84a. Temperature (°C) seaward of Amphitrite Point, January 25, 1962.

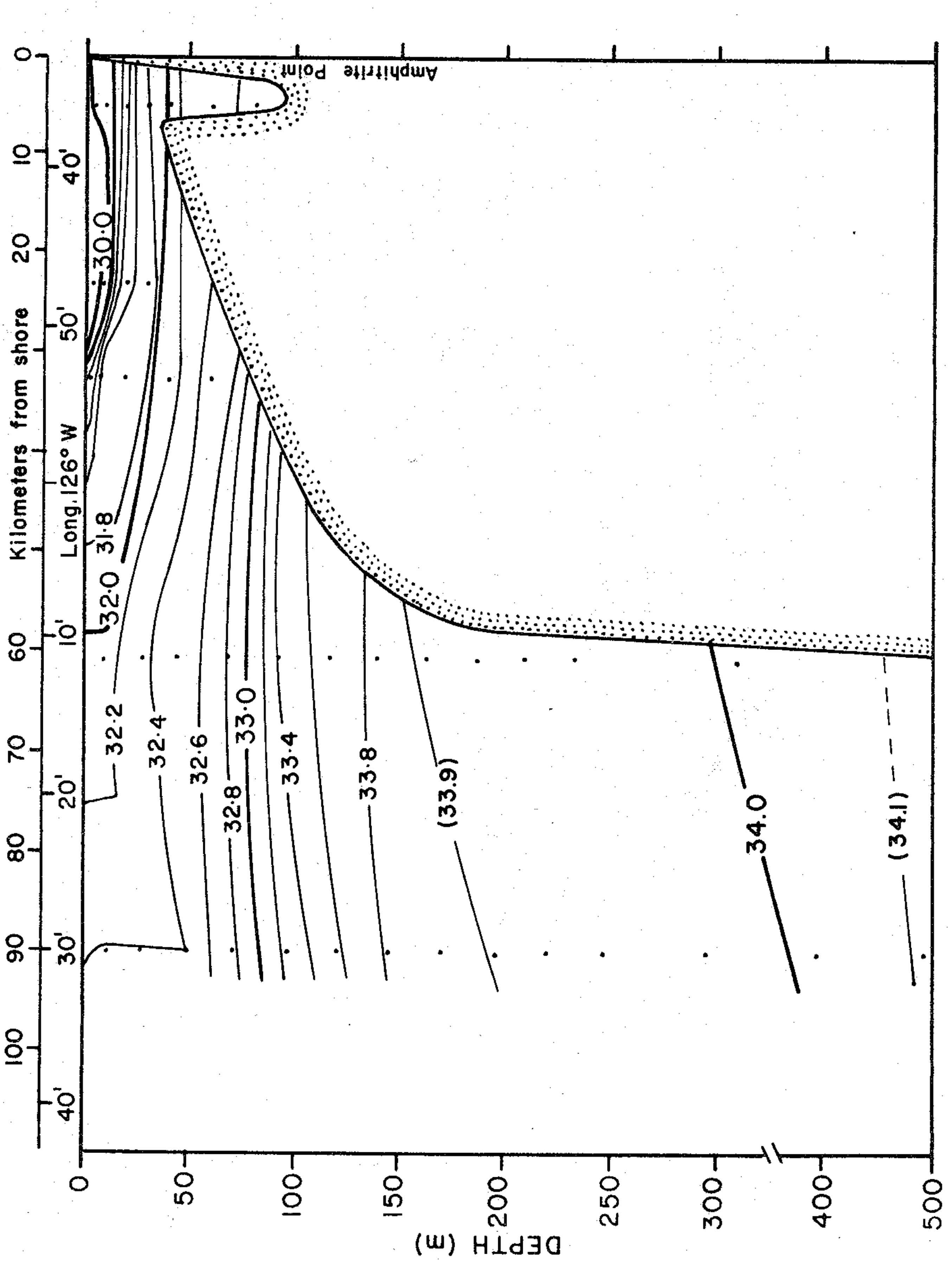

Fig. 84b. Salinity ($^0/_{00}$) seaward of Amphitrite Point, January 25, 1962.

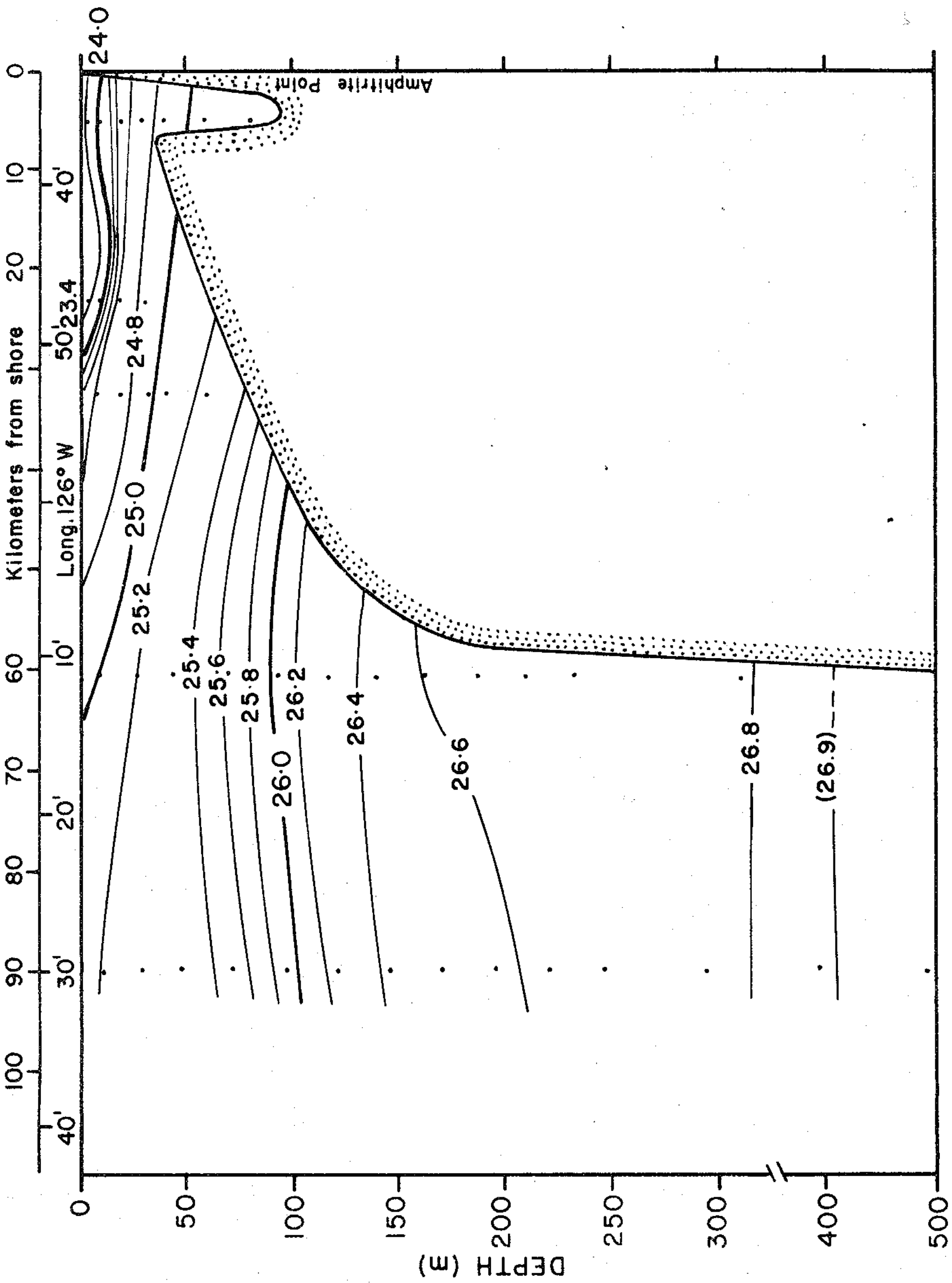

Fig. 84c. Density (σ_t) seaward of Amphitrite Point, January 25, 1962.

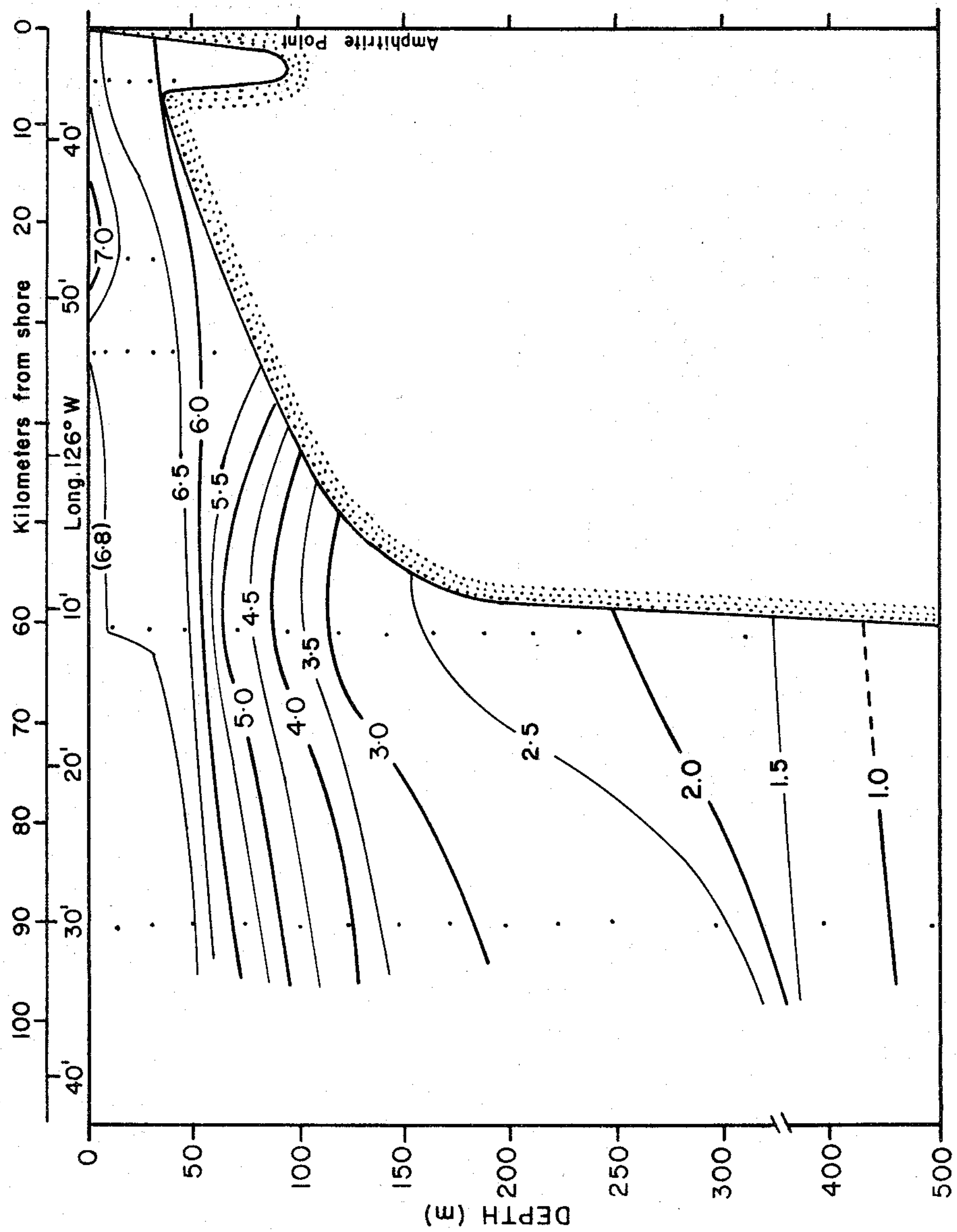

Fig. 84d. Dissolved oxygen (mL/L) seaward of Amphitrite Point, January 25, 1962.

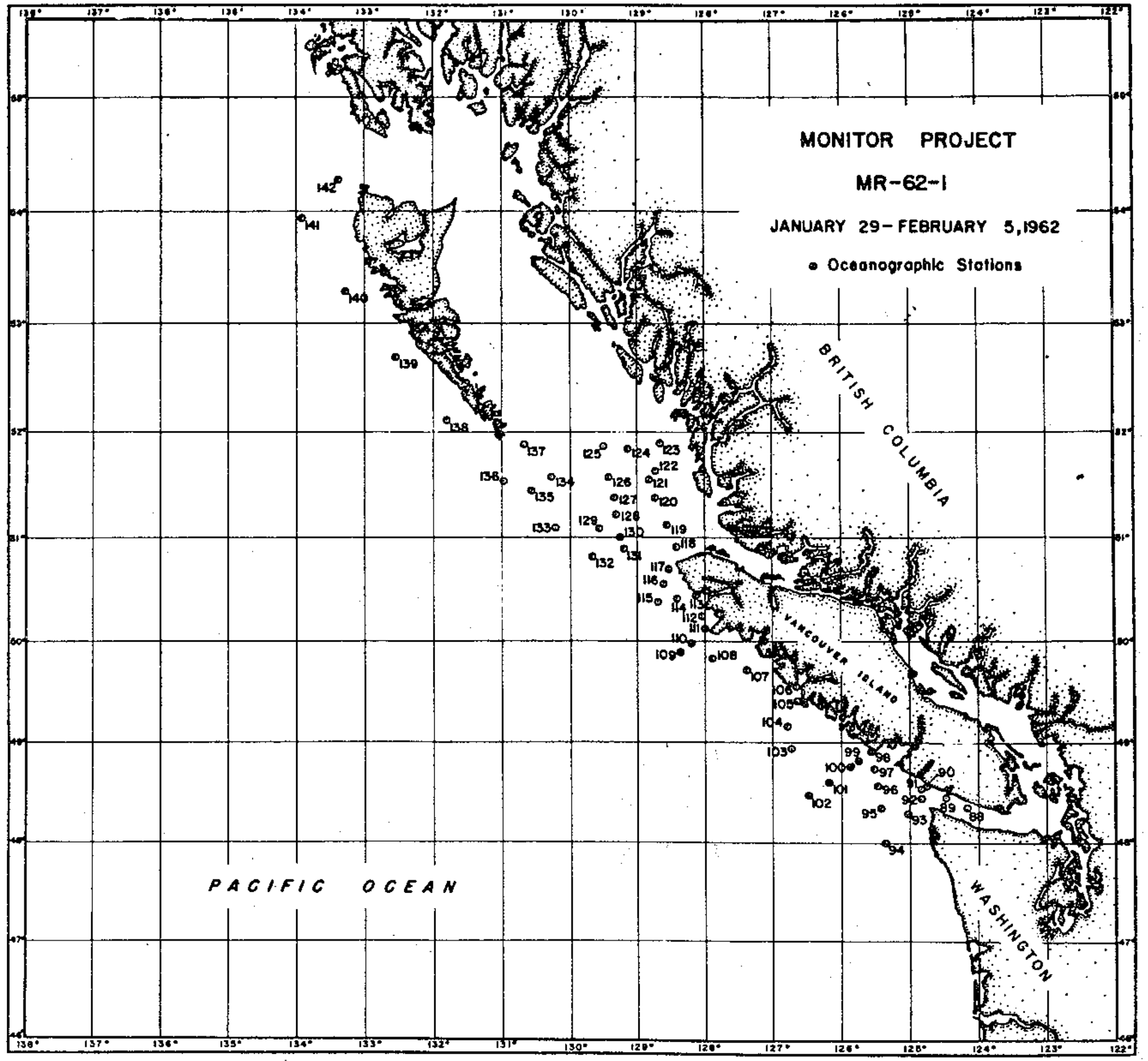

Fig. 85. Monitor project, January 29 - February 5, 1962. Solid circles indicate stations used in the sections.

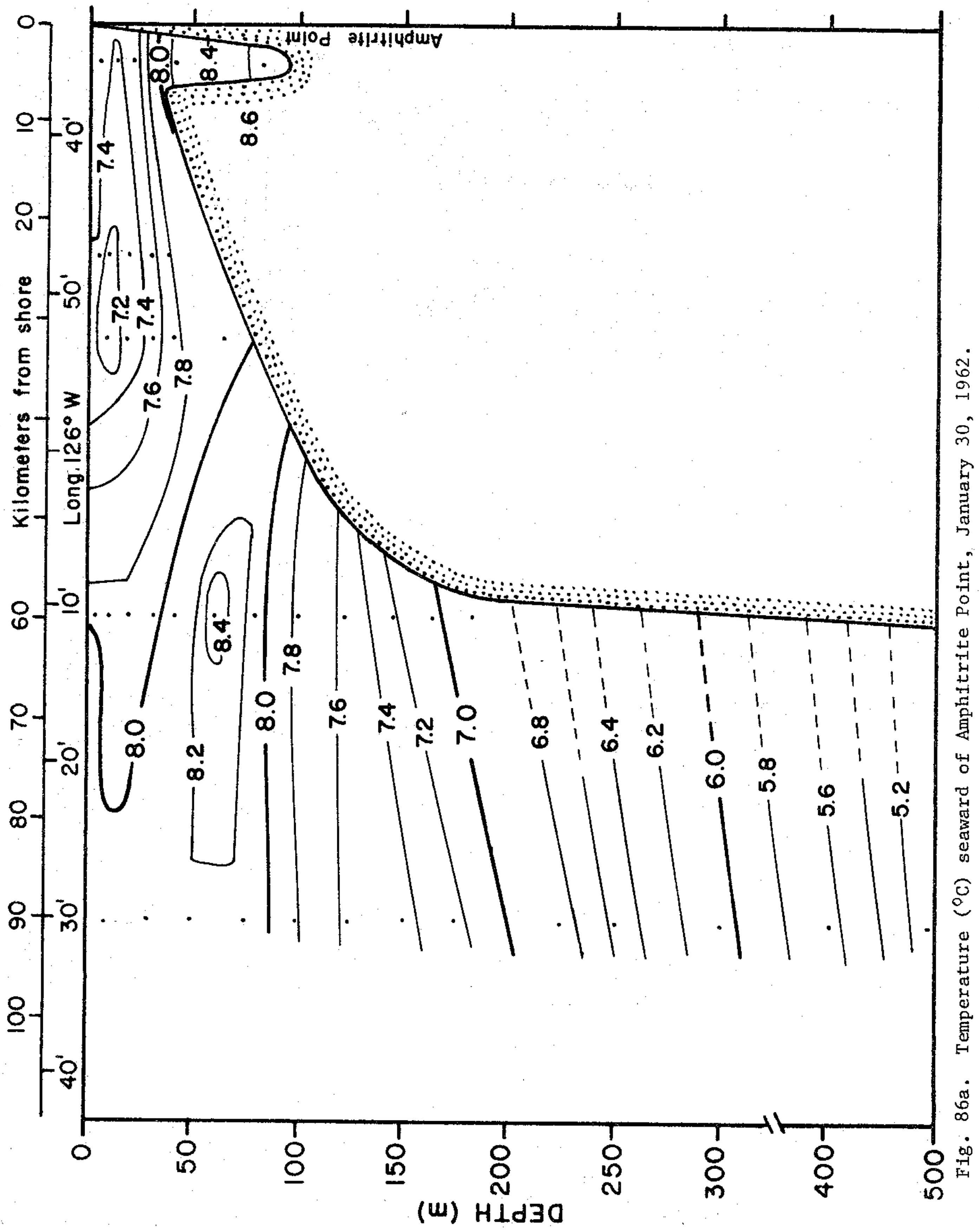

Fig. 86a. Temperature (°C) seaward of Amphitrite Point, January 30, 1962.

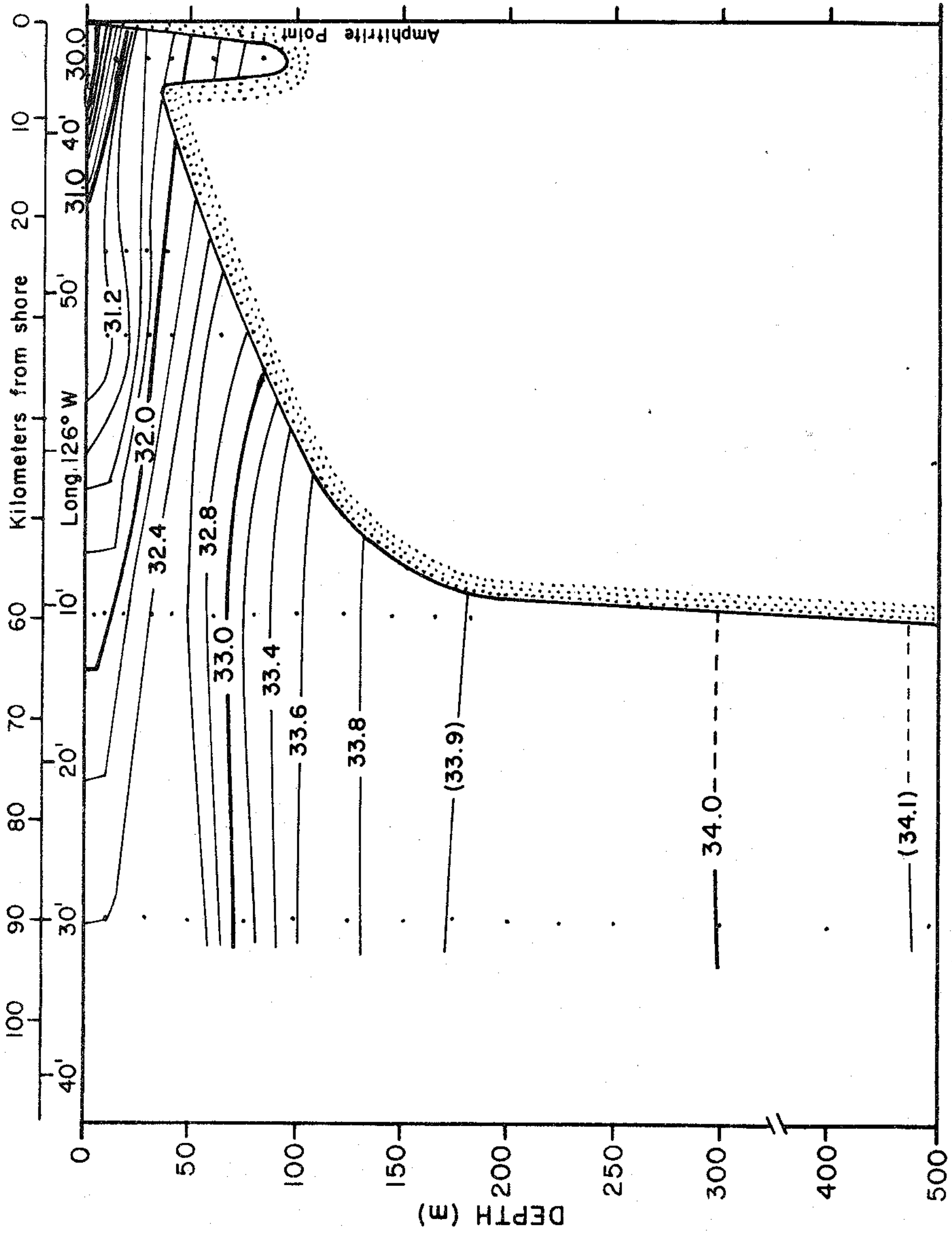

Fig. 86b. Salinity (°/oo) seaward of Amphitrite Point, January 30, 1962.

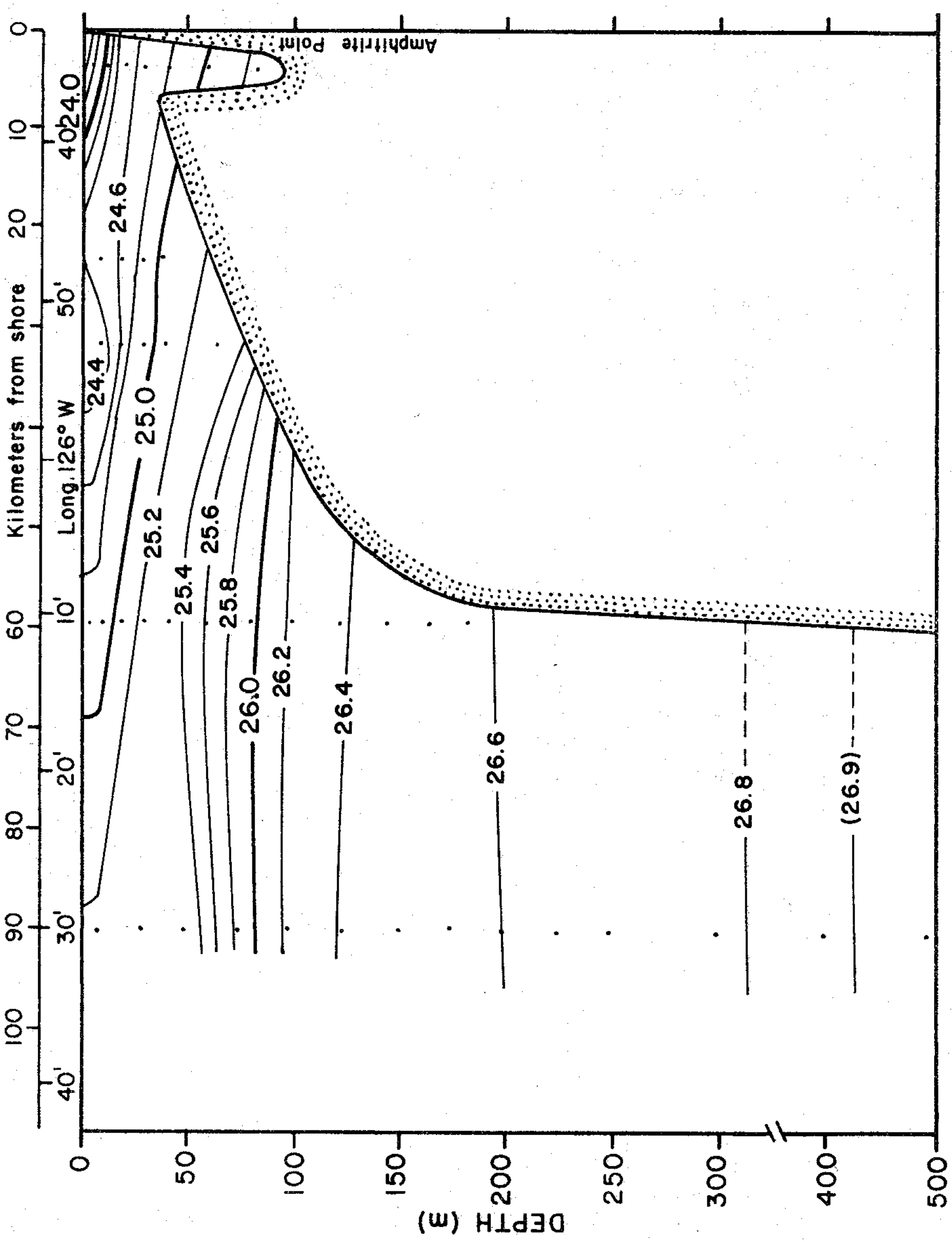

Fig. 86c. Density (σ_t) seaward of Amphitrite Point, January 30, 1962.

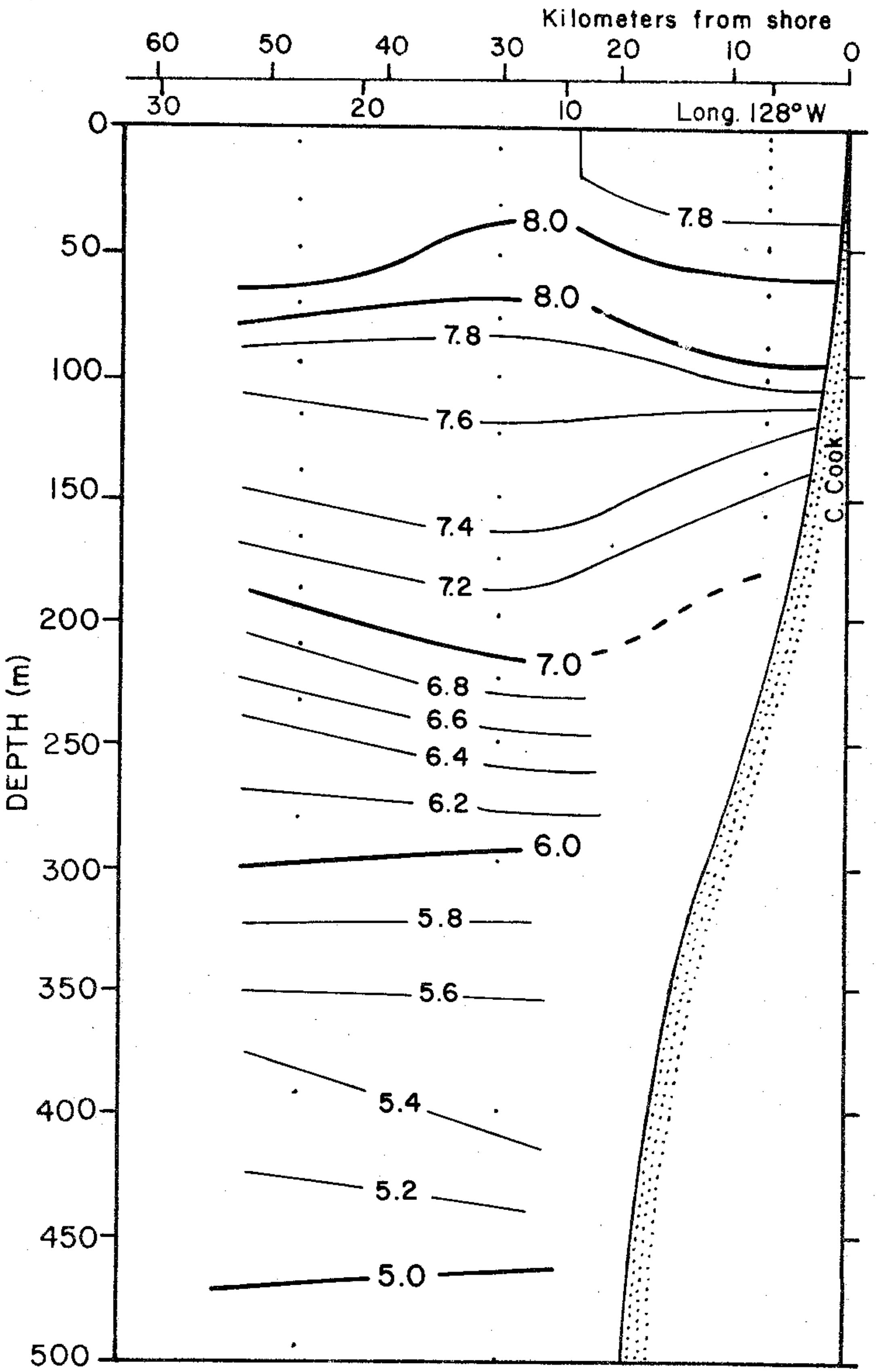

Fig. 87a. Temperature (°C) seaward of Cape Cook, January 31, 1962.

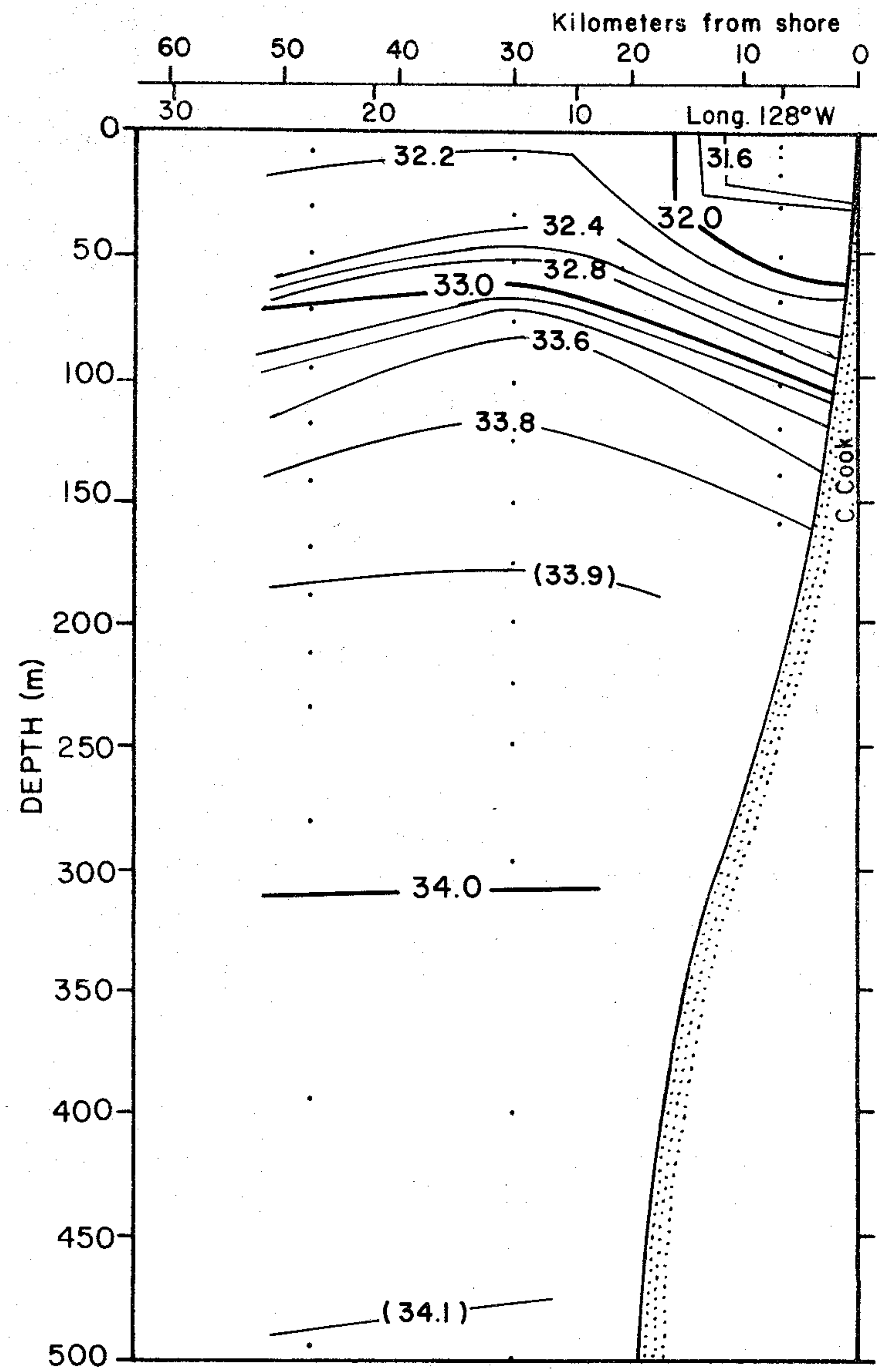

Fig. 87b. Salinity ($^o/_{oo}$) seaward of Cape Cook, January 31, 1962.

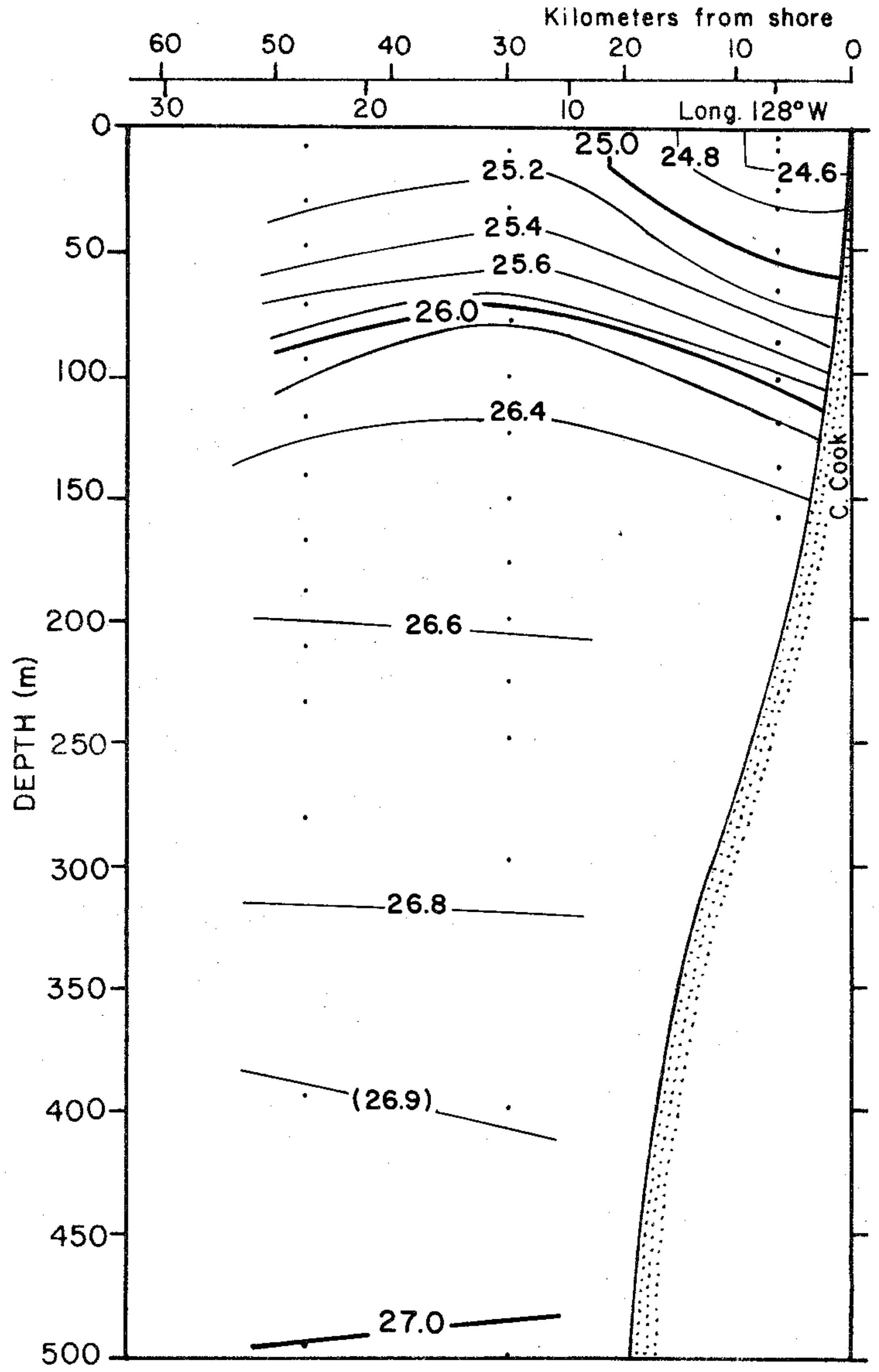

Fig. 87c. Density (σ_t) seaward of Cape Cook, January 31, 1962.

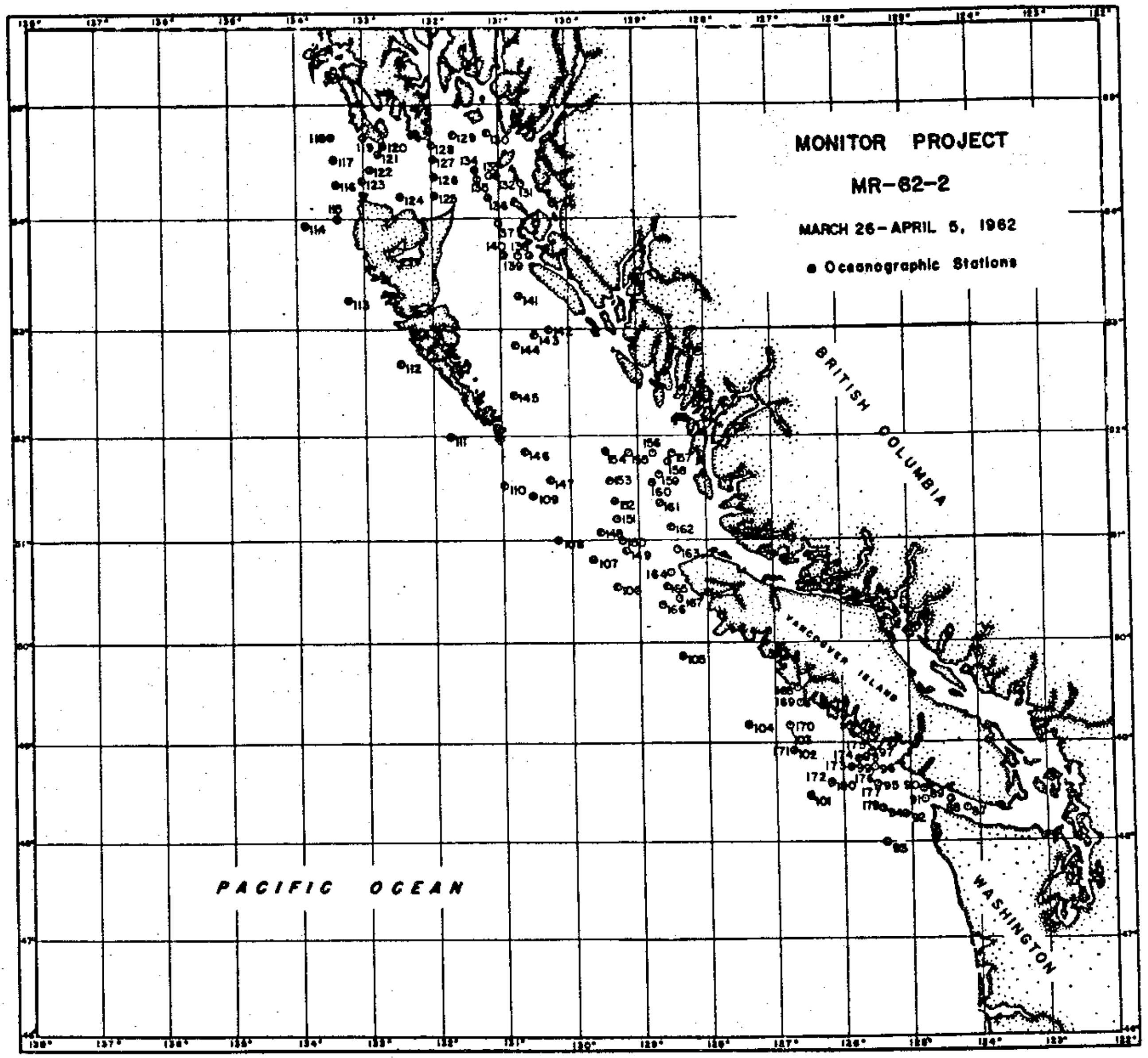

Fig. 88. Monitor project, March 26 - April 5, 1962. Solid circles indicate stations used in the sections.

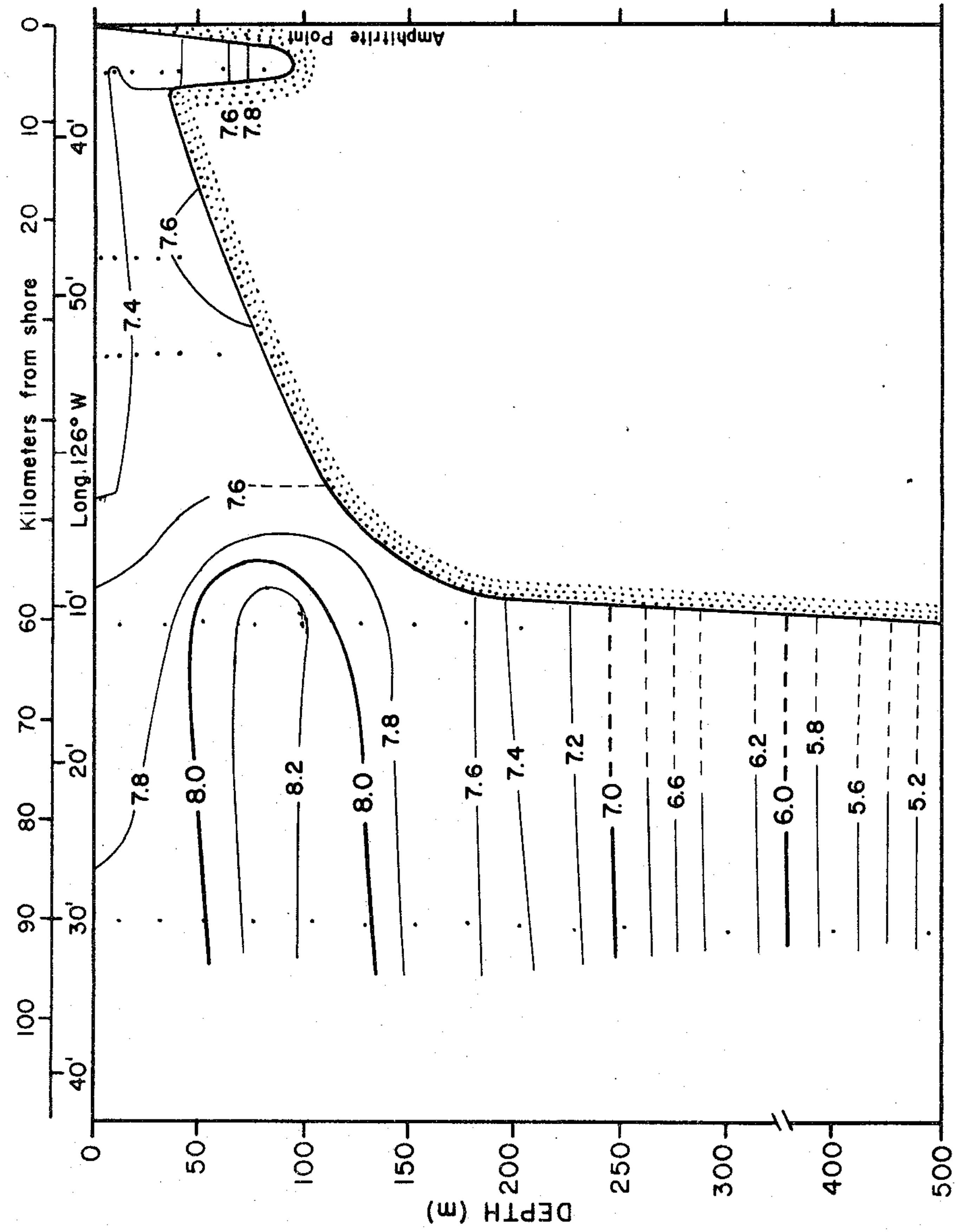

Fig. 89a. Temperature (°C) seaward of Amphitrite Point, March 27, 1962.

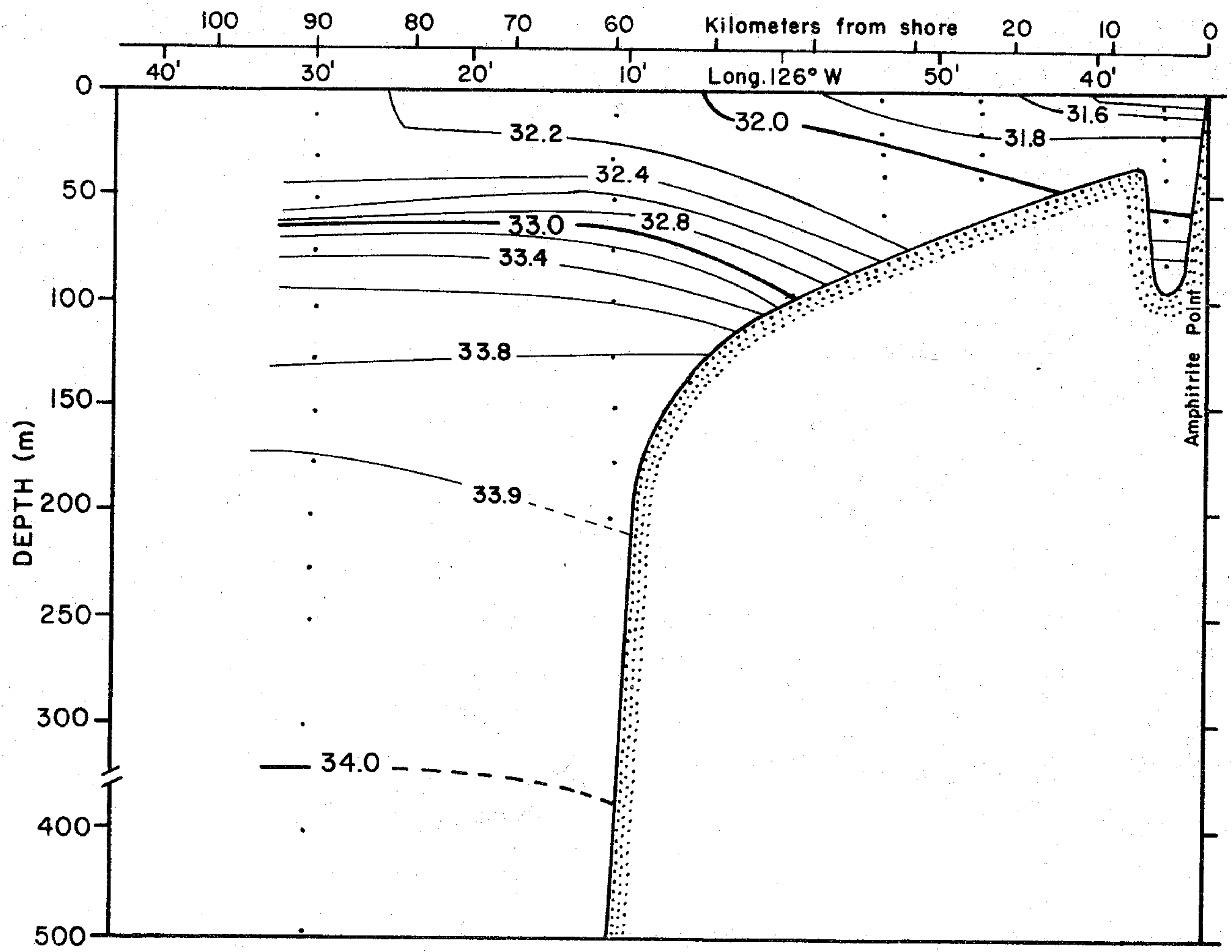

Fig. 89b. Salinity $(^{0}/_{00})$ seaward of Amphitrite Point, March 27, 1962.

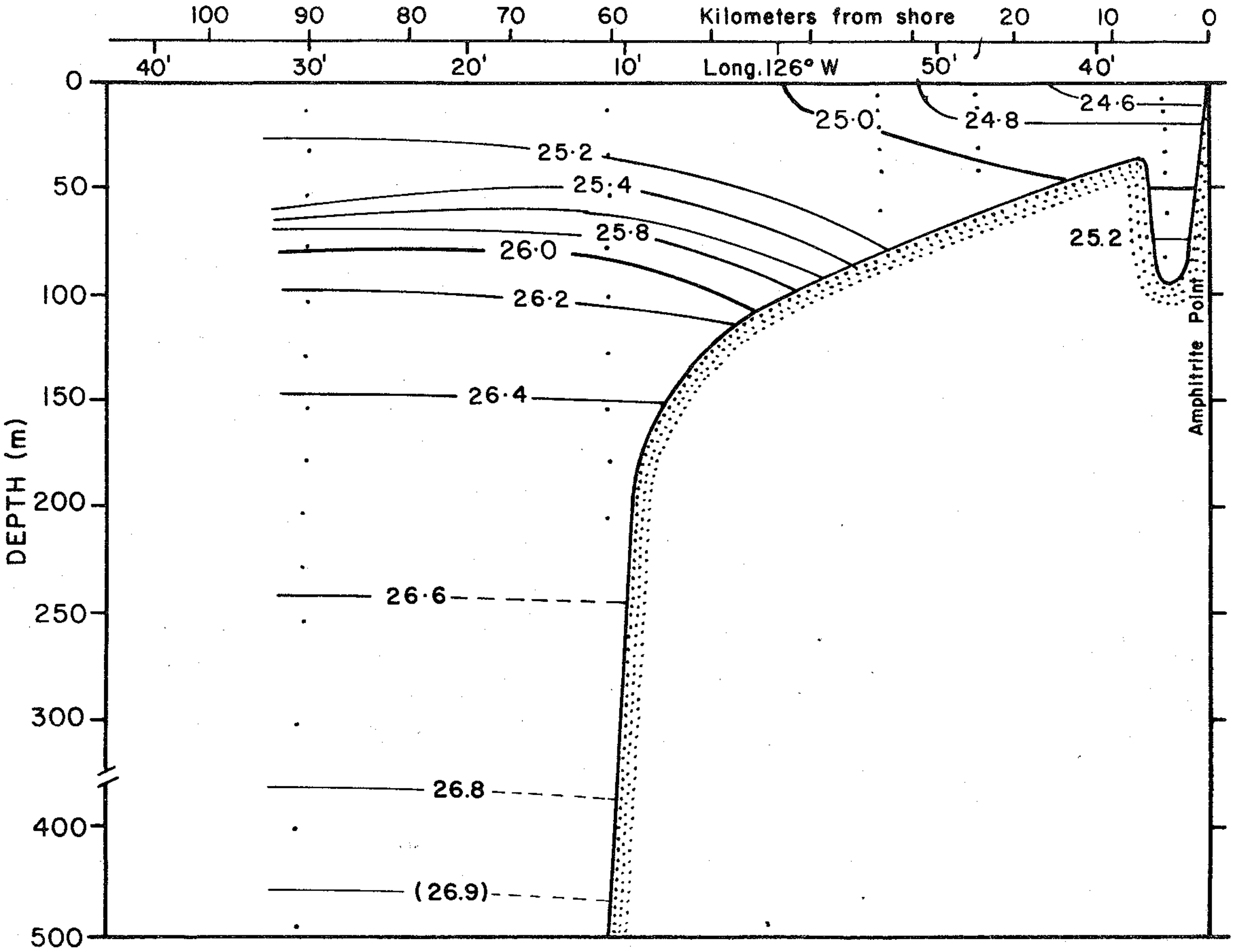

Fig. 89c. Density ($_{t}$) seaward of Amphitrite Point, March 27, 1962.

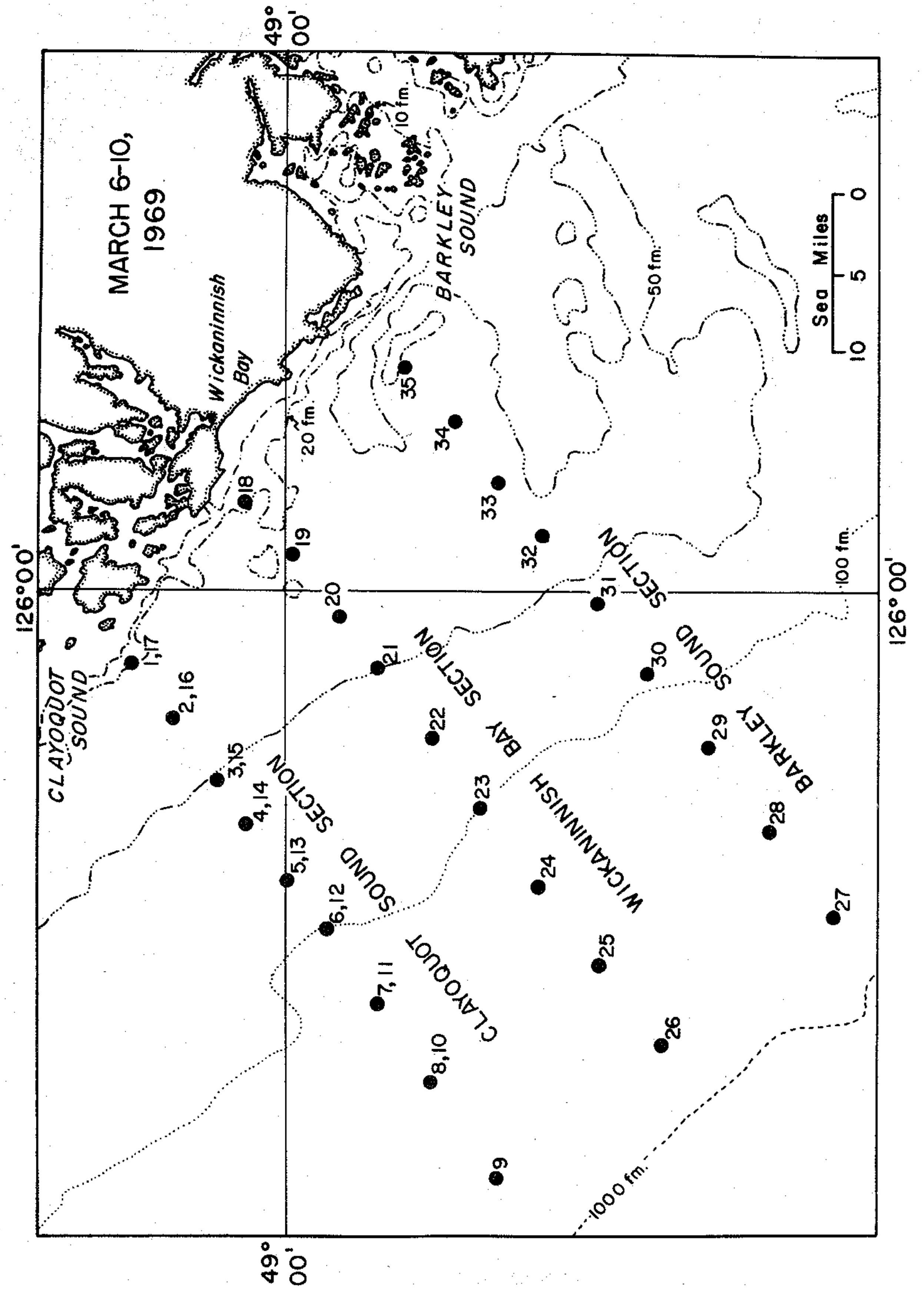

Fig. 90. Station positions, March 6-10, 1969.

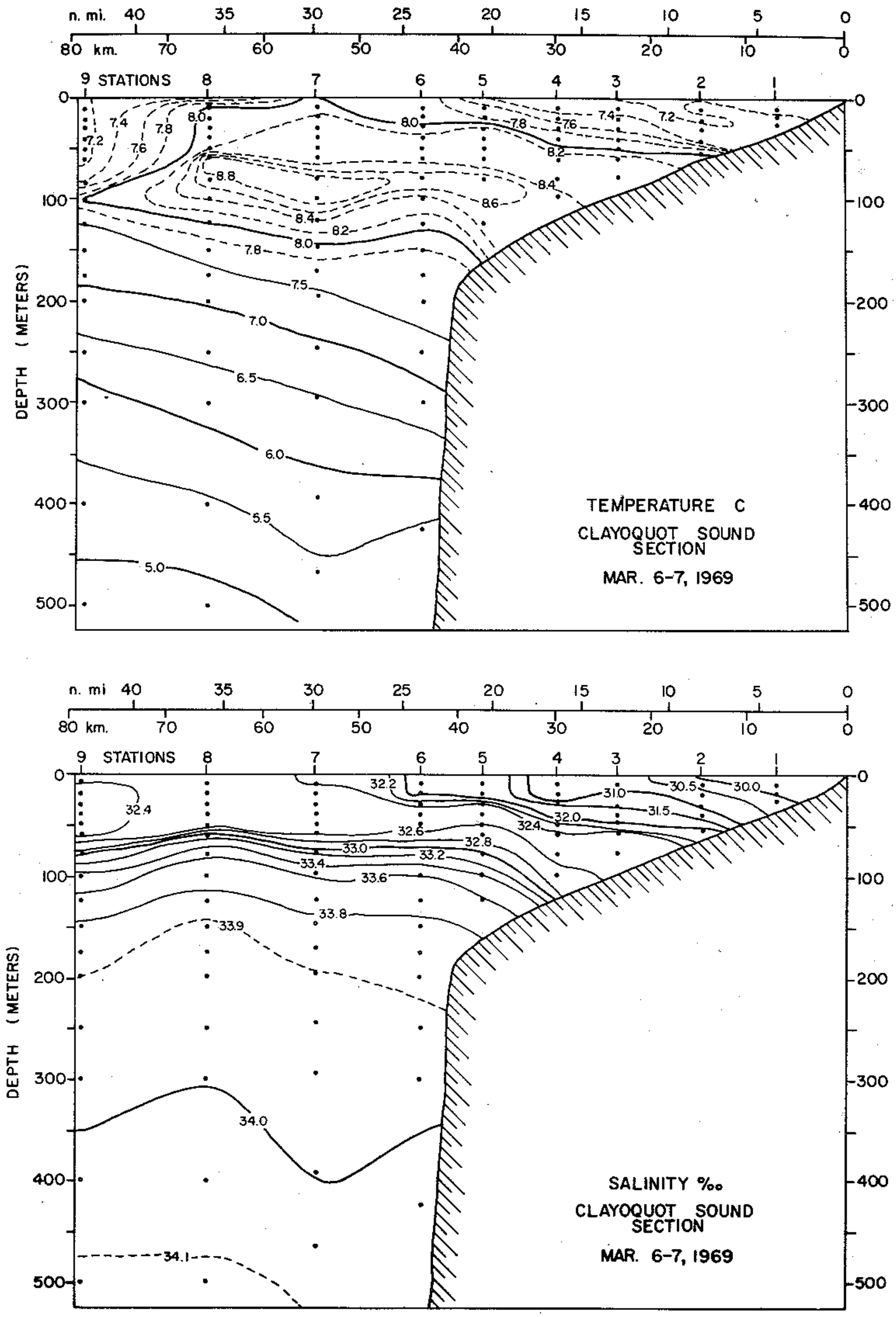

Fig. 91a. Vertical sections of temperature (°C) and salinity (°/oo) seaward of Clayoquot Sound, March 6-7, 1969.

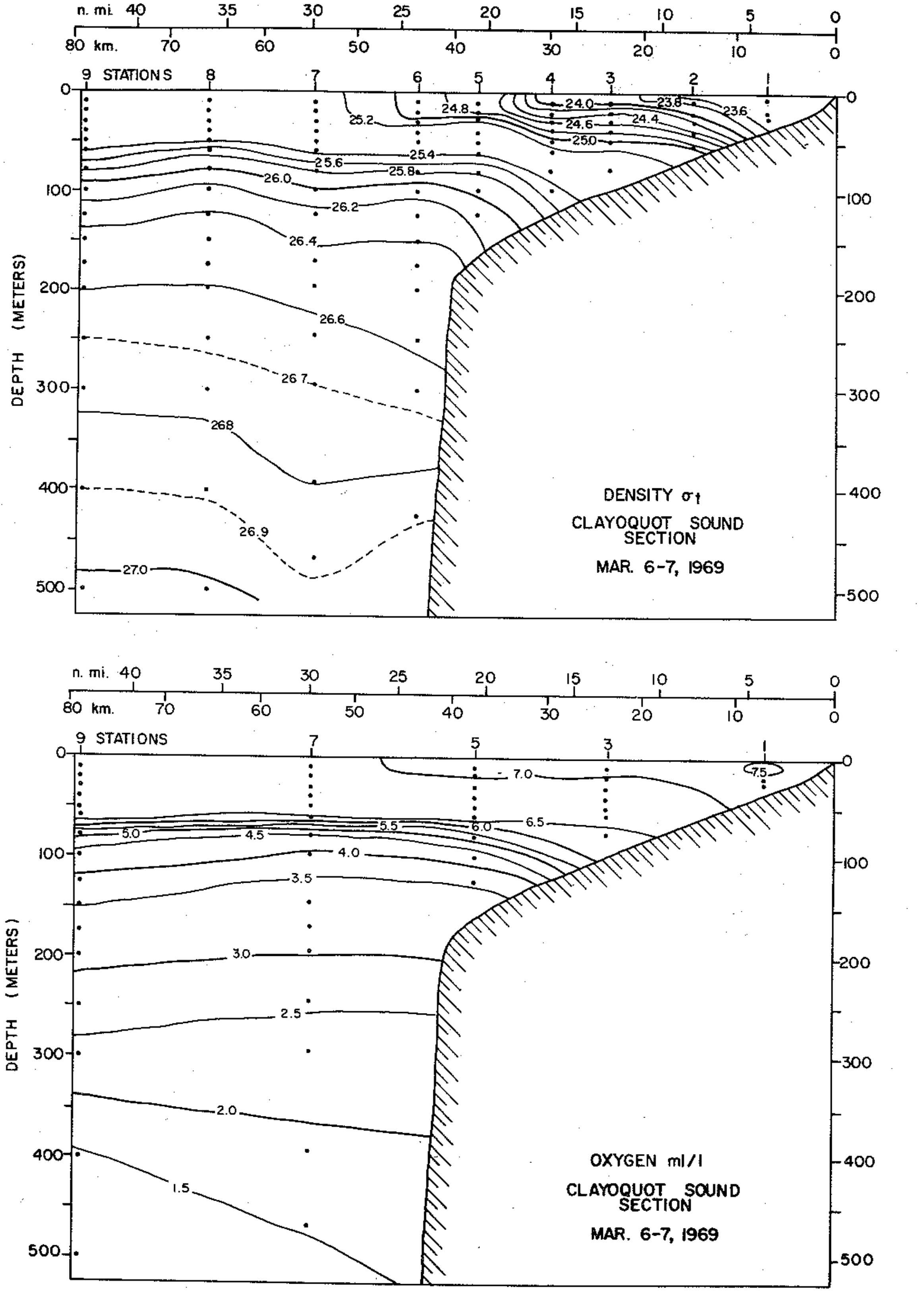

Fig. 91b. Vertical sections of density (σ_t) and dissolved oxygen (mL/L) seaward of Clayoquot Sound, March 6-7, 1969.

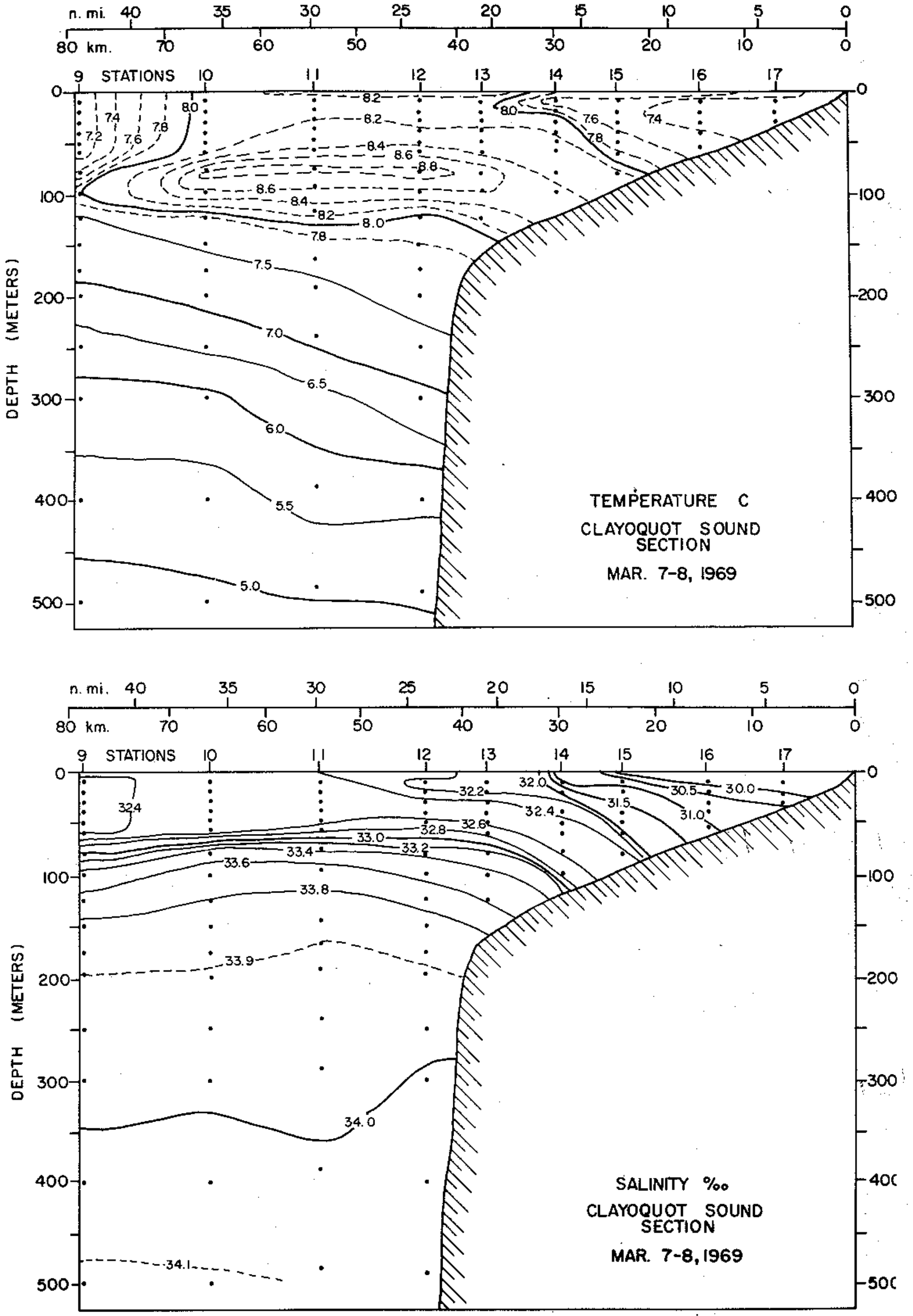

Fig. 92a. Vertical sections of temperature (°C) and salinity (o/oo) seaward of Clayoquot Sound, March 7-8, 1969.

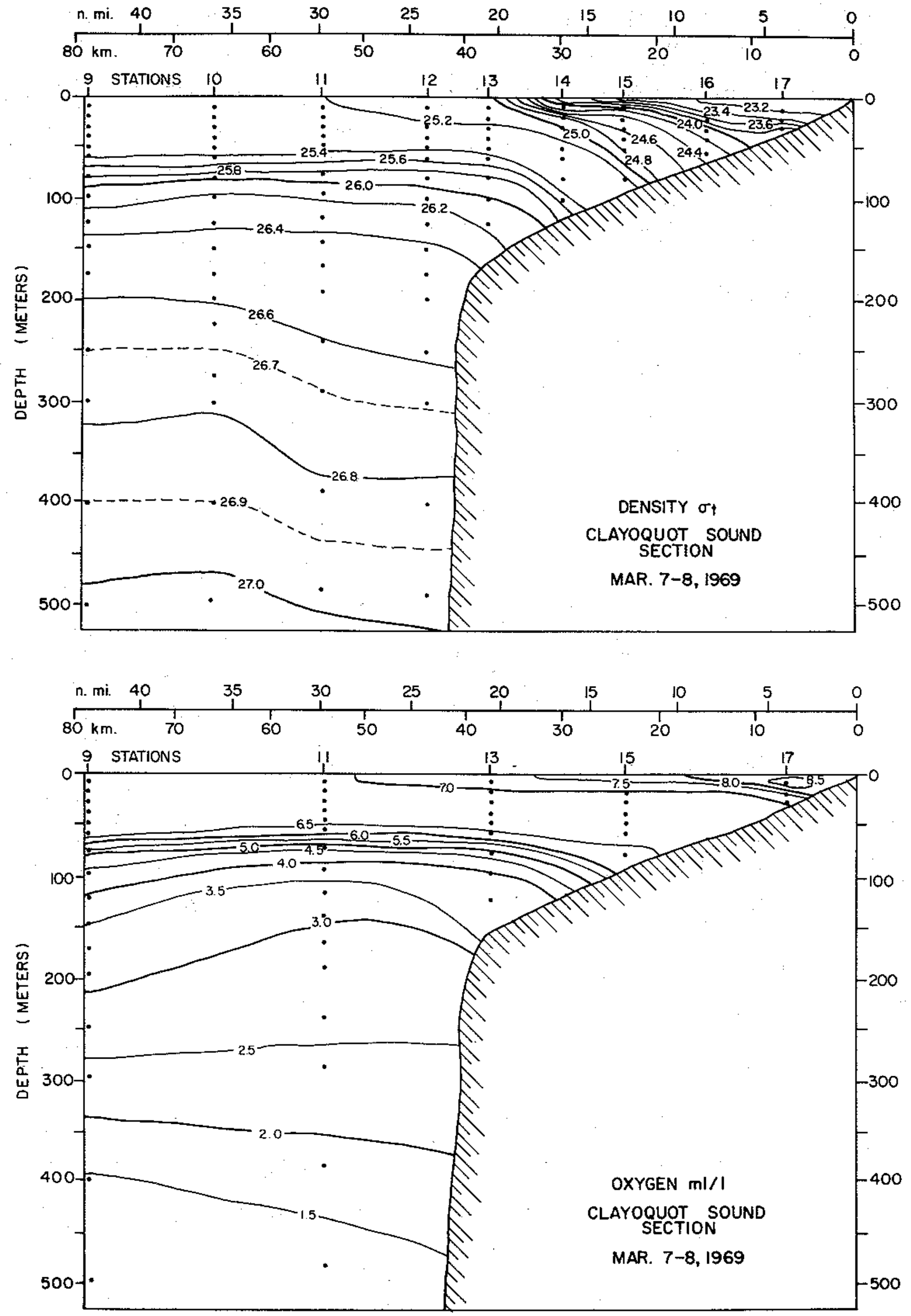

Fig. 92b. Vertical sections of density (σ_t) and dissolved oxygen (mL/L) seaward of Clayoquot Sound, March 7-8, 1969.

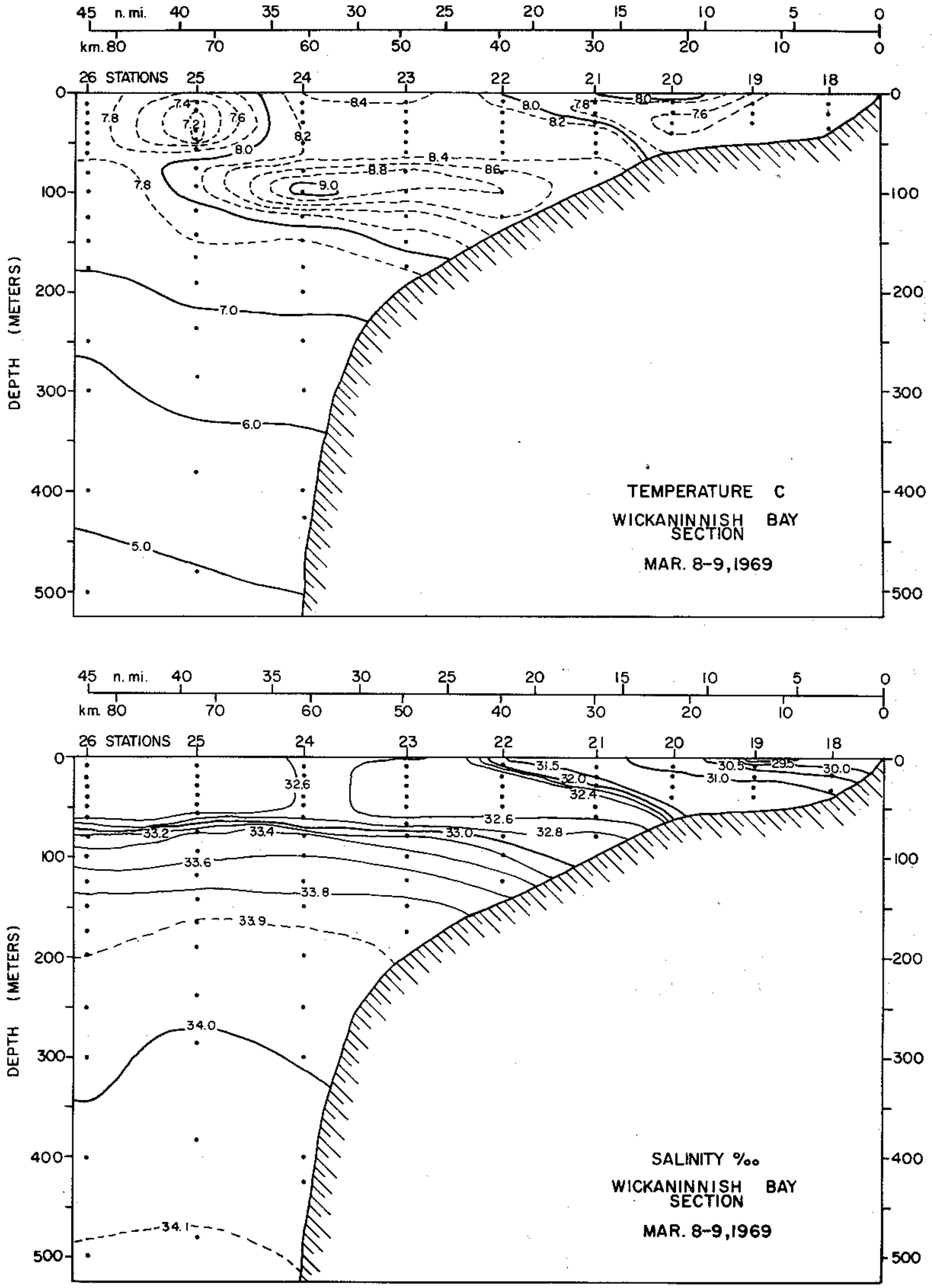

Fig. 93a. Vertical sections of temperature (°C) and salinity (°/oo) seaward of Wickaninnish Bay, March 8-9, 1969.

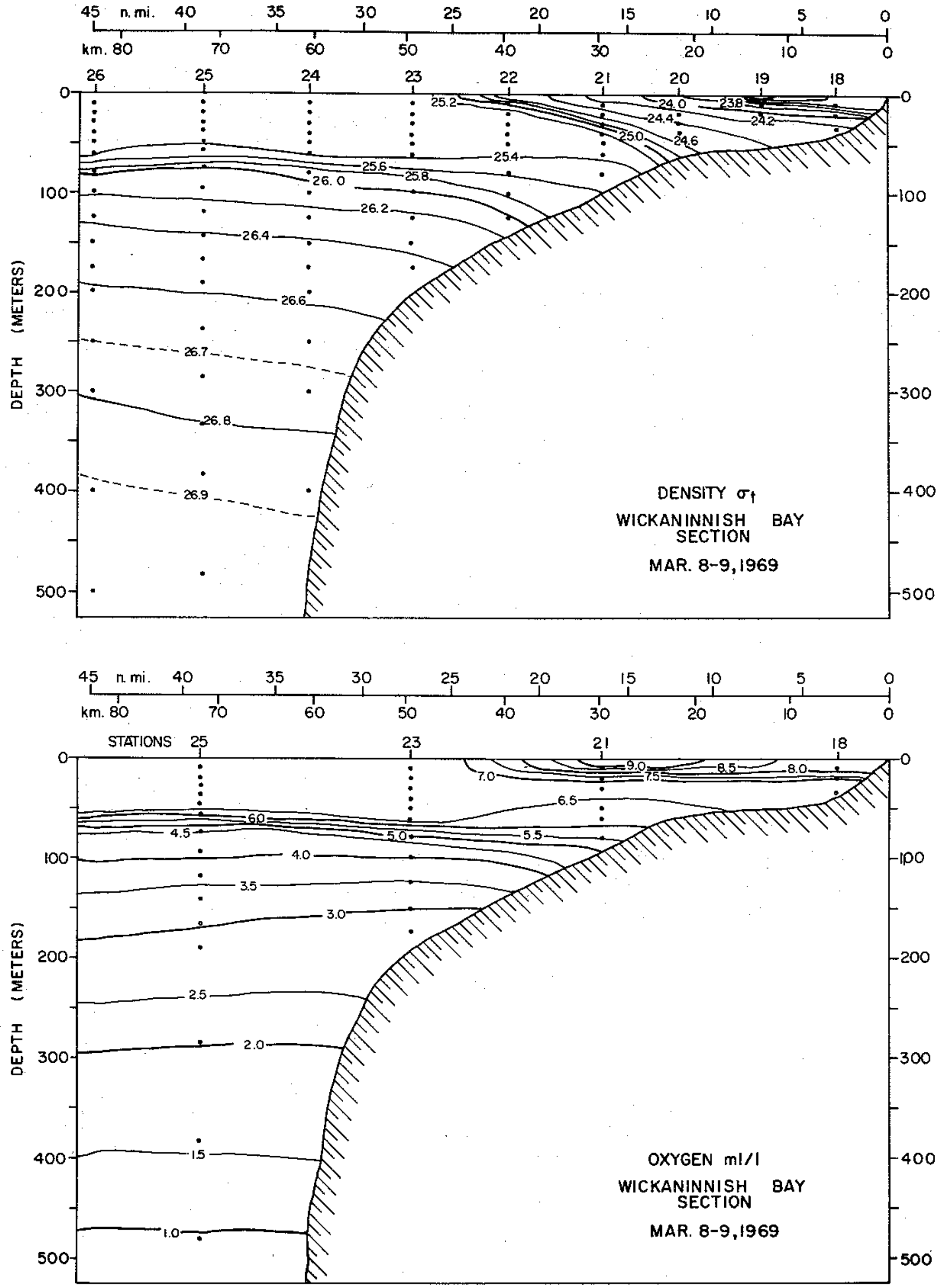

Fig. 93b. Vertical sections of density (σ_t) and dissolved oxygen (mL/L) seaward of Wickaninnish Bay, March 8-9, 1969.

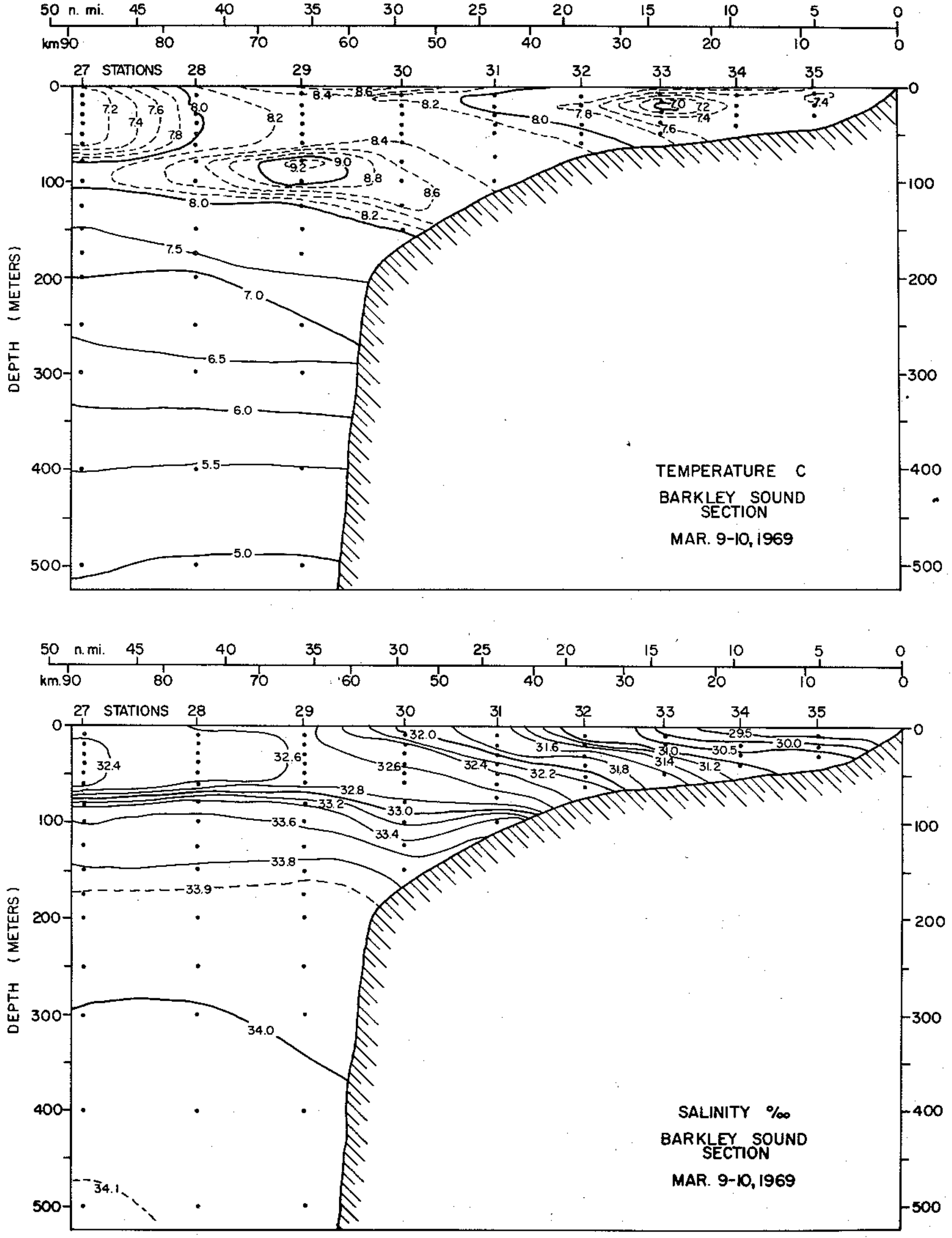

Fig. 94a. Vertical sections of temperature (°C) and salinity (°/oo) seaward of Barkley Sound, March 9-10, 1969.

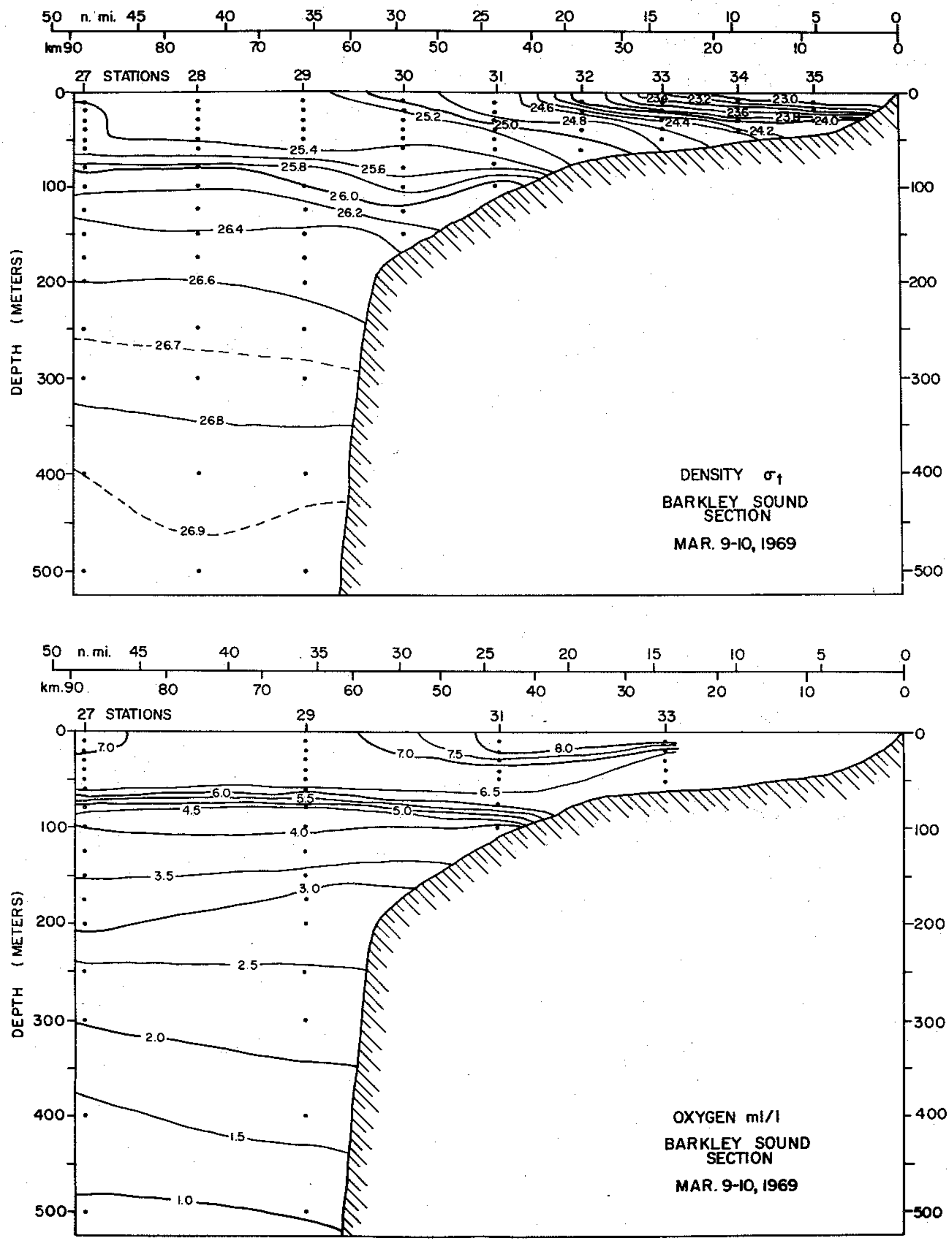

Fig. 94b. Vertical sections of density (σt) and dissolved oxygen (mL/L) seaward of Barkley Sound, March 9-10, 1969.

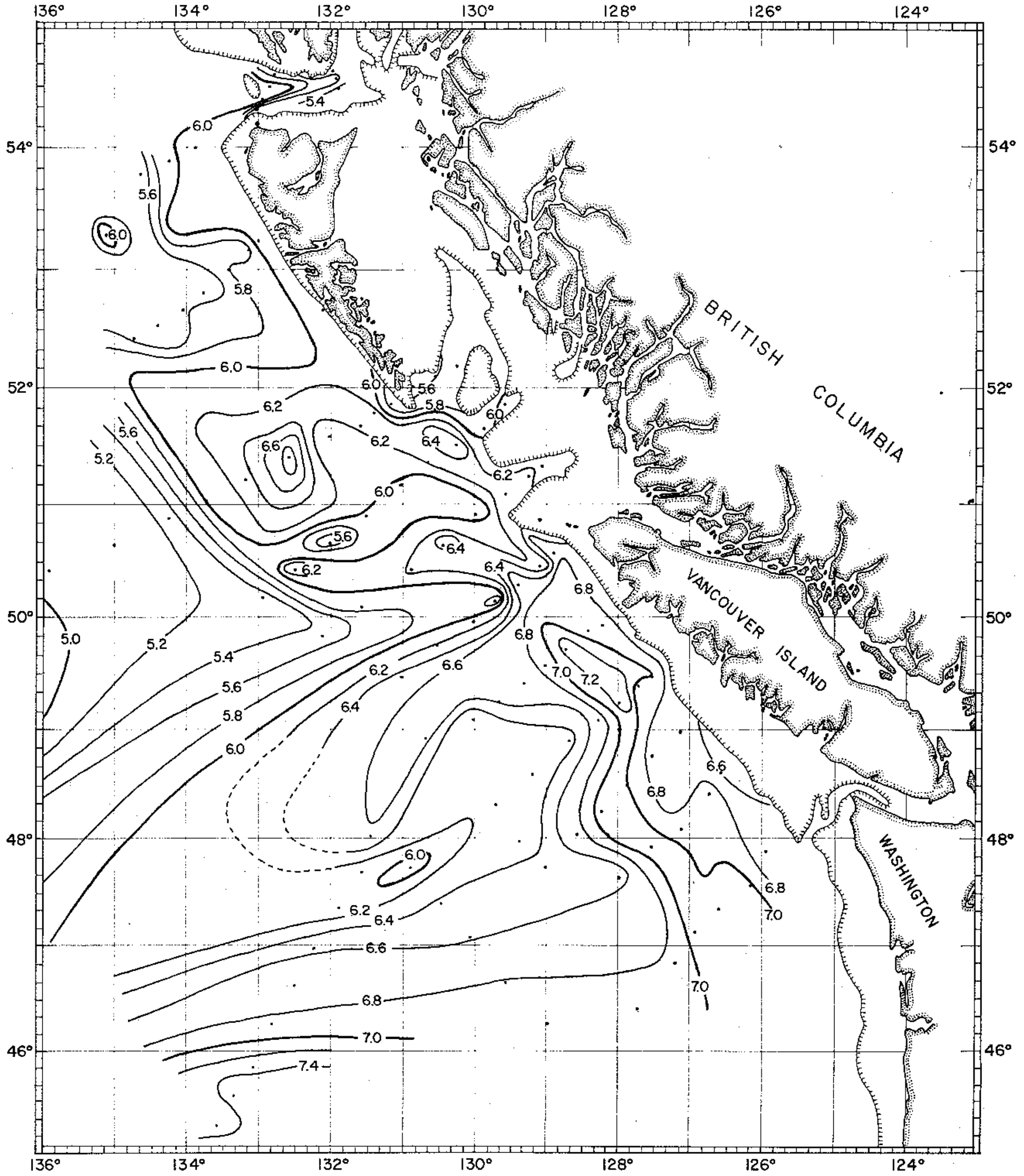

Fig. 95. Temperature (°C) distribution at 200 m depth, September-October, 1967.

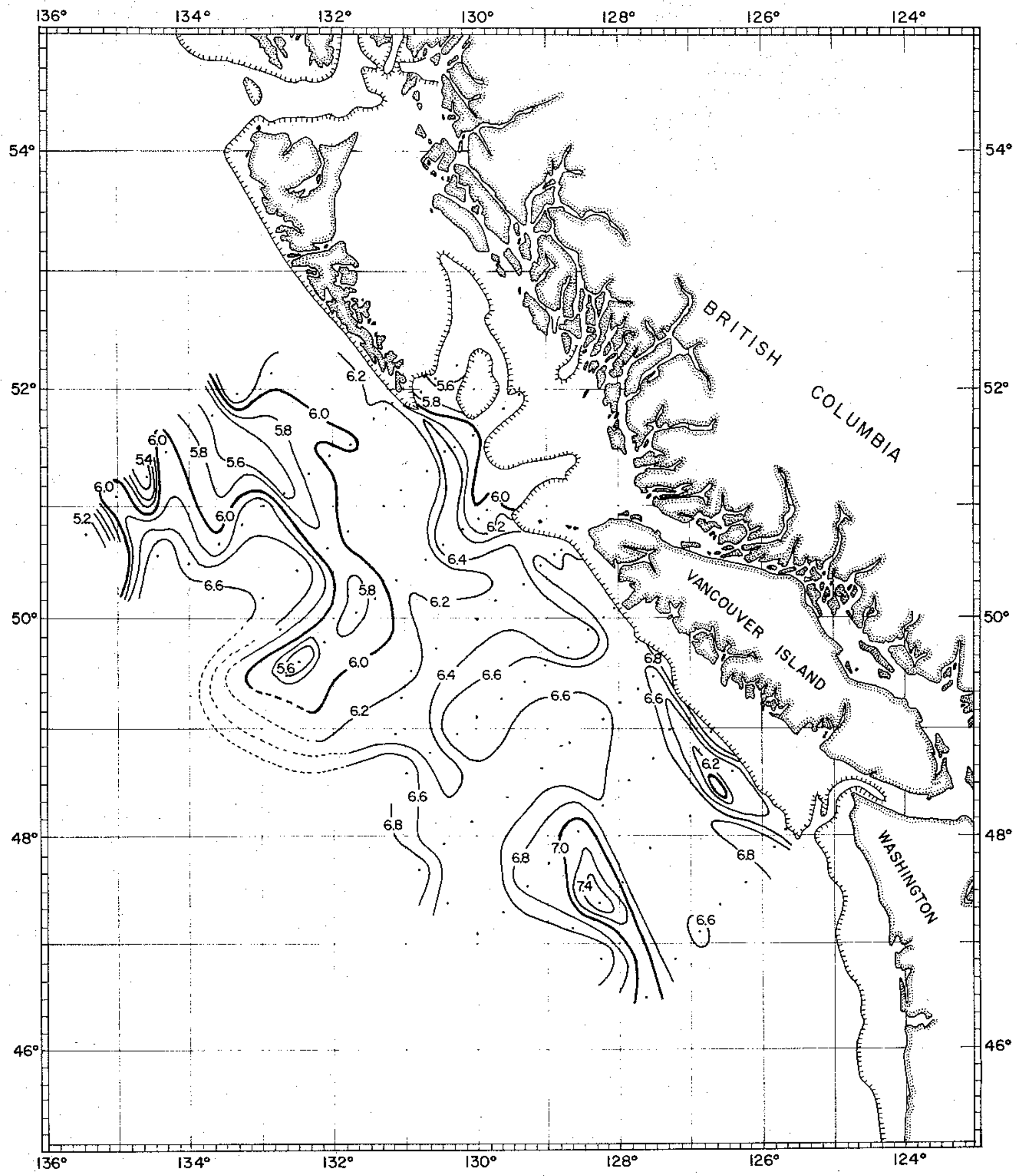

Fig. 96. Temperature (°C) distribution at 200 m depth, October 1968.

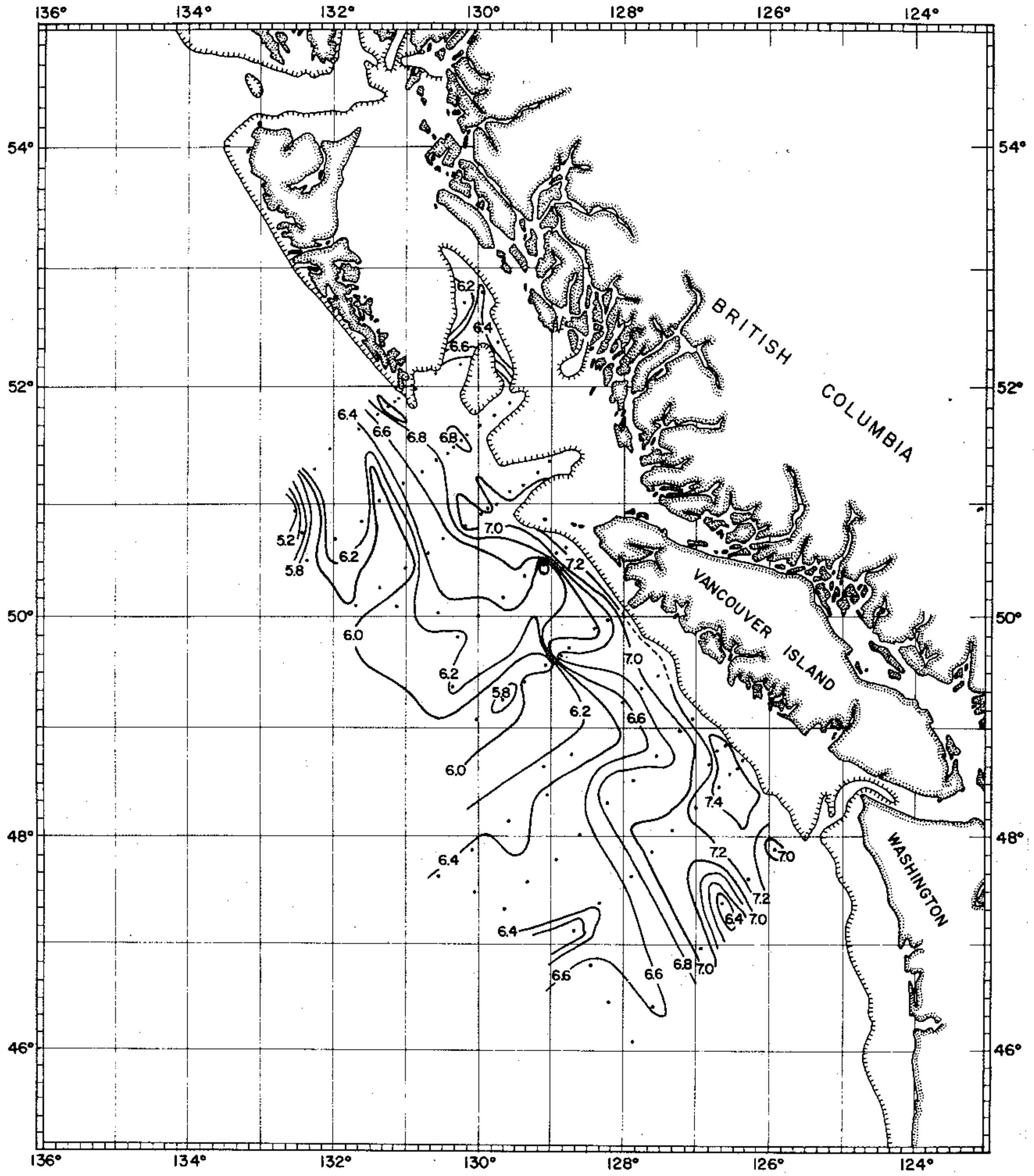

Fig. 97. Temperature (°C) distribution at 200 m depth, April 1969.

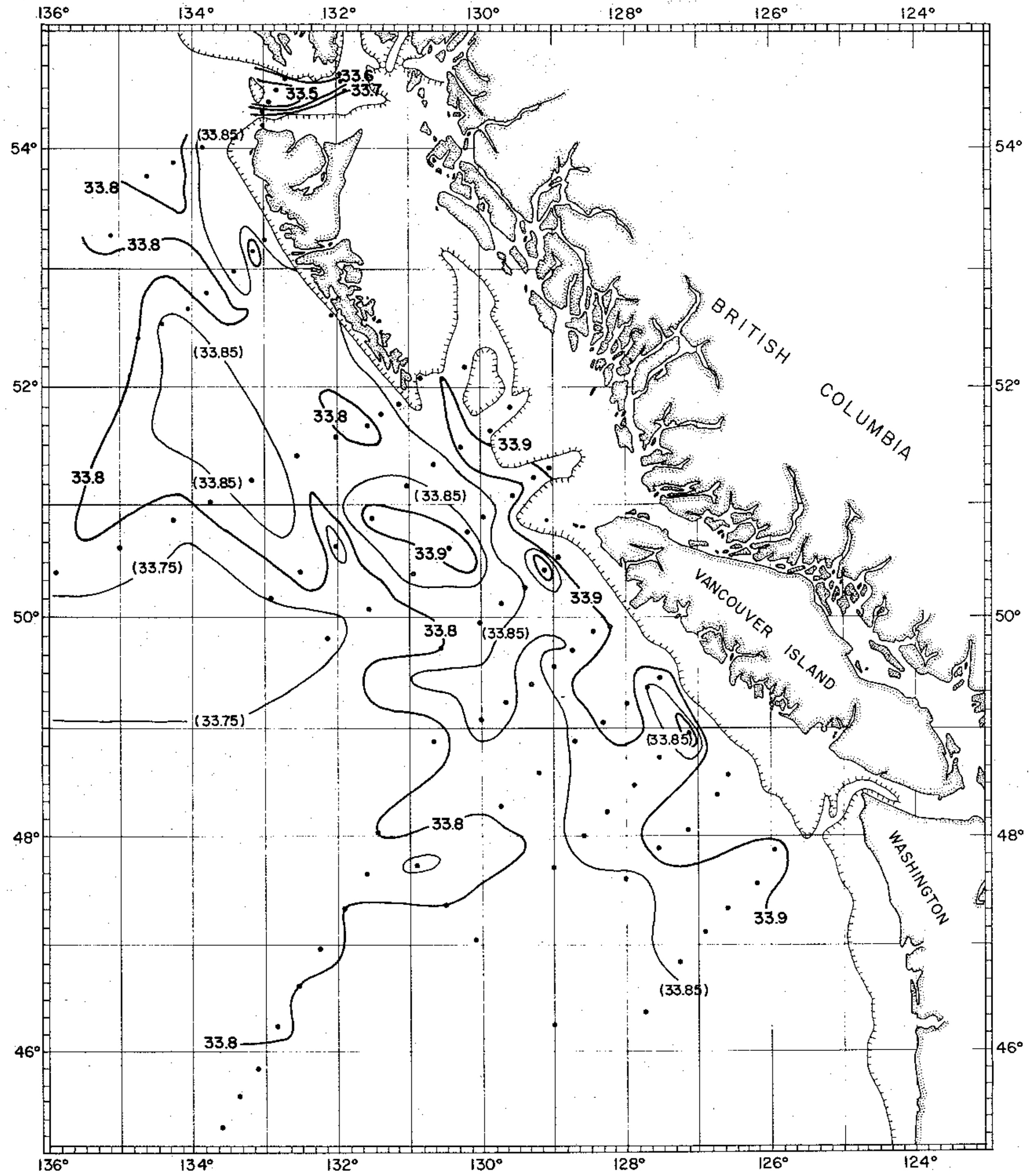

Fig. 98. Salinity (°/oo) distribution at 200 m depth, September-October 1967.

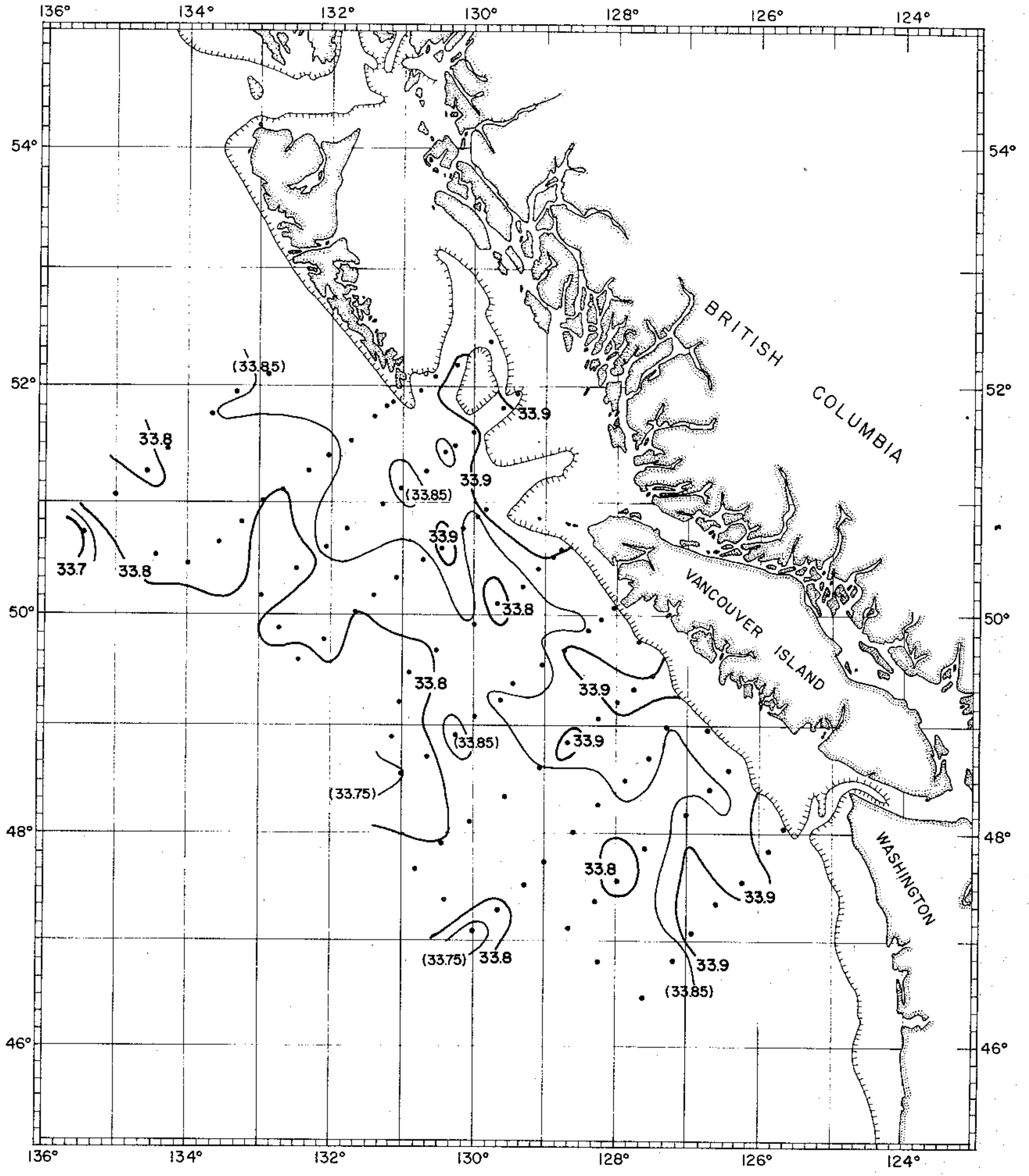

Fig. 99. Salinity (°/oo) distribution at 200 m depth, October 1968.

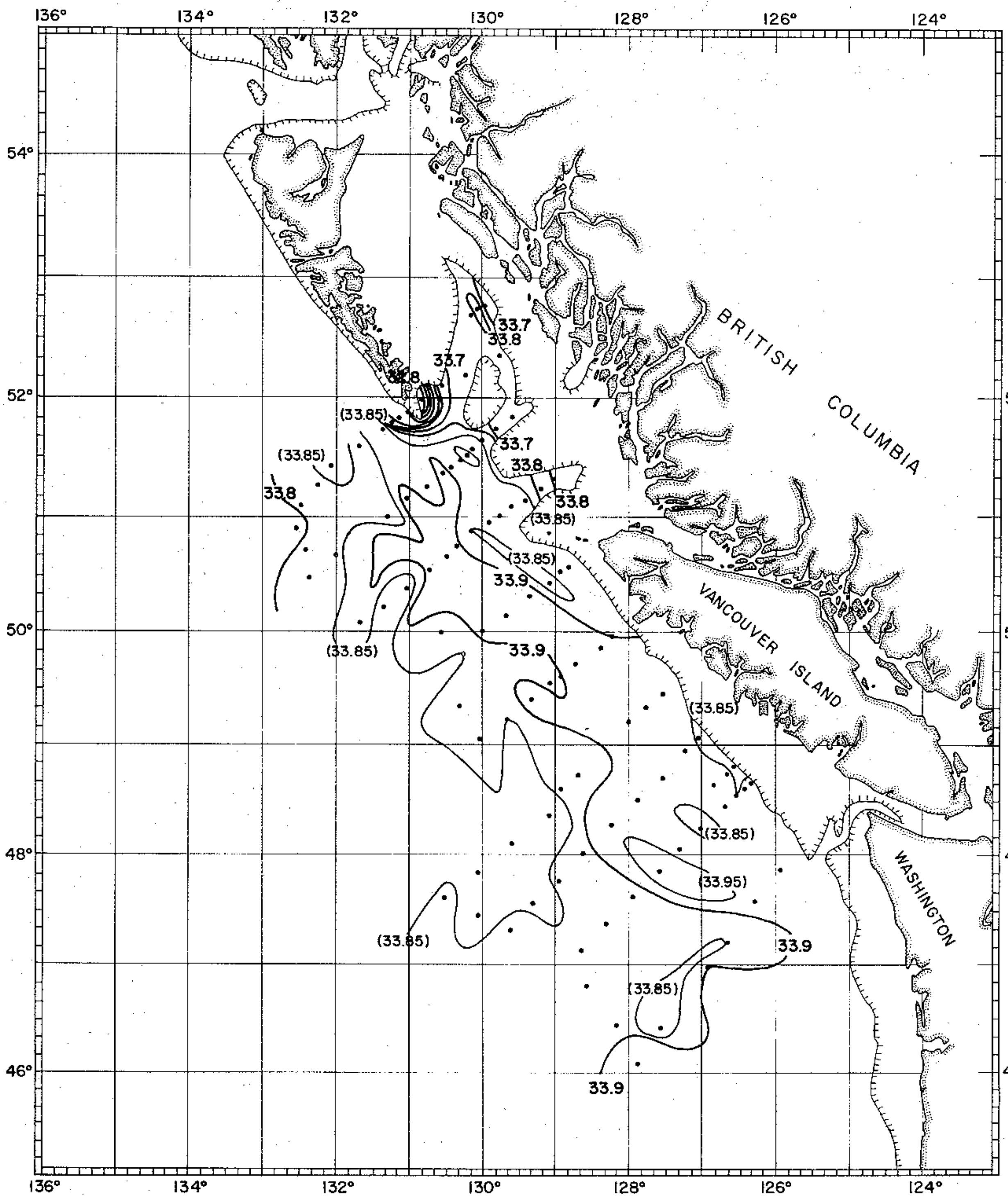

Fig. 100. Salinity (°/oo) distribution at 200 m depth, April 1969.

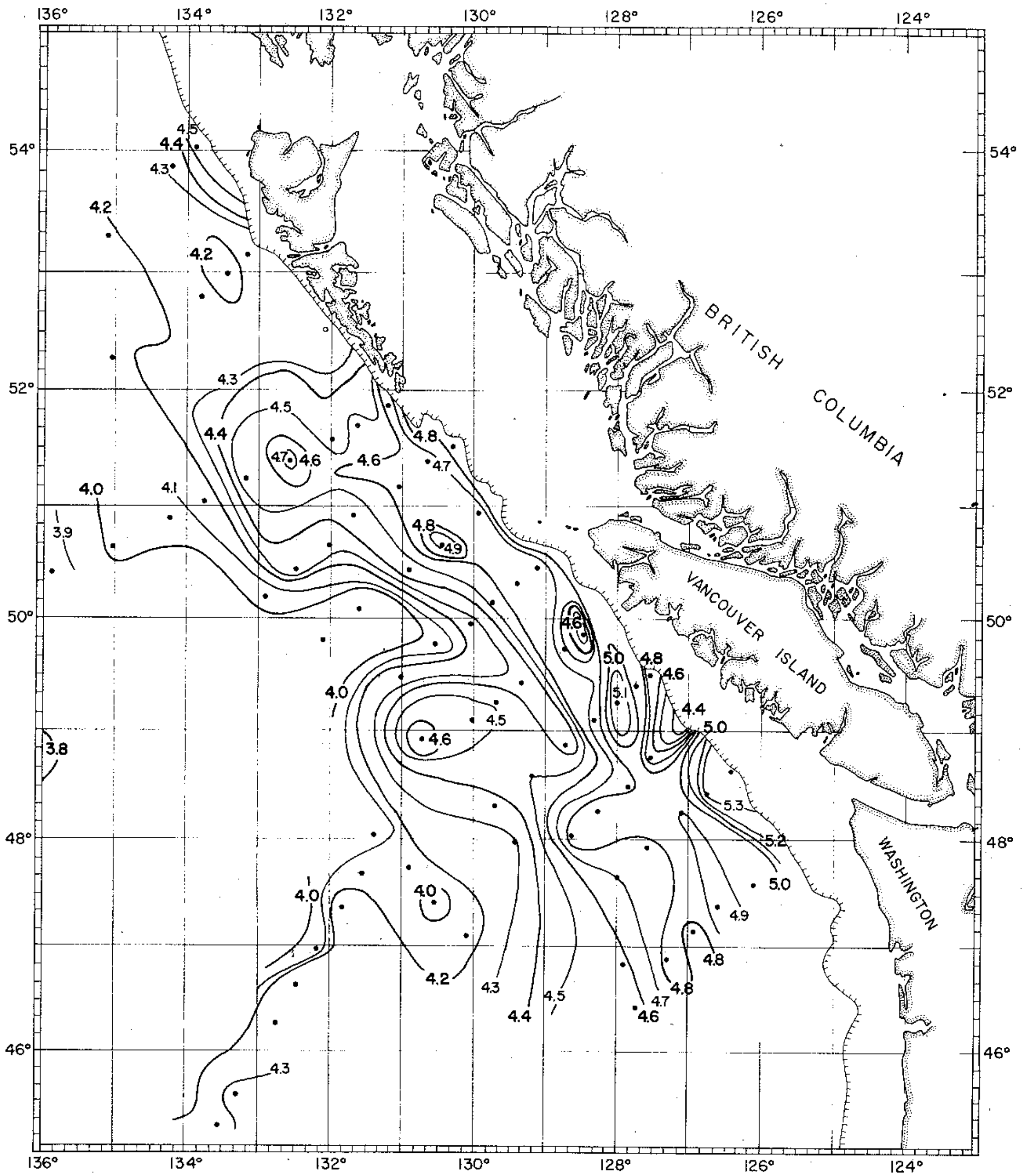

Fig. 101. Temperature (°C) distribution at 500 m depth, September - October 1967.

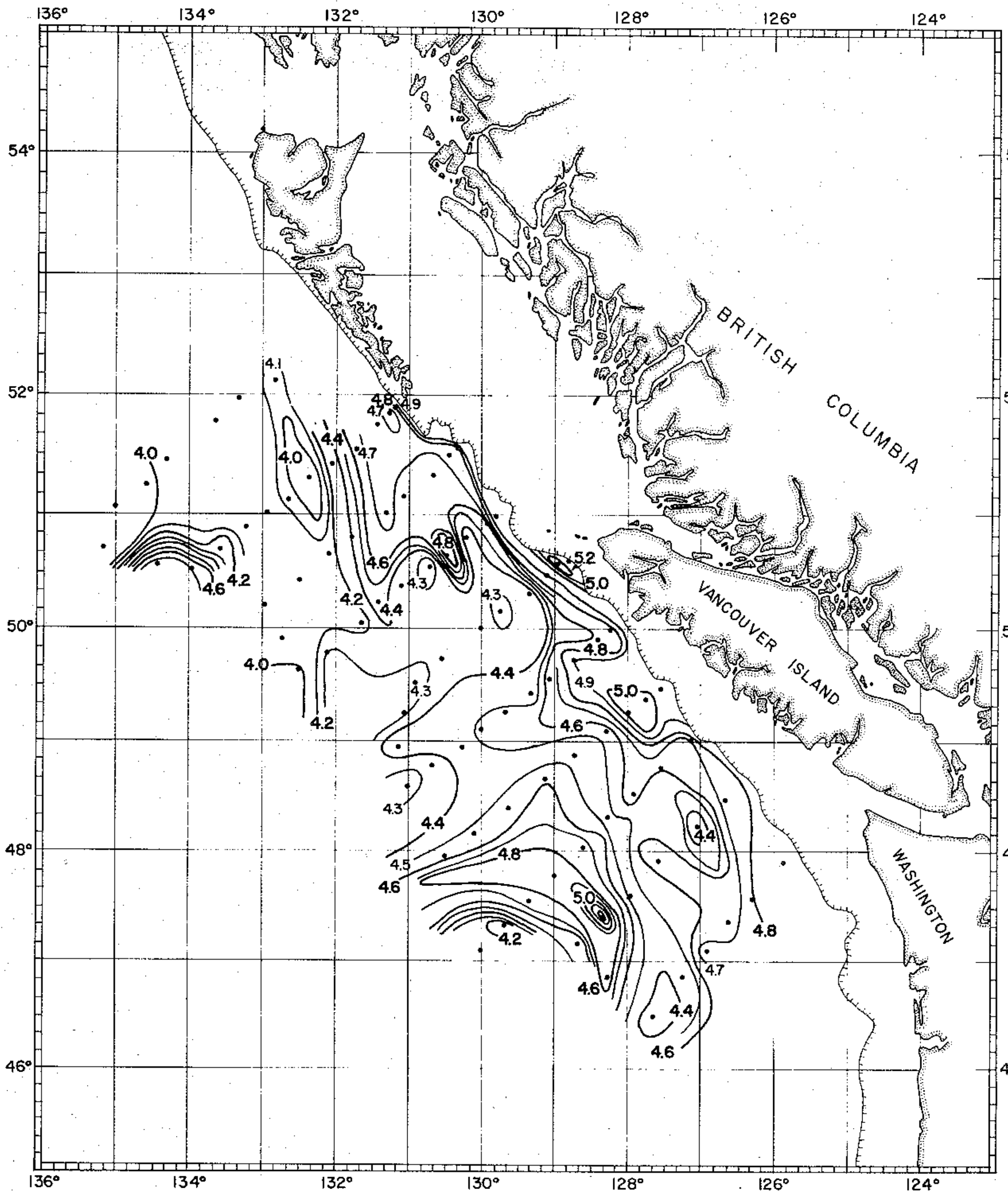

Fig. 102. Temperature (°C) distribution at 500 m depth, October 1968.

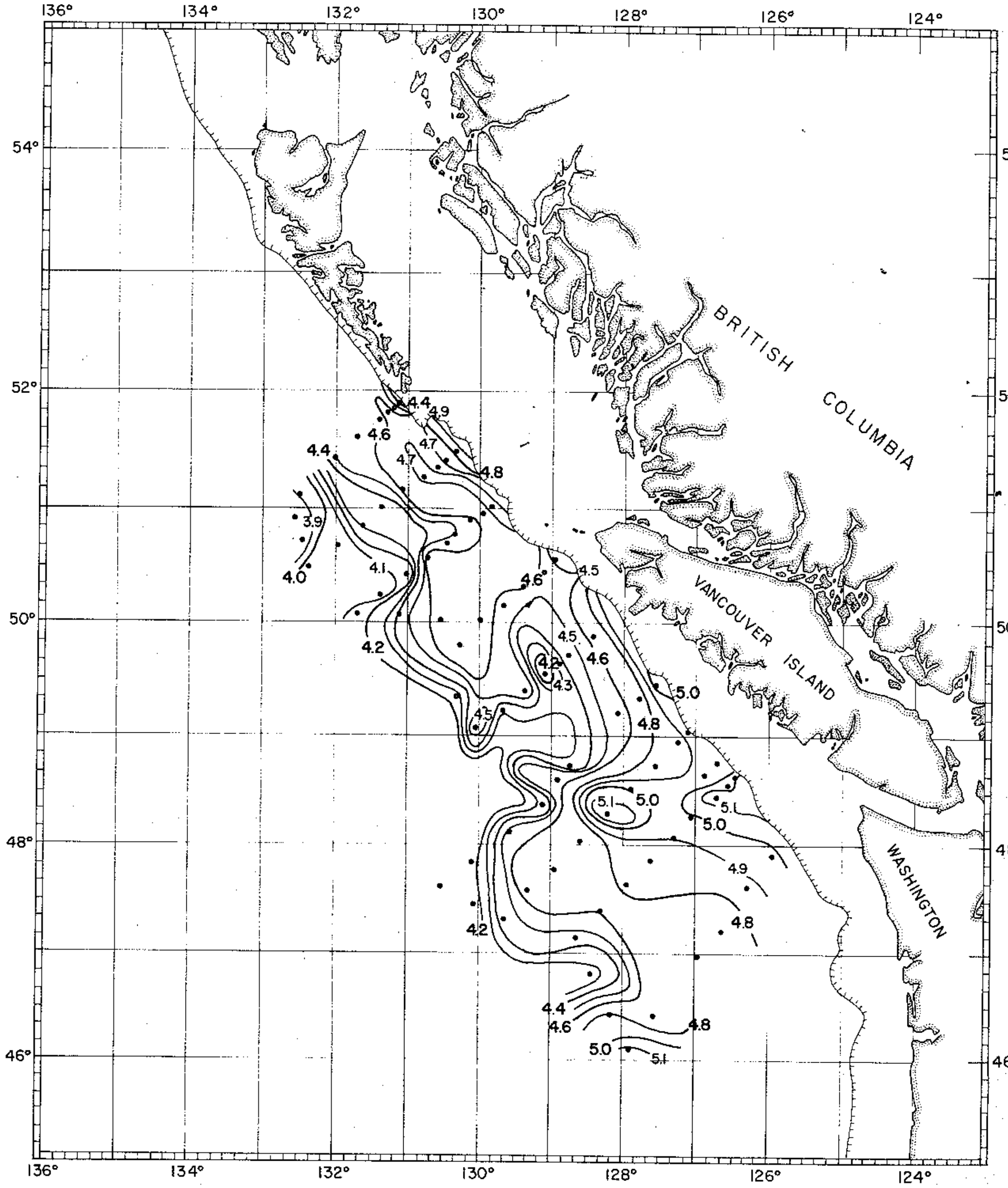

Fig. 103. Temperature (°C) distribution at 500 m depth, April 1969.

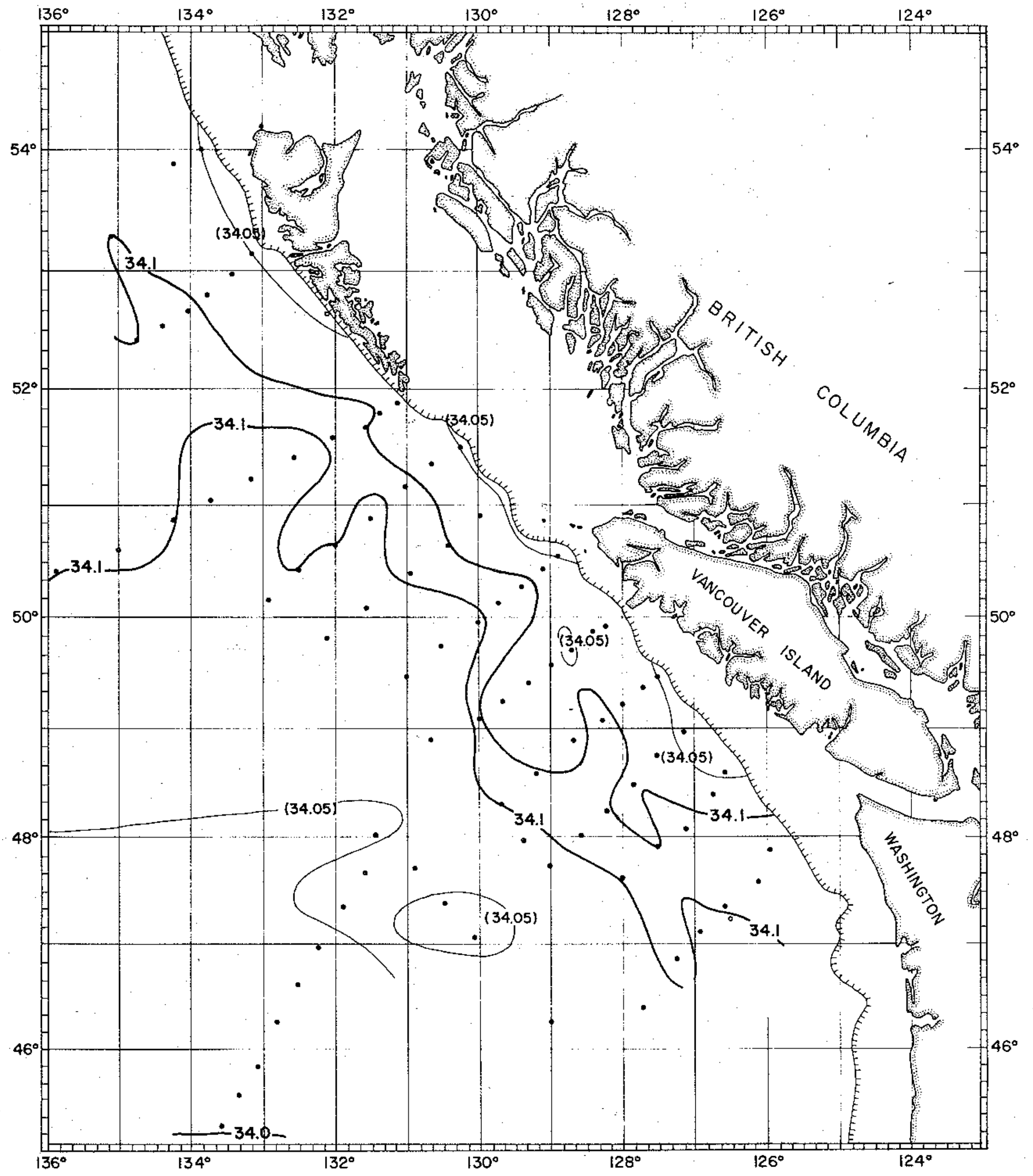

Fig. 104. Salinity (°/oo) distribution at 500 m depth, September - October 1967.

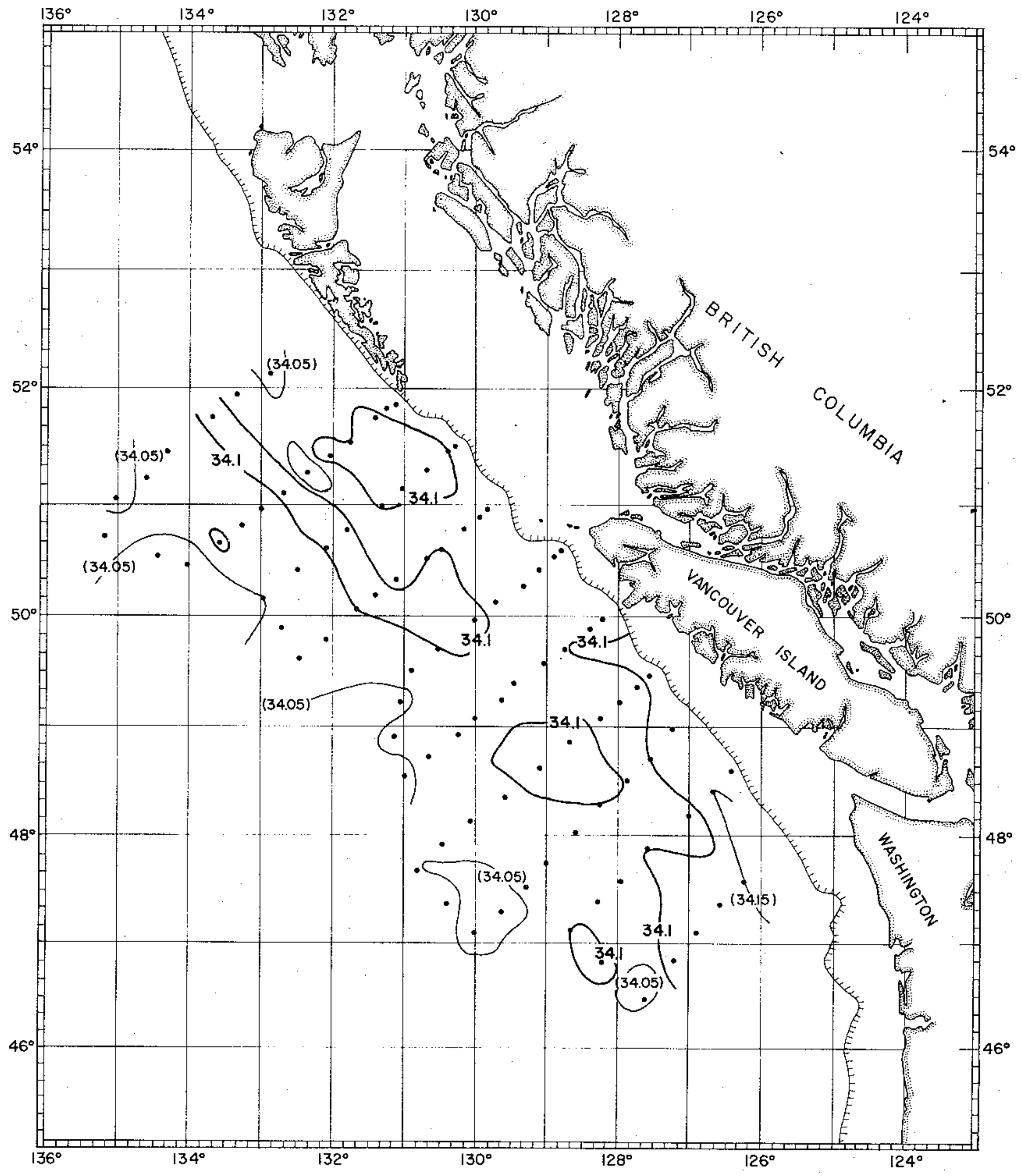

Fig. 105. Salinity (°/oo) distribution at 500 m depth, October 1968.

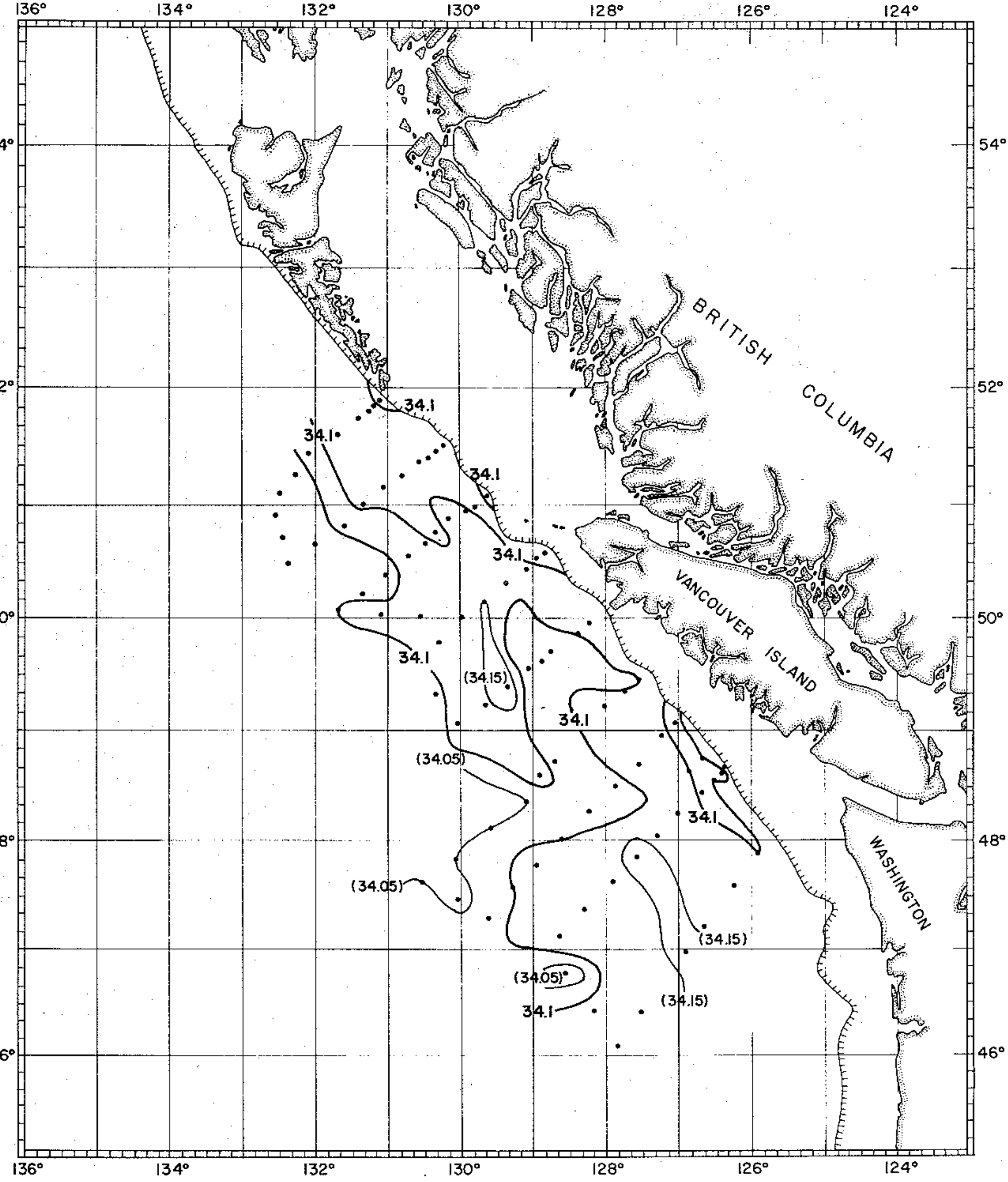

Fig. 106. Salinity ($^0/_{00}$) distribution at 500 m depth, April 1969.

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APPENDIX TABLES

Appendix table 1. Monthly and annual total precipitation (mm), and long-term monthly and annual means and standard deviations, Amphitrite Point, 1958-82.

Apendix table 2. Monthly and annual total precipitation (mm), and long-term monthly and annual means and standard deviations, Cape Scott, 1966-82.

Appendix table 3. Monthly and annual precipitation anomalies (mm) (A), and the number of standard deviations (N) in the anomalies, Amphitrite Point, 1958-82.

Appendix table 4. Monthly and annual precipitation anomalies (mm) (A), and the number of standard deviations (N) in the anomalies, Cape Scott, 1966-82.

Appendix table 5. Monthly and annual mean discharge (cu m/sec) and long-term monthly and annual means and standard deviations for the Somass-Stamp River system, 1957-81.

Appendix table 6. Monthly and annual discharge anomalies (cm m/sec) (A) and the number of standard deviations (N) in the anomalies for the Somass-Stamp River system, 1957-81.

Appendix table 7. Ekman transport (cu m/sec/100 m) normal to the coast and anomalies (A) at 48°N, 125°W, 1946-82. + onshore transport, - offshore transport. (Transport values are from Bakum (1973) and from National Marine Fisheries Service, Monterey, CA., but with the signs reversed. Positive anomalies in Oct-Mar indicate above-average onshore transports; negative anomalies in Apr-Sep, above-average offshore transports. Anomalies are calculated from the 1946-80 long-term monthly means.

Appendix table 8. Ekman transport (cu m/sec/100 m) normal to the coast and anomalies (A) at 51°N, 131°W, 1946-82 + onshore transport, - offshore transport. (Transport values are from Bakun (1973) and from National Marine Fisheries Service, Monterey, CA., but with signs reversed. Positive anomalies in Sep-Apr indicate above-average onshore transports; negative anomalies in May-Aug, above-average offshore transports.)

Appendix table 9. Number of standard deviations in the monthly Ekman transport anomalies at 48°N, 125°W (A) and 51°N, 131°W (B). Positive (negative) values in October-March indicate above-average (below-average) onshore transport; negative (positive) values in June-August indicate above-average (below-average) offshore transport.

Appendix table 10. Unadjusted monthly mean sea level (cm) and anomalies (A), Tofino, B.C., 1940-82. (Long-term means and anomalies provided by National Marine Fisheries Service, Monterey, CA.)

Appendix table 11. Adjusted monthly mean sea level (cm) and anomalies (A), Tofino, B.C., 1946-81. (Values provided by National Marine Fisheries Service, Monterey, CA.)

Appendix table 12. Number of standard deviations in the unadjusted (U) and adjusted (A) monthly sea level anomolies, Tofino, B.C., 1940-82.

Appendix table 13. Monthly and annual mean sea surface temperatures (°C) and anomalies (A), Amphitrite Point, 1934-83.

Appendix table 14. Monthly and annual mean sea surface temperatures (°C) and anomalies (A), Kains Island, 1935-83.

Appendix table 15. Number of standard deviations in the monthly and annual sea surface temperature anomalies, Amphitrite Point (A) and Kains Island (K), 1935-82.

Appendix table 16. Monthly and annual surface salinity (°/oo) anomalies (A) and the number of standard deviations (N) in the anomalies, Amphitrite Point, 1935-82.

Appendix table 17. Monthly and annual surface salinity (°/oo) anomalies (A) and the number of standard deviations (N) in the anomalies, Kains Island, 1935-82.

Appendix table 1. Monthly and annual total precipitation (mm), and long-term monthly and annual means and standard deviations, Amphitrite Point, 1958-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1958	505	410	182	153	45	48	5	23	104	321	307	473	2578
1959	421	357	496	192	52	122	81	70	202	239	266	395	2894
1960	441	327	230	305	243	67	11	130	153	438	429	260	3033
1961	523	886	432	246	137	107	47	110	132	377	345	411	3755
1962	492	164	239	440	77	119	26	288	125	426	726	642	3764
1963	36	337	280	207	145	57	138	40	90	535	476	522	2863
1964	554	320	351	262	163	132	309	117	302	208	352	239	3310
1965	310	374	78	207	110	30	28	88	53	562	542	449	2832
1966	599	215	414	98	69	148	33	102	167	314	446	739	3344
1967	630	402	430	115	119	21	48	67	106	870	253	516	3579
1968	584	295	367	186	92	111	70	137	227	521	439	451	3482
1969	270	246	391	280	90	27	33	155	265	218	493	383	2852
1970	257	120	190	224	102	40	72	44	181	200	339	456	2227
1971	481	298	459	193	83	163	29	97	194	454	384	418	3254
1972	280	381	675	275	54	81	174	34	112	76	379	535	3057
1973	635	280	308	61	226	188	59	41	113	401	442	551	3306
1974	372	598	503	224	252	104	139	8	96	131	388	584	3400
1975	353	275	200	124	138	102	15	284	19	634	528	378	3051
1976	446	343	397	147	178	127	114	172	98	271	122	284	2700
1977	241	359	324	193	216	89	83	80	112	339	467	361	2866
1978	308	238	265	167	164	83	10	267	260	150	290	307	2510
1979	185	485	252	142	113	85	75	57	241	239	242	537	2653
1980	249	303	256	208	97	90	113	50	289	170	537	819	3181
1981	164	304	276	419	149	298	16	80	244	372	501	498	3321
1982	535	634	213	212	62	55	64	62	113	423	423	436	3232
Mean 1958-82	395	358	328	211	127	100	72	104	160	320	404	467	3075
Std Dev	161	159	130	88	60	59	67	78	76	155	127	141	395

Appendix table 2. Monthly and annual total precipitation (mm), and long-term monthly and annual means and standard deviations, Cape Scott, 1966-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1966	461	237	352	119	216	96	40	183	169	409	323	446	3053
1967	432	348	228	65	218	31	122	73	407	603	206	418	3151
1968	470	167	271	345	70	120	93	91	228	656	421	338	3272
1969	195	232	208	362	117	31	83	257	213	326	506	384	2915
1970	255	147	240	253	233	36	119	104	211	278	224	320	2420
1971	725	238	324	226	110	212	42	173	184	424	427	283	3370
1972	248	285	279	295	88	127	72	32	105	136	272	287	2227
1973	537	152	214	212	199	108	75	36	235	380	277	350	2775
1974	478	409	223	232	205	172	84	28	50	224	322	499	2972
1975	231	157	212	148	129	141	59	234	56	432	591	362	2754
1976	328	299	311	181	324	187	195	151	124	355	298	431	3187
1977	146	328	429	214	162	98	120	53	145	376	389	206	2665
1978	118	206	406	103	118	51	18	183	259	314	337	335	2448
1979	151	320	172	123	159	106	98	12	383	212	246	481	2463
1980	261	184	266	209	102	60	61	82	365	243	477	437	2747
1981	231	260	258	282	129	178	10	110	320	216	605	248	2847
1982	455	309	132	170	119	33	71	57	206	371	195	337	2455
Mean 1966-82	337	252	266	208	159	105	86	109	215	349	370	364	2807
Std Dev	167	77	79	83	65	59	48	75	107	139	125	84	334

Appendix table 3. Monthly and annual precipitation anomalies (mm) (A), and the number of standard deviations (N) in the anomalies, Amphitrite Point, 1958-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1958 A	110	52	-146	-58	-82	-52	-67	-81	-56	1	-97	6	-497
N	0.7	0.3	-1.1	-0.7	-1.4	-0.9	-1.0	-1.0	-0.7	0	-0.8	0	-1.3
1959 A	26	-1	168	-19	-75	22	9	-34	42	-81	-138	-72	-181
N	0.2	0	1.3	-0.2	-1.2	0.4	0.1	-0.4	0.5	-0.5	-1.1	-0.5	-0.5
1960 A	46	-31	-98	94	116	-33	-61	26	-7	118	25	-207	-42
N	0.3	-0.2	-0.7	1.1	1.9	-0.6	-0.9	0.3	-0.1	0.8	0.2	-1.5	-0.1
1961 A	128	528	104	35	10	7	-25	6	-28	57	-59	-56	680
N	0.8	3.3	0.8	0.4	0.2	0.1	-0.4	0.1	-0.4	0.4	-0.5	-0.4	1.7
1962 A	97	-194	-89	229	-50	19	-46	184	-35	106	322	175	689
N	0.6	-1.2	-0.7	2.6	-0.8	0.3	-0.7	2.4	-0.5	0.7	2.5	1.2	1.7
1963 A	-359	-21	-48	-4	18	-43	66	-64	-70	215	72	55	-212
N	-2.2	-0.1	-0.4	-0	0.3	-0.7	1.0	-0.8	-0.9	1.4	0.6	0.4	-0.5
1964 A	159	-38	23	51	36	32	237	13	142	-112	-52	-228	235
N	1.0	-0.2	0.2	0.6	0.6	0.5	3.5	0.2	1.9	-0.7	-0.4	-1.6	0.6
1965 A	-85	16	-250	-4	-17	-70	-44	-16	-107	242	138	-18	-243
N	-0.5	0.1	-1.9	-0	-0.3	-1.2	-0.7	-0.2	-1.4	1.6	1.1	-0.1	-0.6
1966 A	204	-143	86	-113	-58	48	-39	-2	7	-6	42	272	269
N	1.3	-0.9	0.7	-1.3	-1.0	0.8	-0.6	-0	0.1	-0	0.3	1.9	0.7
1967 A	235	44	102	-96	-8	-79	-24	-37	-54	550	-151	49	504
N	1.5	0.3	0.8	-1.1	-0.1	-1.3	-0.4	-0.5	-0.7	3.5	-1.2	0.3	1.3
1968 A	189	-63	39	-25	-35	11	-2	33	67	201	35	-16	407
N	1.2	-0.4	0.3	-0.3	-0.6	0.2	-0	0.4	0.9	1.3	0.3	-0.1	1.0
1969 A	-125	-112	63	69	-37	-73	-39	51	105	-102	89	-84	-223
N	-0.8	-0.7	0.5	0.8	-0.6	-1.2	-0.6	0.6	1.4	-0.7	0.7	-0.6	-0.6
1970 A	-138	-238	-138	13	-25	-60	0	-60	21	-120	-65	-11	-848
N	-0.9	-1.5	-1.1	0.1	-0.4	-1.0	0	-0.8	0.3	-0.8	-0.5	-0.1	-2.1
1971 A	86	-60	131	-18	-44	63	-43	-7	34	134	-20	-49	179
N	0.5	-0.4	1.0	-0.2	-0.7	1.1	-0.6	-0.1	0.4	0.9	-0.2	-0.3	0.4
1972 A	-115	23	347	64	-73	-19	102	-70	-48	-244	-25	68	-18
N	-0.7	0.1	2.7	0.7	-1.2	-0.3	1.5	-0.9	-0.6	-1.6	-0.2	0.5	0
1973 A	240	-78	-20	-150	99	88	-13	-63	-47	81	38	84	231
N	1.5	-0.5	-0.1	-1.7	1.6	1.5	-0.2	-0.8	-0.6	0.5	0.3	0.6	0.6
1974 A	-23	240	175	13	125	4	67	-96	-64	-189	-16	117	325
N	-0.1	1.5	1.3	0.1	2.1	0.1	1.0	-1.2	-0.8	-1.2	-0.1	0.8	0.8
1975 A	-42	-83	-128	-87	11	2	-57	180	-141	314	124	-89	-24
N	-0.3	-0.5	-1.0	-1.0	0.2	0	-0.8	2.3	-1.9	2.0	1.0	-0.6	-0.1
1976 A	51	-15	69	-64	51	27	42	68	-62	-49	-282	-183	-375
N	0.3	-0.1	0.5	-0.7	0.8	0.5	0.6	0.9	-0.8	-0.3	-2.2	-1.3	-0.9
1977 A	-154	1	-4	-18	89	-11	11	-24	-48	19	63	-106	-209
N	-1.0	0	-0	-0.2	1.5	-0.2	0.2	-0.3	-0.6	0.1	0.5	-0.7	-0.5
1978 A	-87	-120	-63	-44	37	-17	-62	163	100	-170	-114	-160	-565
N	-0.5	-0.7	-0.5	-0.5	0.6	-0.3	-0.9	2.1	1.3	-1.1	-0.9	-1.1	-1.4

Appendix table 3 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1979 A	-210	127	-76	-69	-14	-15	3	-47	81	-81	-162	70	-422
N	-1.3	0.8	-0.6	-0.8	-0.2	-0.2	0	-0.6	1.1	-0.5	-1.3	0.5	-1.1
1980 A	-146	-55	-72	-3	-30	-10	41	-54	129	-150	133	352	106
N	-0.9	-0.3	-0.5	-0	-0.5	-0.2	0.6	-0.7	1.7	-1.0	1.0	2.5	0.3
1981 A	-231	-54	-52	208	22	198	-56	-24	84	52	97	31	246
N	-1.4	-0.3	-0.4	2.4	0.4	3.4	-0.8	-0.3	1.1	0.3	0.8	0.2	0.6
1982 A	140	276	-115	1	-65	-45	-8	-42	-47	103	19	-31	157
N	0.9	1.7	-0.9	0	-1.1	-0.8	-0	-0.5	-0.6	0.7	0.1	-0.2	0.4
Mean 1958-82	395	358	328	211	127	100	72	104	160	320	404	467	3075
Std Dev	161	159	130	88	60	59	67	78	76	155	127	141	395

Appendix table 4. Monthly and annual precipitation anomalies (mm) (A), and the number of standard deviations (N) in the anomalies, Cape Scott, 1966-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1966 A	124	-15	86	-89	57	-9	-46	74	-46	60	-47	82	246
N	0.7	-0.2	1.1	-1.1	0.9	-0.1	-1.0	1.0	-0.4	0.4	-0.4	1.0	0.7
1967 A	95	96	-38	-143	59	-74	36	-36	192	254	-164	54	344
N	0.6	1.2	-0.7	-1.7	0.9	-1.2	0.7	-0.5	1.8	1.8	-1.3	0.6	1.0
1968 A	133	-85	5	137	-89	15	7	-18	14	307	51	-26	465
N	0.8	-1.1	0.1	1.6	-1.4	0.2	0.1	-0.2	0.1	2.2	0.4	-0.3	1.4
1969 A	-142	-20	-58	154	-42	-74	-3	148	-2	-23	136	20	108
N	-0.8	-0.3	-0.7	1.9	-0.6	-1.2	-0.1	2.0	-0	-0.2	1.1	0.2	0.2
1970 A	-82	-105	-26	45	74	-69	33	-5	-4	-71	-146	-44	-387
N	-0.5	-1.4	-0.3	0.5	1.1	-1.2	0.7	-0.1	-0	-0.5	-1.2	-0.5	-1.2
1971 A	388	-14	58	18	-49	107	-44	64	-31	75	57	-81	563
N	2.3	-0.2	0.7	0.2	-0.7	1.8	-0.9	0.8	-0.3	0.5	0.5	-1.0	1.6
1972 A	-89	33	13	87	-71	22	-14	-77	-110	-231	-98	-77	-580
N	-0.5	0.4	0.2	1.0	-1.1	0.4	-0.3	-1.0	-1.0	-1.5	-0.8	-0.9	-1.6
1973 A	200	-100	-52	4	40	3	-11	-73	20	31	-93	-14	-32
N	1.2	-1.3	-0.7	0	0.6	0	-0.2	-1.0	0.2	0.2	-0.7	-0.2	-0.2
1974 A	141	157	-43	24	46	67	-2	-81	-165	-125	-48	135	120
N	0.8	2.0	-0.5	0.3	0.7	1.1	-0	-1.1	-1.5	-0.9	-0.4	1.6	0.3
1975 A	-106	-95	-54	-60	-30	36	-27	125	-159	83	221	-2	-53
N	-0.6	-1.2	-0.7	-0.7	-0.5	0.6	-0.6	1.7	-1.5	0.6	1.8	0	-0.2
1976 A	-9	47	45	-27	165	82	109	42	-91	6	-72	67	380
N	-0	0.6	0.6	-0.3	2.5	1.4	2.3	0.6	-0.8	0	-0.6	0.8	1.1
1977 A	-191	76	163	6	3	-7	34	-56	-70	27	19	-158	-142
N	-1.1	1.0	2.1	0.1	0	-0.1	0.7	-0.7	-0.6	0.2	0.1	-1.9	-0.5
1978 A	-219	-46	140	-105	-41	-54	-68	74	44	-35	-33	-29	-359
N	-1.3	-0.6	1.8	-1.3	-0.6	-0.9	-1.4	1.0	0.4	0.2	-0.3	0-0.3	-1.1
1979 A	-186	68	-94	-85	0	1	12	-97	168	-137	-124	117	-344
N	-1.1	0.9	-1.2	-1.0	0	0	0.2	-1.3	1.6	-1.0	-1.0	1.4	-1.1
1980 A	-76	-68	0	1	-57	-164	75	-27	150	-106	107	73	-60
N	-0.5	-0.9	0	0	-0.9	-2.8	1.6	-0.4	1.4	-0.8	0.9	0.9	-0.2
1981 A	-106	8	-8	74	-30	73	-76	1	105	-133	235	-116	40
N	-0.6	0.1	-0.1	0.9	-0.5	1.2	-1.6	0	1.0	-1.0	1.9	-1.4	0.1
1982 A	118	57	-134	-38	-40	-72	-15	-52	-9	22	-175	-27	-352
N	0.7	0.7	-1.7	-0.5	-0.6	-1.2	-0.3	-0.7	-0.1	0.2	-1.4	-0.3	-1.0
Mean 1966-82	337	252	266	208	159	105	86	109	215	349	370	364	2807
Std Dev	167	77	79	83	65	59	48	75	107	139	125	84	334

Appendix table 5. Monthly and annual mean discharge (cu m/sec) and long-term monthly and annual means and standard deviations for the Somass-Stamp River system, 1957-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1957	-	-	-	-	-	-	-	-	-	58	89	216	-
1958	284	337	132	104	118	76	36	24	51	128	151	338	147
1959	228	73	103	123	168	158	73	39	40	52	89	184	111
1960	82	184	78	177	139	126	68	38	35	112	173	188	116
1961	360	292	174	129	154	113	57	39	40	75	109	127	138
1962	176	126	55	85	88	78	49	47	39	169	252	372	128
1963	151	293	128	117	102	59	47	30	34	209	279	238	139
1964	223	114	81	73	105	161	112	54	56	88	102	147	110
1965	65	135	76	78	92	62	34	33	33	207	229	266	109
1966	209	151	133	160	106	118	83	46	71	112	217	352	147
1967	195	145	96	71	120	132	60	40	39	286	172	193	129
1968	401	193	191	72	109	89	61	42	54	225	273	208	160
1969	-	98	104	187	-	-	68	45	95	-	-	198	-
1970	107	-	-	-	-	72	44	35	41	73	113	113	-
1971	130	189	103	96	199	164	116	72	84	96	248	86	131
1972	64	108	253	138	130	131	105	48	51	48	103	220	117
1973	-	79	-	-	-	-	-	-	41	61	129	-	-
1974	228	150	180	179	143	178	129	76	54	53	138	228	145
1975	102	72	103	71	114	123	65	53	68	214	501	180	139
1976	146	118	85	102	140	127	103	58	53	46	119	139	103
1977	99	125	131	108	87	84	36	31	52	115	253	207	111
1978	131	138	129	89	81	70	45	64	121	77	95	75	94
1979	49	113	151	82	126	66	77	43	114	122	115	285	112
1980	143	162	144	131	88	69	62	43	47	60	223	336	127
1981	237	203	81	102	84	62	47	33	53	157	329	204	133
1982	92	174	112	82	118	161	74	51	45	217	172	226	127
Mean 1958-79	171	154	124	112	122	109	70	46	57	119	179	207	126
Std Dev	96	73	47	38	30	38	28	13	25	69	97	80	18

Appendix table 6. Monthly and annual discharge anomalies (cu m/sec) (A) and the number of standard deviations (N) in the anomalies for the Somass-Stamp River system, 1958-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1958 A	113	183	8	-8	-4	-33	-34	-22	-6	9	-28	131	21
N	1.2	2.5	0.2	-0.2	-0.1	-0.9	-1.2	-1.7	-0.2	0.1	-0.3	1.6	1.2
1959 A	57	-81	-21	11	46	49	3	-7	-17	-67	-90	-23	-15
N	0.6	-1.1	-0.4	0.3	1.5	1.3	0.1	-0.5	-0.7	-1.0	-0.9	-0.3	-0.8
1960 A	-89	30	-46	65	17	17	-2	-6	-22	-7	-6	-19	-10
N	-0.9	0.4	-1.0	1.7	0.6	0.4	-0.1	-0.5	-0.9	-0.1	-0.1	-0.2	-0.6
1961 A	189	138	50	17	32	4	-13	-7	-18	-44	-70	-80	12
N	2.0	1.9	1.1	0.4	1.1	0.1	-0.5	-0.5	-0.7	-0.6	-0.7	-1.0	0.7
1962 A	5	-28	-69	-27	-34	-31	-21	1	-18	50	73	65	2
N	0	-0.4	-1.5	-0.7	-1.1	-0.8	-0.7	0.1	-0.7	0.7	0.7	2.1	0.1
1963 A	-20	139	4	5	-20	-50	-23	-16	-23	90	100	31	13
N	-0.2	1.9	0.1	0.1	-0.7	-1.3	-0.8	-1.2	-0.9	1.3	1.0	0.4	0.7
1964 A	52	-40	-43	-39	-17	52	42	8	-1	-31	-77	-60	-16
N	0.5	-0.6	-0.9	-1.0	-0.6	1.4	1.5	0.6	0	-0.4	-0.8	-0.7	-0.9
1965 A	-106	-19	-48	-34	-30	-47	-36	-13	-24	88	50	59	-17
N	-1.1	-0.3	-1.0	-0.9	-1.0	-1.2	-1.3	-1.0	-1.0	1.3	0.5	0.7	-0.9
1966 A	38	-3	9	48	-16	9	13	0	14	-7	38	145	21
N	0.4	-0	0.2	1.3	-0.5	0.2	0.5	0	0.6	-0.1	0.4	1.8	1.2
1967 A	24	-9	-28	-41	-2	23	-10	-6	-18	167	-7	-14	3
N	0.2	-0.1	-0.6	-1.1	-0.1	0.6	-0.4	-0.5	-0.7	2.4	-0.1	-0.2	0.2
1968 A	230	39	67	-40	-13	-20	-9	-4	-3	106	94	1	34
N	2.4	0.5	1.4	-1.0	-0.4	-0.5	-0.3	-0.3	-0.1	1.5	1.0	0	1.9
1969 A	-	-56	-20	75	-	-	-2	-1	38	-	-	-9	-
N	-	-0.8	-0.4	2.0	-	-	-0.1	-0.1	1.5	-	-	-0.1	-
1970 A	-64	-	-	-	-	-37	-26	-11	-16	-46	-66	-94	-
N	-0.7	-	-	-	-	-1.0	-0.9	-0.8	-0.6	-0.7	-0.7	-1.2	-
1971 A	-41	35	-21	-16	77	55	46	26	27	-23	69	-121	5
N	-0.4	0.5	-0.4	-0.4	2.6	1.4	1.6	2.0	1.1	-0.3	0.7	-1.5	0.3
1972 A	-107	-46	129	26	8	22	35	2	-6	-71	-76	13	-9
N	-1.1	-0.6	2.7	0.7	0.3	0.6	1.2	0.1	-0.2	-1.0	-0.8	0.2	-0.5
1973 A	-	-75	-	-	-	-	-	-	-16	-58	-50	-	-
N	-	-1.0	-	-	-	-	-	-	-0.6	-0.8	-0.5	-	-
1974 A	57	-4	56	67	21	69	59	30	-3	-66	-41	21	19
N	0.6	-0	1.2	1.8	0.7	1.8	2.1	2.3	-0.1	-1.0	-0.4	0.3	1.1
1975 A	-69	-82	-21	-41	-8	14	-5	7	11	95	322	-27	13
N	-0.7	-1.1	-0.4	-1.1	-0.3	0.4	-0.2	0.5	0.4	1.4	3.3	-0.3	0.7
1976 A	-25	-36	-39	-10	18	18	33	12	-4	-73	-60	-68	-24
N	-0.3	-0.5	-0.8	-0.3	0.6	0.5	1.2	0.9	-0.2	-1.1	-0.6	-0.8	-1.3
1977 A	-72	-29	7	-4	-35	-25	-34	-15	-5	-4	74	0	-15
N	-0.7	-0.4	0.1	-0.1	-1.2	-0.7	-1.2	-1.1	-0.2	-0.1	0.8	0	-0.8

Appendix table 6 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1978 A	-40	-16	5	-23	-41	-39	-25	18	64	-42	-84	-132	-32
N	-0.4	-0.2	0.1	-0.6	-1.4	-1.0	-0.9	1.4	2.6	-0.6	-0.9	-1.6	-1.8
1979 A	-122	-41	27	-30	4	-43	7	-3	57	3	-64	78	-14
N	-1.3	-0.6	0.6	-0.8	0.1	-1.1	0.2	-0.2	2.3	0	-0.7	1.0	-0.8
1980 A	-28	8	20	19	-34	-40	-8	-3	-10	-59	44	129	1
N	-0.3	0.1	0.4	0.5	-1.1	-1.0	-0.3	-0.2	-0.4	-0.9	0.4	1.6	0.1
1981 A	66	49	-43	-10	-38	-47	-23	-13	-4	38	150	-3	7
N	0.7	0.7	-0.9	-0.3	-1.3	-1.2	-0.8	-1.0	-0.2	0.5	1.5	-0	0.4
1982 A	-79	20	12	-30	-4	52	4	5	-12	98	7	19	1
N	-0.8	0.3	0.3	-0.8	-0.1	1.4	0.1	0.4	-0.5	1.4	0.1	0.2	0.1
Mean 1958-79	171	154	124	112	122	109	70	46	57	119	119	207	126
Std Dev	96	73	47	38	30	38	28	13	25	69	97	80	18

Appendix table 7. Ekman transport (cu m/sec/100 m) normal to the coast and anomalies (A) at 48°N,125°W, 1946-82. + onshore transport,- offshore transport. (Transport values are from Bakun (1973) and from National Marine Fisheries Service, Monterey, CA., but with the signs reversed. Positive anomalies in Oct-Mar indicate above-average onshore transports; negative anomalies in Apr-Sep, above-average offshore transports.)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1946		63	83	19	13	-12	1	-7	-27	1	2	49	23
	A	-16	18	0	14	6	29	27	-2	4	-31	-33	-68
1947		29	40	9	0	-21	-6	1	-28	-4	96	1	78
	A	-50	-25	-10	1	-3	22	35	-3	-1	63	-81	13
1948		67	10	8	7	3	-25	-14	-11	2	14	48	61
	A	-12	-55	-11	8	21	3	20	14	5	-19	-34	-30
1949		2	32	13	15	0	-23	-18	1	3	2	219	20
	A	-77	-33	-6	16	18	5	16	26	6	-31	137	-71
1950		17	201	40	24	-18	-8	-12	-1	0	74	91	140
	A	-62	136	21	25	0	20	22	24	3	41	9	49
1951		68	48	8	-8	-2	-51	-12	-37	2	30	165	18
	A	-11	-17	-11	-7	16	-23	22	-12	5	-3	83	-73
1952		162	35	7	35	-2	-10	-32	-14	1	13	104	293
	A	83	-30	-12	36	16	18	2	11	4	-20	22	202
1953		108	13	30	9	6	-4	-10	0	0	51	190	32
	A	29	-52	11	10	12	24	24	25	3	18	108	-59
1954		45	85	3	-3	-4	2	-6	-16	0	85	133	166
	A	-34	20	-16	-2	14	30	28	9	3	48	51	75
1955		49	1	-2	5	-37	-30	-20	-39	-11	32	68	96
	A	-30	-66	-21	6	-19	-2	14	-14	-8	-1	-14	5
1956		170	22	28	-28	-32	-7	-50	-31	-2	14	46	71
	A	91	-33	9	-27	-14	21	-16	-6	1	-19	-36	-20
1957		57	18	37	-8	-9	-22	-29	-9	0	13	35	114
	A	-22	-47	18	-7	9	6	5	16	3	-20	-47	23
1958		240	148	10	3	-26	-44	-90	-36	-1	31	35	157
	A	161	83	-9	4	-8	-16	-56	-11	2	-2	-47	66
1959		86	30	25	-10	-19	-10	-42	-43	0	4	34	109
	A	7	-35	6	-9	-1	18	-8	-15	3	-29	-48	18
1960		127	32	29	36	11	-39	-28	-21	-7	56	85	111
	A	48	-33	10	37	29	-11	6	4	-4	23	3	20
1961		254	106	91	-14	-1	-5	-32	-13	-23	4	66	45
	A	175	41	72	-13	17	23	2	12	-20	-29	-16	-46
1962		42	20	6	16	-27	-12	-54	-7	-2	35	121	106
	A	-37	-45	-13	17	-9	16	-20	18	1	2	39	15
1963		1	101	1	3	-3	-43	-24	-19	9	106	74	100
	A	-80	36	-18	4	15	-15	10	6	12	73	-8	9
1964		79	-11	-5	-39	-35	-22	-18	-15	-7	28	45	85
	A	0	-76	-24	-38	-17	6	16	10	-4	-5	-37	-6
1965		64	4	4	0	-54	-58	-62	-29	-36	77	117	67
	A	-15	-61	-15	1	-36	-30	-28	-4	-33	44	45	-24
1966		101	25	70	-32	-55	-11	-55	-49	0	9	44	166
	A	22	-40	51	-31	-34	17	-21	-14	3	-24	-38	75
1967		67	27	12	-10	-51	-85	-70	-58	-3	97	32	51
	A	-12	-38	-7	-9	-33	-57	-36	-33	0	64	-50	-40

Appendix table 7 (cont'd)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968		107	175	55	-30	-18	-30	-53	-18	-8	76	132	87
	A	28	110	36	-27	0	-2	-19	7	-5	43	50	-4
1969		61	116	6	41	-9	-57	-62	-18	3	27	99	196
	A	-18	51	-13	42	9	-29	-28	7	0	-6	17	105
1970		91	73	2	-23	-18	-33	-43	-36	-1	25	63	106
	A	12	8	-17	-22	0	-5	-9	-11	2	-8	-19	15
1971		26	18	55	14	-42	-6	-39	-15	-1	7	56	20
	A	-53	-47	46	13	-14	22	-5	10	2	-26	-26	-71
1972		8	83	32	5	-11	-27	-15	-27	-8	-5	84	66
	A	-71	18	13	4	7	1	19	-2	-5	-38	2	-25
1973		151	56	7	-23	-9	-11	-32	-54	0	11	26	104
	A	72	-9	-12	-22	9	17	2	-29	3	-22	-56	13
1974		31	46	31	3	-12	-38	-19	-37	-4	1	50	80
	A	-48	-19	12	4	6	-10	15	-12	-1	-32	-32	-11
1975		24	90	4	-17	-15	-59	-45	-14	-10	60	104	48
	A	-55	25	-15	-16	3	-31	-11	11	-7	27	22	-43
1976		63	35	24	3	-6	-31	-5	-9	-1	6	37	53
	A	-16	-30	5	4	12	-3	29	16	2	-27	-45	-38
1977		45	99	-11	-2	-9	-39	-42	-24	-2	30	65	63
	A	-34	34	-30	3	9	-11	-8	1	1	-3	-17	-28
1978		127	111	4	3	-17	-28	-58	-3	16	0	16	10
	A	48	46	-15	4	1	0	-24	22	19	-33	-66	-81
1979		73	82	2	-10	-24	-83	-25	-35	2	16	187	140
	A	-6	17	-17	-9	-6	-55	9	-10	5	-17	105	49
1980		68	218	-3	15	-41	-32	-63	-68	-5	39	145	113
	A	-11	153	-22	16	-13	-4	-29	-43	-2	6	63	22
1981		251	76	16	1	-8	-5	-80	-	6	10	123	102
	A	172	11	-3	2	10	23	-46	-	9	-23	41	11
1982		24	73	1	0	-58	-74	-36	-38	-7	44	57	97
	A	-55	8	-18	1	-40	-46	-2	-13	-4	11	-25	6
Mean 1946-80		79	65	19	-1	-18	-28	-34	-25	-3	33	82	91
Std Dev		60	57	22	19	17	22	22	17	8	32	53	58

Appendix table 8. Ekman transport (cu m/sec/100 m) normal to the coast and anomalies (A) at 51°N, 131°W, 1946-82. + onshore transport,- offshore transport. (Transport values are from Bakun (1973) and from National Marine Fisheries Service, Monterey, CA., but with the signs reversed. Positive anomalies in Sep-Apr indicate above-average onshore transports; negative anomalies in May-Aug, above-average offshore transports.)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1946	48	97	4	16	-1	0	-1	-12	10	-14	13	-13
A	2	48	-7	8	0	14	12	2	9	-58	-37	-60
1947	-12	61	8	5	-2	-3	1	-44	-7	68	6	23
A	-58	12	-3	-3	-1	11	14	-30	-8	24	-44	-24
1948	43	-2	-1	-2	7	-31	-11	-24	-2	18	-16	-5
A	-3	-51	-12	-10	8	-17	2	-10	-3	-26	-66	-52
1949	0	3	12	57	0	-26	-11	4	3	12	154	-3
A	-46	-46	1	49	1	-12	2	18	2	-32	104	-50
1950	0	122	17	46	-4	-2	-3	11	7	32	40	92
A	-46	73	6	38	-3	12	10	25	6	-12	-10	45
1951	58	8	3	-2	-1	-65	-11	-19	3	23	75	5
A	12	-41	-8	-10	0	-51	2	-5	2	-21	25	-42
1952	39	26	-20	58	3	-8	-23	-20	4	31	52	174
A	-7	-23	-31	50	4	6	-10	-6	3	-13	2	127
1953	70	24	22	22	6	-5	-4	-1	-4	85	94	18
A	24	-25	11	14	7	11	9	13	-5	41	44	-29
1954	14	40	-2	-7	5	17	4	-31	-2	69	188	38
A	-32	-9	-13	-15	6	31	9	-17	-3	25	138	-9
1955	35	-20	-14	-5	-13	-9	-16	-12	-3	35	103	76
A	-9	-69	-25	-13	-12	5	-3	2	-4	-9	53	29
1956	216	1	19	-4	-5	1	-10	-6	-6	2	44	45
A	170	-48	8	-12	-4	15	3	8	-7	-42	-6	-2
1957	14	1	40	-2	2	1	-14	-2	1	13	56	47
A	-32	-48	29	-10	3	15	-1	12	0	-31	6	0
1958	238	209	2	1	-2	-48	-71	0	-4	41	37	150
A	192	160	-9	-7	-1	-34	-58	14	-5	-3	-13	103
1959	111	11	28	-9	-6	6	-9	-28	2	18	49	83
A	65	-38	17	-17	-5	20	4	-14	1	-26	-1	36
1960	2	-11	35	27	13	-6	16	-22	-7	3	-10	5
A	-44	-60	24	19	14	8	29	-8	-8	-41	-60	-42
1961	131	48	42	-32	8	25	-7	3	-29	56	28	61
A	85	-1	31	-40	9	39	6	17	-30	12	-22	14
1962	9	4	1	39	-23	-5	-24	-15	-2	21	64	113
A	-37	-45	-10	31	-22	9	-11	-1	-3	-23	14	66
1963	-8	165	-15	-3	4	-48	-26	-20	70	151	64	123
A	-54	116	-26	-11	5	-34	-13	-6	69	107	14	76
1964	44	-29	-22	-46	-19	-2	0	-9	-18	58	24	26
A	-2	-78	-33	-54	-18	12	13	5	-19	14	-26	-21
1965	39	-14	-2	3	-33	-5	-9	-16	-69	110	29	12
A	-7	-63	-13	-5	-32	9	4	-2	-70	66	-21	-35
1966	69	9	87	-17	-5	10	-47	-14	41	14	10	78
A	23	-40	76	-25	-4	24	-34	0	40	-30	-40	31
1967	23	50	-7	-30	-3	-75	-8	-1	69	48	11	17
A	-23	1	-18	-38	-2	-61	5	13	68	4	-39	-30

Appendix table 8 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968	-1	136	67	-13	-2	-1	-10	-13	-5	52	118	20
A	-47	87	56	-21	-1	13	3	1	-6	8	68	-27
1969	7	45	9	71	2	-31	-23	-8	9	51	79	225
A	-39	-4	-2	63	3	-17	-10	6	8	7	29	178
1970	50	84	15	-36	12	-10	-9	-8	-9	4	32	17
A	4	35	4	-44	13	4	4	6	-10	-40	-18	-30
1971	2	23	41	25	-11	-2	-28	15	-10	-1	37	-5
A	-44	-26	30	17	-10	12	-15	29	-11	-45	-13	-52
1972	-2	59	25	-3	-2	-6	-17	-4	-38	-9	91	7
A	-48	10	14	-11	-1	8	-4	10	-39	-53	41	-40
1973	75	50	3	-5	20	15	-5	-40	6	19	-2	81
A	29	1	-8	-13	21	29	8	-26	5	-25	-52	34
1974	-5	37	6	9	3	-7	-8	-44	-3	35	42	62
A	-51	-12	-5	1	4	7	5	-30	-4	-9	-8	15
1975	9	72	-2	-17	1	-38	-6	-7	-7	24	35	30
A	-37	29	-13	-25	2	-24	7	7	-8	-20	-15	-17
1976	81	-1	16	33	21	-20	23	-4	12	6	68	48
A	35	-50	5	25	22	-6	36	10	11	-38	18	1
1977	40	152	-35	6	-9	-10	-10	-27	-16	79	37	28
A	-6	103	-46	-2	-8	4	3	-13	-17	35	-13	-19
1978	127	129	21	2	-6	-53	-49	2	32	13	2	-21
A	81	80	10	-6	-5	-39	-36	16	31	-31	-52	-68
1979	32	22	5	-8	3	-15	0	-14	22	53	87	57
A	-14	-27	-6	-16	4	-1	13	0	21	9	37	10
1980	12	110	-15	115	-7	-24	-19	-70	-17	81	77	40
A	-34	61	-26	107	-6	-10	-6	-56	-18	37	27	-7
1981	309	9	77	4	16	14	-68		43	1	86	45
A	263	-40	66	-4	15	0	-55		42	-43	36	-2
1982	-5	13	0	4	-9	-25	-8	-11	-9	7	11	51
A	-51	-36	-11	-4	-8	-11	5	3	-10	-37	-39	4
Mean 1946-80	46	49	11	8	-1	-14	-13	-14	1	44	50	47
Std Dev	59	59	25	32	11	23	17	17	25	47	46	58

Appendix table 9. Number of standard deviations in the monthly Ekman transport anomalies at 48°N, 125°W (A) and 51°N, 131°W (B). Positive (negative) values in October-March indicate above-average (below-average) onshore transport, and negative (positive) values in June-August indicate above-average (below-average) offshore transport.

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1946	A	-0.3	0.3	0	0.7	0.3	1.3	1.2	0.1	0.5	-1.0	-0.6	-1.2
	B	0	0.8	-0.3	0.2	0	0.6	0.1	0.1	0.4	-1.2	-0.8	-1.0
1947	A	-0.8	-0.4	-0.4	0	-0.2	1.0	1.6	-0.2	-0.1	2.0	-1.5	-0.2
	B	-1.0	0.3	-0.1	-0.1	-0.1	0.5	0.8	-1.8	-0.3	0.5	-1.0	-0.4
1948	A	-0.2	-1.0	-0.5	0.4	1.2	0.1	0.9	0.8	0.6	-0.6	-0.6	-0.5
	B	0	-0.9	-0.5	-0.3	0.7	0.7	0.1	-0.6	-0.1	-0.5	-1.4	-0.9
1949	A	-1.3	-0.6	-0.3	0.8	1.1	0.2	0.7	1.5	0.7	-1.0	2.6	-1.2
	B	-0.8	-0.8	0	1.5	0.1	-0.5	0.1	1.1	0.1	-0.7	2.3	-0.9
1950	A	-1.0	2.4	0.9	1.3	0	0.9	1.0	1.4	0.4	1.3	0.2	0.8
	B	-0.8	1.2	0.2	1.2	-0.3	0.5	0.6	1.5	0.2	-0.3	-0.2	0.8
1951	A	-0.2	-0.3	-0.5	-0.4	0.9	-1.0	1.0	-0.7	0.6	-0.1	1.6	-1.3
	B	0.2	-0.7	-0.3	-0.3	0	-2.2	0.1	-0.3	0.1	-0.4	0.5	-0.7
1952	A	1.4	-0.5	-0.5	1.9	0.9	0.8	0.1	0.6	0.5	-0.6	0.4	3.5
	B	-0.1	-0.4	-1.2	1.6	0.2	0.3	-0.6	-0.3	0.1	-0.3	0	2.2
1953	A	0.5	-0.9	0.5	0.5	0.7	1.1	1.1	1.5	0.4	0.6	2.0	-1.0
	B	0.4	-0.4	0.4	0.4	0.6	0.5	0.5	0.8	-0.2	0.9	1.0	-0.5
1954	A	-0.6	0.3	-0.7	-0.1	0.8	1.4	1.3	0.5	0.4	1.5	1.0	1.3
	B	-0.5	-0.1	-0.5	-0.5	0.5	1.3	0.5	-1.0	-0.1	0.5	3.0	-0.2
1955	A	-0.5	-1.2	-0.9	0.3	-1.1	-0.1	0.6	-0.8	-1.0	0	-0.3	0.1
	B	-0.1	-1.2	-1.0	-0.4	-1.1	0.2	-0.2	0.1	-0.2	-0.2	1.1	0.5
1956	A	1.5	-0.6	0.4	-1.4	-0.8	0.9	-0.7	-0.3	0.1	-0.6	-0.7	-0.3
	B	2.9	-0.8	0.3	-0.4	-0.4	0.6	0.3	0.5	-0.3	-0.9	-0.1	0
1957	A	-0.4	-0.8	0.8	-0.4	0.5	0.3	0.2	0.9	0.4	-0.6	-0.9	0.4
	B	-0.5	-0.8	1.1	-0.3	0.3	0.6	-0.1	0.7	0	-0.7	0.1	0
1958	A	2.7	1.5	-0.4	0.2	-0.5	-0.7	-2.5	-0.6	0.2	-0.1	-0.9	1.1
	B	3.2	2.7	-0.4	-0.2	-0.1	-1.5	-3.4	0.8	-0.2	-0.1	-0.3	1.8
1959	A	0.1	-0.6	0.3	-0.5	0	0.8	-0.2	-0.9	0.4	-0.9	-0.9	0.3
	B	1.1	-0.6	0.7	-0.5	-0.4	0.9	0.2	-0.8	0	-0.5	-0	0.6
1960	A	0.8	-0.6	0.4	1.9	1.7	-0.5	0.3	0.2	-0.5	0.7	0.1	0.3
	B	-0.7	-1.0	1.0	0.6	1.3	0.3	1.7	-0.5	-0.3	-0.9	-1.3	-0.7
1961	A	2.9	0.7	3.3	-0.7	1.0	1.0	0.1	0.7	-2.5	-0.9	-0.3	-0.8
	B	1.4	0	1.2	-1.2	0.7	1.7	0.3	1.0	-1.2	0.3	-0.5	0.4
1962	A	-0.6	-0.8	-0.6	0.9	-0.5	0.7	-0.9	1.1	0.1	0.1	0.7	0.3
	B	-0.6	-0.8	-0.4	1.0	-2.0	0.4	-0.6	-0.1	-0.1	-0.5	0.3	1.1
1963	A	-1.3	0.6	-0.8	0.2	0.9	-0.7	0.4	0.3	1.5	2.3	-0.1	0.2
	B	-0.9	2.0	-1.0	-0.3	0.4	-1.5	-0.8	-0.3	2.8	2.3	0.3	1.3
1964	A	0	-1.3	-1.1	-2.0	-1.0	0.3	0.7	0.6	-0.5	0.2	-0.7	-0.1
	B	0	-1.3	-1.3	-1.7	-1.6	0.5	0.8	0.3	-0.8	0.3	-0.6	-0.4
1965	A	-0.2	-1.1	-0.7	0	-2.1	-1.4	-1.3	-0.2	-4.2	1.4	0.8	-0.4
	B	-0.1	-1.1	-0.5	-0.2	-2.9	0.4	0.2	-0.1	-2.8	1.4	-0.5	-0.6
1966	A	0.4	-0.7	2.3	-1.6	-2.0	0.8	-0.9	-0.7	0.4	-0.7	0.7	1.3
	B	0.4	-0.7	3.0	-0.8	-0.4	1.0	-2.0	0	1.6	-0.6	-0.9	0.5
1967	A	-0.2	-0.7	-0.3	-0.5	-1.9	-2.6	-1.6	-1.9	0	2.0	-0.9	-0.7
	B	-0.4	0	-0.7	-1.2	-0.2	-2.6	0.3	0.8	2.7	0.1	-0.8	-0.5

Appendix table 9 (cont'd)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968	A	0.5	1.9	1.6	-1.4	0	-0.1	-0.9	0.4	-0.6	1.3	0.9	-0.1
	B	-0.8	1.5	2.2	-0.7	-0.1	0.6	0.2	0.1	-0.2	0.2	1.5	-0.5
1969	A	-0.3	0.9	-0.5	2.2	0.5	-1.3	-1.3	0.4	0	-0.2	0.3	1.8
	B	-0.7	-0.1	-0.1	2.0	0.3	-0.7	-0.6	0.3	0.3	0.1	0.6	3.1
1970	A	0.2	-0.1	-0.8	-1.2	0	-0.2	-0.4	-0.6	0.2	0.2	-0.4	0.3
	B	0.1	0.6	0.2	-1.4	1.2	0.2	0.2	0.3	-0.4	-0.8	-0.4	-0.5
1971	A	-0.9	-0.8	2.1	0.7	-0.8	1.0	-0.2	0.6	0.2	-0.8	-0.5	-1.2
	B	-0.7	-0.4	1.2	0.5	-0.9	0.5	-0.9	1.7	-0.4	-1.0	-0.3	-0.9
1972	A	-1.2	0.3	0.6	0.2	0.4	-0	0.9	-0.1	-0.6	-0.2	0	-0.4
	B	-0.8	0.2	0.6	-0.3	-0.1	0.3	-0.2	0.6	-1.6	-1.1	0.9	-0.7
1973	A	1.2	-0.2	-0.5	-1.2	0.5	0.8	0.1	-1.7	0.4	0.7	-1.1	0.2
	B	0.5	0	-0.3	-0.4	1.9	1.3	0.5	-1.5	0.2	-0.5	-1.1	0.6
1974	A	-0.8	-0.3	0.5	0.2	0.3	-0.4	0.7	-0.7	0.7	-1.0	-0.6	-0.2
	B	-0.9	-0.2	-0.2	0	0.4	0.3	0.3	-1.8	-0.2	-0.2	-0.2	0.3
1975	A	-0.9	0.4	-0.7	-0.8	0.2	-1.4	-0.5	0.6	-0.9	0.8	0.4	-0.7
	B	-0.6	0.5	-0.5	-0.8	0.2	-1.0	0.4	0.4	-0.3	-0.4	-0.3	-0.3
1976	A	-0.3	-0.5	0.2	0.2	0.7	-0.1	1.3	0.9	0.2	-0.8	-0.8	-0.7
	B	0.6	-0.8	0.2	0.8	2.0	-0.3	2.1	0.6	0.4	-0.8	0.4	0
1977	A	-0.6	0.6	-1.4	0.2	0.5	-0.5	-0.4	0.1	0.1	-0.1	-0.3	-0.5
	B	-0.1	1.7	-1.8	-0.1	-0.7	0.2	0.2	-0.8	-0.7	0.7	-0.3	-0.3
1978	A	0.8	0.8	-0.7	0.2	0.1	0	-1.1	1.3	2.4	-1.0	-1.2	-1.4
	B	1.4	1.4	0.4	-0.2	-0.4	-1.6	-2.1	0.9	1.2	-0.7	-1.1	-1.7
1979	A	-0.1	0.3	-0.8	-0.5	-0.3	-2.5	0.4	-0.6	0.6	-0.5	2.0	0.8
	B	-0.2	-0.5	-0.2	-0.5	0.4	0	0.8	0	0.8	0.2	0.8	0.2
1980	A	-0.2	2.7	-1.0	0.8	-0.8	-0.2	-1.3	-2.5	-0.2	0.2	1.2	0.4
	B	-0.6	1.0	-1.0	3.3	-0.5	-0.4	-0.3	-3.3	-0.7	0.8	0.6	-0.1
1981	A	2.9	0.2	-0.1	0.1	0.6	1.0	-2.1	-	1.1	-0.7	0.8	0.2
	B	2.8	-0.7	2.6	-0.1	1.4	0	-3.2	-	1.7	-0.9	0.8	-0
1982	A	-1.7	-0.1	-0.8	0	-2.4	-2.1	-0.1	-0.8	-0.3	0.3	-0.5	0.1
	B	-0.9	-0.6	-0.4	-0.1	-0.7	-0.5	0.3	0.2	-0.4	-0.8	-0.8	0.1
Mean	A	79	65	19	-1	-18	-28	-34	-25	-3	33	82	91
Std Dev		60	57	22	19	17	22	22	17	8	32	53	58
Mean	B	46	49	11	8	-1	-14	-13	-14	1	44	50	47
Std Dev		59	59	25	32	11	23	17	17	25	47	46	58

Appendix table 10. Unadjusted monthly mean sea level (cm) and anomalies (A), Tofino, B.C., 1940-82. (Long-term means and standard deviations and anomalies provided by National Marine Fisheries Service, Monterey, CA.)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1940		238.0	241.4	226.2	213.1	211.8	200.9	208.5	208.5	219.5	228.0	226.5	242.6
	A	12.9	18.7	10.1	5.0	9.3	-2.3	5.8	2.4	11.0	14.2	4.6	16.5
1941		246.0	242.3	230.7	217.3	218.2	210.0	209.1	212.1	217.3	217.9	231.3	245.1
	A	20.9	19.6	14.6	9.2	15.7	4.8	6.4	6.2	8.8	4.1	9.4	17.0
1942		-	-	-	-	-	-	-	-	-	-	-	-
1943		221.3	222.5	214.6	218.8	200.6	206.6	204.8	206.3	207.6	219.8	218.5	215.5
	A	-3.8	-0.2	-1.5	10.7	-2.0	3.5	2.1	0.5	-0.9	6.0	-3.4	-12.6
1944		228.3	214.3	202.7	210.9	202.4	202.1	202.1	203.0	207.6	214.2	231.3	221.6
	A	3.2	-8.4	-13.4	2.8	-0.1	-1.1	-0.6	-2.9	-0.9	-1.4	9.4	-6.5
1945		221.9	213.4	216.1	193.5	208.2	199.3	203.9	202.7	204.8	206.0	226.8	235.6
	A	-3.2	-9.3	0	-14.6	5.6	-3.8	1.2	-3.2	-3.7	-7.8	4.8	7.5
1946		221.6	228.3	217.6	211.8	205.7	208.8	207.6	202.7	210.0	208.5	214.6	224.3
	A	-3.5	5.6	1.6	3.7	3.2	5.6	4.8	-3.2	1.5	-5.3	-7.4	-3.7
1947		216.4	222.22	217.9	206.0	203.6	210.0	210.0	203.6	203.6	229.5	210.6	230.4
	A	-8.7	-0.5	1.9	-2.1	1.1	6.8	7.3	-2.3	-4.9	15.7	-11.3	2.3
1948		223.1	222.2	216.7	226.5	218.8	209.7	209.1	210.3	213.1	209.7	215.8	225.5
	A	-2.0	-0.5	-0.6	18.3	16.3	6.5	6.4	4.4	4.6	-4.1	-6.1	-2.5
1949		202.7	227.7	223.7	206.6	210.0	201.5	199.0	207.6	208.2	199.0	221.0	218.2
	A	-22.4	5.0	7.7	-1.5	7.5	-1.7	-3.7	1.7	-0.3	-14.8	-1.0	-9.8
1950		220.4	224.3	224.6	211.2	196.9	203.3	202.7	204.5	205.4	227.4	225.5	235.6
	A	-4.8	1.7	8.6	3.1	-5.6	0.1	-0	-1.4	-3.0	13.6	3.6	7.5
1951		227.4	227.1	209.7	201.5	204.8	203.3	206.0	203.9	210.0	218.8	231.6	226.2
	A	2.2	4.4	-6.4	-6.6	2.3	0.1	3.3	-2.0	1.5	5.0	9.7	-1.9
1952		239.9	227.7	215.2	203.6	199.6	203.6	201.8	206.6	205.7	204.2	216.7	243.2
	A	14.7	5.0	-0.9	-4.5	-2.9	0.4	-0.9	0.8	-2.7	-9.6	5.2	15.1
1953		245.7	212.4	213.7	205.1	209.4	199.9	199.3	203.6	208.2	215.2	236.5	222.2
	A	20.5	-10.2	-2.4	-3.0	6.9	-3.2	-3.4	-2.3	-0.3	1.4	14.6	-5.9
1954		237.4	231.0	217.6	207.6	203.3	210.0	205.1	206.3	210.3	215.8	231.3	235.0
	A	12.3	8.4	1.6	-0.6	0.8	6.8	2.4	0.5	1.8	2.0	9.4	6.9
1955		220.4	208.2	200.9	212.4	192.3	199.0	201.5	197.8	202.4	209.1	217.6	233.2
	A	-4.8	-14.5	-15.2	4.3	-10.2	-4.2	-1.3	-8.1	-6.1	-4.7	-4.3	5.1
1956		243.2	214.0	214.6	202.4	201.2	209.7	204.8	202.1	206.0	214.9	204.2	216.4
	A	18.1	-8.7	-1.5	-5.7	-1.4	6.5	2.1	-3.8	-2.4	1.1	-17.7	-11.7
1957		212.7	217.0	221.3	208.8	214.0	206.3	207.9	211.5	215.8	220.1	217.0	237.4
	A	-12.4	-5.6	5.2	0.7	11.4	3.2	5.1	5.6	7.3	6.3	-4.9	9.3
1958		240.8	249.0	224.6	220.1	204.5	208.8	206.6	208.2	210.3	216.1	220.1	231.0
	A	15.7	26.4	8.6	11.9	2.0	5.6	3.9	2.3	1.8	2.3	-1.9	2.9
1959		233.5	227.7	209.7	203.9	200.9	205.7	200.2	202.7	212.1	209.7	207.3	220.4
	A	8.3	5.0	-6.4	-4.2	-1.7	2.5	-2.5	-3.2	3.7	-4.1	-14.7	-7.7
1960		223.1	220.7	214.2	216.1	212.1	199.6	192.6	204.2	205.1	213.1	227.4	226.2
	A	-2.0	-2.0	-3.6	8.0	9.6	-3.5	-10.1	-1.7	-3.3	-0.7	5.4	-1.9
1961		236.8	235.0	235.9	204.2	209.4	205.4	204.5	206.0	204.2	205.1	211.2	218.2
	A	11.7	12.3	19.8	-3.9	6.9	2.2	1.8	0.2	-4.3	-8.7	-10.7	-9.8
1962		210.9	222.8	210.0	203.0	204.5	196.9	197.2	206.3	208.8	221.0	226.2	225.9
	A	-14.2	0.1	-6.1	-5.1	2.0	-6.3	-5.5	0.5	0.3	7.2	4.2	-2.2
1963		206.6	224.9	211.5	222.2	209.7	201.8	207.9	207.0	214.6	227.4	235.3	226.5
	A	-18.5	2.3	-4.5	14.1	7.2	-1.4	5.1	1.1	6.1	13.6	13.4	-1.6

Appendix table 10 (cont'd)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1964		235.3	198.1	205.4	192.0	193.5	200.6	202.1	208.5	205.4	209.1	218.5	229.2
	A	10.2	-24.5	-10.6	-16.1	-9.0	-2.6	-0.6	2.6	-3.0	-4.7	-3.4	1.1
1965		229.2	212.1	207.9	211.5	194.5	199.9	200.6	210.0	208.2	218.2	238.7	237.4
	A	4.1	-10.5	-8.2	3.4	-8.1	-3.2	-2.2	4.1	-0.3	4.4	16.7	9.3
1966		235.0	222.2	224.6	204.2	194.2	202.1	204.2	203.6	205.7	208.2	224.3	239.9
	A	9.9	-0.5	8.6	-3.9	-8.4	-1.1	1.5	-2.3	-2.7	-5.6	2.4	11.8
1967		228.0	213.7	223.1	215.5	202.1	204.2	202.1	204.2	210.9	221.6	216.7	219.8
	A	2.9	-9.0	7.0	7.4	-0.4	1.0	-0.6	-1.7	2.4	7.8	-5.2	-8.3
1968		227.7	229.5	222.8	201.2	206.0	202.4	205.4	214.9	210.6	222.2	229.5	237.1
	A	2.5	6.8	6.7	-7.0	3.5	-0.8	2.7	9.0	2.1	8.4	7.6	9.0
1969		235.6	237.1	209.4	219.1	201.8	204.8	198.4	203.6	213.1	216.4	220.1	235.6
	A	10.5	14.5	-6.7	11.0	-0.7	1.6	-4.3	-2.3	4.6	2.6	-1.9	7.5
1970		229.8	222.2	211.5	195.7	193.2	199.3	199.6	201.8	202.7	212.7	221.6	235.0
	A	4.7	-0.5	-4.5	-12.4	-9.3	-3.8	-3.1	-4.1	5.8	-1.0	0.3	6.9
1971		216.4	207.3	217.0	213.7	200.6	205.7	203.6	208.8	210.3	209.7	218.2	223.1
	A	-8.7	-15.4	0.9	5.5	-2.0	2.5	0.9	2.9	1.8	-4.1	-3.7	-5.0
1972		215.2	225.9	224.9	216.4	204.8	207.6	201.0	210.6	211.8	209.4	224.3	229.5
	A	-9.9	3.2	8.9	8.3	2.3	4.4	7.3	4.7	3.3	-4.4	2.4	1.4
1973		236.2	224.6	219.1	192.0	198.1	201.5	198.4	199.6	203.3	208.5	226.4	236.8
	A	11.1	2.0	3.1	-16.1	-4.4	-1.7	-4.3	-6.2	-5.2	-5.3	4.5	8.7
1974		224.0	222.5	228.3	214.6	204.5	203.9	207.3	203.0	204.8	199.0	215.2	219.1
	A	-1.1	-0.2	12.2	6.4	2.0	0.7	4.5	-2.9	-3.7	-14.8	-6.7	-8.9
1975		213.1	221.9	215.2	198.1	194.5	195.7	198.4	202.4	200.6	219.1	226.8	212.7
	A	-12.1	-0.8	-0.9	-10.0	-8.1	-7.5	-4.3	-3.5	-7.9	5.3	4.8	-15.3
1976		217.0	219.1	210.9	207.9	199.0	203.0	209.1	210.0	213.2	210.9	210.9	217.9
	A	-8.1	-3.5	-5.1	-0.2	-3.5	0.2	6.4	4.1	4.6	-2.9	-11.0	-10.1
1977		214.0	221.9	207.9	195.1	206.0	199.0	196.0	208.2	-	214.9	222.8	235.9
	A	-11.2	-0.8	-8.2	-13.0	3.5	-4.2	-6.7	2.3	-	1.1	0.9	7.8
1978		242.9	235.0	217.0	211.8	195.1	199.0	197.8	215.8	224.0	-	-	-
	A	17.8	12.3	0.9	3.7	-7.5	-4.2	-4.9	9.9	15.5	-	-	-
1979		195.7	228.6	213.1	206.6	199.6	198.1	202.1	211.5	210.6	216.1	220.1	229.2
	A	-29.4	5.9	-3.0	-1.5	-2.9	-5.1	-0.6	5.6	2.1	2.3	-1.9	1.1
1980		226.8	228.9	214.3	210.6	201.5	200.6	195.4	201.5	205.1	207.3	219.8	228.6
	A	1.6	6.2	-1.8	2.5	-1.1	-2.6	-7.3	-4.4	-3.3	-6.5	-2.2	0.5
1981		230.7	222.5	214.3	205.4	204.5	205.4	201.2	204.2	208.2	218.2	233.2	231.6
	A	5.6	-0.2	-1.8	-2.7	2.0	2.2	-1.6	-1.7	-0.3	4.4	11.2	3.6
1982		218.5	221.0	224.6	217.0	195.7	207.4	204.1	207.2	218.3	223.6	236.4	238.7
	A	-6.6	-1.7	8.6	8.9	-6.8	4.2	1.4	1.3	9.8	9.8	14.5	10.6
Mean 1943-82		225.1	222.7	216.1	208.1	202.5	203.2	202.7	205.9	208.5	213.8	221.9	228.1
Std Dev		11.4	8.9	7.1	8.3	6.0	3.8	4.2	3.9	4.4	7.1	8.0	7.7

Appendix table 11. Adjusted monthly mean sea level (cm) and anomalies (A), Tofino, B.C., 1946-81. (Values provided by National Marine Fisheries Service, Monterey, CA.)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1946	223.5	225.4	214.4	213.0	206.8	209.7	210.1	205.1	209.5	208.1	215.0	225.4
A	-1.5	3.1	-0.4	4.4	3.2	5.7	5.7	-1.7	0.6	-4.6	-5.7	-1.2
1947	218.2	224.7	217.7	208.7	204.5	209.1	210.3	204.1	206.4	222.7	215.1	230.1
A	-6.8	2.4	2.9	0.1	0.8	5.1	5.9	-2.7	-2.5	9.1	-5.5	3.5
1948	228.9	222.2	214.0	222.2	216.8	211.2	210.0	209.8	212.5	210.9	215.5	222.4
A	3.9	-0.1	-0.8	13.5	13.2	7.2	5.6	3.0	3.5	-2.7	-5.1	-4.3
1949	213.5	220.9	222.3	208.6	209.8	204.1	201.5	208.9	208.8	202.7	218.4	214.9
A	-11.5	-1.4	7.5	-0.1	6.1	0.1	-2.8	2.1	-0.3	-10.9	-2.3	-11.7
1950	217.4	221.4	221.1	211.5	200.9	204.1	205.3	205.9	206.9	220.2	223.3	232.4
A	-7.6	-0.9	6.3	2.8	-2.7	0.1	0.9	-0.9	-2.0	6.6	2.6	5.8
1951	224.9	225.4	209.9	203.7	206.6	205.9	207.1	205.6	210.0	217.7	227.7	224.7
A	-0.1	3.1	-4.9	-5.0	3.0	1.9	2.8	-1.2	1.1	4.1	7.1	-2.0
1952	232.1	226.9	211.5	203.9	203.4	202.8	205.8	207.7	207.2	208.7	220.2	234.8
A	7.1	4.6	-3.3	-4.8	-0.2	-1.2	1.4	0.9	-1.7	-4.9	-0.4	0.2
1953	238.6	218.9	211.5	203.2	208.3	201.7	203.1	203.6	209.6	216.9	230.1	225.1
A	13.6	-3.4	-3.4	-5.4	4.6	-2.2	-1.2	-3.2	0.6	3.3	9.5	-1.5
1954	231.3	230.5	218.6	209.3	204.3	209.2	206.9	207.0	210.5	216.8	230.6	233.3
A	6.3	8.2	3.8	0.6	0.6	5.2	2.5	0.3	1.6	3.2	10.0	6.6
1955	222.1	212.9	203.3	209.5	195.9	200.5	200.6	200.5	203.4	207.4	215.7	228.1
A	-2.9	-9.4	-11.6	0.9	-7.7	-3.4	-3.8	-6.3	-5.6	-6.2	-4.9	1.4
1956	236.7	212.9	214.3	204.2	202.9	210.2	207.4	204.6	206.3	211.7	213.3	218.5
A	11.7	-9.4	-0.6	-4.5	-0.8	6.2	3.0	-2.2	-2.6	-1.9	-7.3	-8.1
1957	217.1	216.0	217.6	209.6	211.4	206.6	208.9	212.6	215.7	219.3	220.9	231.4
A	-7.8	-6.3	2.7	0.9	7.7	2.7	4.5	5.8	6.7	5.7	0.3	4.8
1958	236.5	240.7	219.8	218.6	204.9	207.7	206.6	209.2	209.5	216.9	220.4	232.8
A	11.5	18.4	5.0	9.9	1.3	3.7	2.2	2.4	0.6	3.3	-0.3	6.2
1959	231.9	226.4	211.6	205.6	202.2	205.1	203.6	203.7	210.2	210.7	213.4	222.9
A	6.9	4.1	-3.2	-3.1	-1.5	1.2	-0.8	-3.1	1.3	-2.9	-7.3	-3.8
1960	223.9	220.2	211.3	214.2	209.8	202.5	195.4	204.0	207.8	211.7	224.0	232.0
A	-1.1	-2.1	-3.5	5.5	6.2	-1.4	-8.9	-2.8	-1.1	-2.0	3.3	5.3
1961	236.6	232.1	228.9	205.7	209.4	206.7	206.1	207.7	205.3	205.6	209.5	217.2
A	11.6	9.8	14.1	-3.0	5.7	2.7	1.7	1.0	-3.6	-8.0	-11.1	-9.4
1962	218.3	219.3	207.8	203.7	205.7	198.6	200.8	207.4	207.1	220.0	223.2	227.9
A	-6.7	-3.0	-7.0	-5.0	2.1	-5.4	-3.6	0.7	1.9	6.4	2.5	1.2
1963	216.8	224.1	210.2	218.5	211.4	202.1	208.8	208.3	212.6	224.7	230.6	230.1
A	-8.2	1.8	-4.6	9.8	7.7	-1.9	4.4	1.5	3.6	11.1	10.0	3.4
1964	230.2	206.6	203.6	194.5	194.8	200.1	201.8	208.3	206.4	210.2	216.7	221.3
A	5.2	-15.7	-11.2	-14.1	-8.8	-3.9	-2.6	1.5	-2.5	-3.4	-3.9	-5.3
1965	226.9	213.5	212.1	209.2	197.2	200.8	202.5	210.1	210.0	218.2	232.5	231.9
A	1.9	-8.8	-2.8	0.6	-6.5	-3.1	-1.9	3.3	1.0	4.6	11.8	5.3
1966	230.6	222.1	222.4	208.2	196.4	203.1	205.3	205.1	206.0	209.7	221.3	234.4
A	5.6	-0.2	7.6	-0.5	-7.3	-0.9	0.9	-1.7	-2.9	-3.9	0.7	7.7
1967	224.1	217.8	218.7	212.9	206.3	203.6	204.5	205.3	209.8	218.2	218.1	219.8
A	-0.9	-4.5	3.9	4.2	2.6	-0.4	0.1	-1.5	0.9	4.6	-2.5	-6.9
1968	225.0	228.8	221.5	206.0	206.4	203.8	207.2	214.0	211.5	219.0	227.9	232.2
A	0	6.5	6.7	-2.7	2.8	-0.2	2.8	7.2	2.6	5.4	7.3	5.6

Appendix table 11 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1969	228.2	228.5	212.7	217.4	202.6	202.5	201.1	203.7	210.6	217.6	221.7	233.3
A	3.2	6.2	-2.1	8.8	-1.1	-1.5	-3.3	-3.1	1.6	4.0	1.0	6.7
1970	226.7	225.6	214.4	196.9	197.3	199.7	200.8	202.4	204.3	212.0	218.8	227.0
A	1.7	3.3	-0.4	-11.8	-6.3	-4.2	-3.5	-4.1	-4.6	-1.6	-1.9	0.3
1971	216.4	208.0	214.9	213.2	201.9	205.8	205.6	207.8	210.2	211.2	217.4	219.4
A	-8.6	-14.3	0.1	4.5	-1.8	1.9	1.2	1.0	1.3	-2.4	-3.2	-7.2
1972	215.5	227.7	224.1	215.8	205.7	207.5	210.8	211.5	211.5	213.7	222.4	229.1
A	-9.5	0.3	9.3	7.1	2.1	3.6	6.4	4.7	2.6	0.1	1.8	2.5
1973	234.0	224.5	215.9	197.2	199.5	201.8	200.8	200.9	203.3	208.0	217.8	232.9
A	9.0	2.2	1.1	-11.4	-4.3	-2.2	-3.6	-5.8	-5.6	-5.6	-2.9	6.3
1974	222.3	222.0	222.1	215.6	205.3	204.4	208.4	204.1	206.3	203.2	214.7	218.3
A	-2.7	-0.3	7.3	6.9	1.7	0.4	4.0	-2.7	-2.6	-10.4	-6.0	-8.3
1975	213.9	219.5	212.2	213.5	195.5	197.5	198.7	203.0	204.5	214.7	224.2	215.0
A	11.0	-2.8	-2.6	4.8	-8.2	-6.5	-5.7	-3.8	-4.5	1.1	3.5	-11.6
1976	221.1	216.2	210.6	208.0	200.4	204.5	209.4	210.5	213.7	213.7	216.7	220.8
A	-3.9	-6.1	-4.2	-0.7	-3.2	0.5	5.0	3.7	4.7	0.1	-3.9	-5.8
1977	219.1	224.3	206.3	198.4	202.5	201.3	198.8	206.2	-	215.3	221.9	230.9
A	-5.0	2.0	-8.6	-10.3	-1.1	-2.6	-5.6	-0.6	-	1.7	1.3	4.3
1978	240.3	231.5	216.1	209.4	197.8	200.0	199.2	215.5	222.7	-	-	-
A	15.3	9.2	1.3	0.8	-5.9	-3.9	-5.2	8.7	13.8	-	-	-
1979	199.3	223.1	213.6	206.8	201.1	201.5	202.6	211.3	209.3	214.5	222.8	227.3
A	-25.7	0.8	-1.3	-1.9	-2.5	-2.5	-1.8	4.5	0.4	0.9	2.1	0.7
1980	227.3	225.0	213.3	210.1	201.1	201.8	197.5	201.9	204.6	209.9	220.2	228.0
A	2.3	2.7	-1.6	1.4	-2.6	-2.2	-6.9	-4.9	-4.3	-3.7	-0.5	1.5
1981	230.4	222.5	213.6	205.4	204.5	205.5						
A	5.4	0.2	-1.3	-3.2	0.9	1.5						
Mean 1946-81	225.0	222.6	214.8	208.7	203.6	204.0	204.4	206.8	208.9	213.6	220.7	226.5
Std Dev	8.6	6.4	5.6	6.3	5.1	3.4	4.1	3.7	3.9	5.4	5.6	6.2

Appendix table 12. Number of standard deviations in the unadjusted (U) and adjusted (A) monthly sea level anomalies, Tofino, B.C., 1940-82.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1940 U	1.1	2.1	1.4	0.6	1.5	-0.6	1.4	0.6	2.9	2.0	0.6	2.1
1941 U	1.8	2.2	2.0	1.1	2.6	1.3	1.5	1.6	2.0	0.6	1.2	2.2
1942	-	-	-	-	-	-	-	-	-	-	-	-
1943 U	-0.3	0	-0.2	1.3	-0.3	0.9	0.5	0.1	-0.2	0.8	-0.4	-1.6
1944 U	0.3	-0.9	-1.9	0.3	0	-0.3	-0.1	-0.5	-0.2	-0.2	1.2	-0.8
1945 U	-0.3	-1.0	0	-1.8	0.9	-1.0	0.3	-0.8	-0.8	-1.1	0.6	1.0
1946 U	-0.3	0.6	0.2	0.4	0.5	1.5	1.1	-0.8	0.3	-0.7	-0.9	-0.5
A	-0.2	0.5	-0.1	0.7	0.6	1.7	1.4	-0.5	0.1	-0.8	-1.0	-0.2
1947 U	-0.8	-0.1	0.3	-0.2	0.2	1.8	1.7	-0.6	-1.1	2.2	-1.4	0.3
A	-0.8	0.4	0.5	0	0.2	1.5	1.4	-0.7	-0.6	1.7	-1.0	0.6
1948 U	-0.2	-0.1	-0.1	2.2	2.7	1.7	1.5	1.1	1.0	-0.6	-0.8	-0.3
A	0.4	0	-0.1	2.1	2.6	2.1	1.4	0.8	0.9	-0.5	-0.9	-0.7
1949 U	-2.0	0.6	1.1	-0.2	1.2	-0.4	-0.9	0.4	-0.1	-2.1	-0.1	-1.3
A	-1.3	-0.2	1.3	0	1.2	0	-0.7	0.6	-0.1	-2.0	-0.4	-1.9
1950 U	-0.4	0.2	1.2	0.4	-0.9	0	0	-0.4	-0.7	1.9	0.4	1.0
A	-0.9	-0.1	1.1	0.4	-0.5	0	0.2	-0.2	-0.5	1.2	0.5	0.9
1951 U	0.2	0.5	-0.9	-0.8	0.4	0	0.8	-0.5	0.3	0.7	1.2	-0.2
A	0	0.5	-0.9	-0.8	0.6	0.6	0.7	-0.3	0.3	0.8	1.3	-0.3
1952 U	1.3	0.6	-0.1	-0.5	-0.5	0.1	-0.2	0.2	-0.6	-1.3	-0.6	2.0
A	0.8	0.7	-0.6	-0.8	0	-0.3	0.3	0.2	-0.4	-0.9	-0.1	0
1953 U	1.8	-1.1	-0.3	-0.4	1.1	-0.8	-0.8	-0.6	-0.1	0.2	1.8	-0.8
A	1.6	-0.5	-0.6	-0.9	0.9	-0.6	-0.3	-0.9	0.1	0.6	1.7	-0.2
1954 U	1.1	0.9	0.2	-0.1	0.1	1.8	0.6	0.1	0.4	0.3	1.2	0.9
A	0.7	1.3	0.7	0.1	0.1	1.5	0.6	0.1	0.4	0.6	1.8	1.1
1955 U	-0.4	-1.6	-2.1	0.5	-1.7	-1.1	-0.3	-2.1	-1.4	-0.7	-0.5	0.7
A	-0.3	-1.5	-2.1	0.1	-1.5	-1.0	-0.9	-1.7	-1.4	-1.1	0.9	-0.2
1956 U	1.6	-1.0	-0.2	-0.7	-0.2	1.7	0.5	-1.0	-0.5	0.1	-2.2	-1.5
A	1.4	-1.5	-0.1	-0.7	-0.2	1.8	0.7	-0.6	-0.7	-0.3	-1.3	-1.3
1957 U	-1.1	-0.6	0.7	0.1	1.9	0.8	1.2	1.4	1.7	0.9	-0.6	1.2
A	-0.9	-1.0	0.5	0.1	1.5	0.8	1.1	1.6	1.7	1.1	0	0.8
1958 U	1.4	3.0	1.2	1.4	0.3	1.5	0.9	0.6	0.4	0.3	-0.2	0.4
A	1.3	2.9	0.9	1.6	0.2	1.1	0.5	0.6	0.1	0.6	0	1.0
1959 U	0.7	0.6	-0.9	-0.5	-0.3	0.7	-0.6	-0.8	0.8	-0.6	-1.8	-1.0
A	0.8	0.6	-0.6	-0.5	-0.3	0.3	-0.2	-0.8	0.3	-0.5	-1.3	-0.6
1960 U	-0.2	-0.2	-0.5	1.0	1.6	-0.9	-2.4	-0.4	-0.7	-0.1	0.7	-0.2
A	-0.1	-0.3	-0.6	0.9	1.2	-0.4	-2.2	-0.8	-0.3	-0.3	0.6	0.8
1961 U	1.0	1.4	2.8	-0.5	1.1	0.6	0.4	0	-1.0	-1.2	-1.3	-1.3
A	1.3	1.5	2.5	-0.5	1.1	0.8	0.4	0.3	-0.9	-1.5	-2.0	-1.5
1962 U	-1.2	0	-0.9	-0.6	0.3	-1.7	-1.3	0.1	0.1	1.0	0.5	-0.3
A	-0.8	-0.5	-1.2	-0.8	0.4	-1.6	-0.9	0.2	-0.5	1.2	0.4	0.2
1963 U	-1.6	0.3	-0.6	1.7	1.2	-0.4	1.2	0.3	1.4	1.9	1.7	-0.2
A	-0.9	0.3	-0.8	1.6	1.5	-0.6	1.1	0.4	0.9	2.1	1.8	0.5
1964 U	0.9	-2.7	-1.5	-1.9	-1.5	-0.7	-0.1	0.7	-0.7	-0.7	-0.4	0.1
A	0.6	-2.4	-2.0	-2.2	-1.7	-1.1	-0.6	0.4	-0.6	-0.6	-0.7	-0.8
1965 U	0.4	-1.2	-1.1	0.4	-1.3	-0.8	-0.5	1.0	-0.1	0.6	2.1	1.2
A	0.2	-1.4	-0.5	0.1	-1.3	-0.9	-0.5	0.9	0.3	0.8	2.1	0.8
1966 U	0.9	-0.1	1.2	-0.5	-1.4	-0.3	0.4	-0.6	-0.6	-0.8	0.3	1.5
A	0.6	0	1.4	-0.1	-1.4	-0.3	0.2	-0.5	-0.7	-0.7	0.3	1.2

Appendix table 12 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967 U	0.2	-1.0	1.0	0.9	-0.1	0.3	-0.1	-0.4	0.5	1.1	-0.6	-1.1
A	-0.1	-0.7	0.7	0.7	0.5	-0.1	0	-0.4	0.2	0.8	-0.4	-1.1
1968 U	0.2	0.8	0.9	-0.8	0.6	-0.2	0.6	2.3	0.5	1.2	0.9	1.2
A	0	1.0	1.2	-0.4	0.5	-0.1	0.7	1.9	0.7	1.0	1.3	0.9
1969 U	0.9	1.6	-0.9	1.3	-0.1	0.4	-1.0	-0.6	1.0	0.4	-0.2	1.0
A	0.4	1.0	-0.4	1.4	-0.2	-0.4	-0.8	-0.8	0.4	0.7	0.2	1.1
1970 U	0.4	-0.1	-0.6	-1.5	-1.5	-1.0	-0.7	-1.0	-1.3	-0.1	-0	0.9
A	0.2	0.5	-0.1	-1.9	-1.2	-1.2	-0.8	-1.1	-1.2	-0.3	-0.3	0
1971 U	-0.8	-1.7	0.1	0.7	-0.3	0.7	0.2	0.7	0.4	-0.6	-0.5	-0.6
A	-1.0	-2.2	0	0.7	-0.3	0.6	0.3	0.3	0.3	-0.4	-0.6	-1.2
1972 U	-0.9	0.4	1.2	1.0	0.4	1.2	1.7	1.2	0.7	-0.6	0.3	0.2
A	-1.1	0	1.7	1.1	0.4	1.1	1.6	1.3	0.7	0.2	0.3	0.4
1973 U	1.0	0.2	0.4	-1.9	-0.7	-0.4	-1.0	-1.6	-1.2	-0.7	0.6	1.1
A	1.0	0.3	0.2	-1.8	-0.8	-0.6	-0.9	-1.6	-1.4	-1.0	-0.5	1.0
1974 U	-0.1	0	1.7	0.8	0.3	0.2	1.1	-0.7	-0.8	-2.1	-0.8	-1.2
A	-0.3	0	1.3	1.1	0.3	0.1	1.0	-0.7	-0.7	-1.9	-1.1	-1.3
1975 U	-1.1	-0.1	-0.1	-1.2	-1.3	-2.0	-1.0	-0.9	-1.8	0.7	0.6	-2.0
A	-1.3	-0.4	-0.5	0.8	-1.6	-1.9	-1.4	-1.0	-1.1	0.2	0.6	-1.9
1976 U	-0.7	-0.4	-0.7	0	-0.6	0	1.5	1.0	1.0	-0.4	-1.4	-1.3
A	-0.4	-0.9	-0.7	-0.1	-0.6	0.1	1.2	1.0	1.2	0	-0.7	-0.9
1977 U	-1.0	-0.1	-1.1	-1.6	0.6	-1.1	-1.5	0.6	-	0.1	0.1	1.0
A	-0.7	0.3	-1.5	-1.6	-0.2	-0.8	-1.4	-0.2	-	0.3	0.2	0.7
1978 U	1.6	1.4	0.1	0.4	-1.2	-1.1	-1.2	2.5	3.5	-	-	-
A	1.8	1.4	0.2	0.1	-1.1	-1.1	-1.3	2.3	3.5	-	-	-
1979 U	-2.6	0.7	-0.4	-0.2	-0.5	-1.3	-0.1	1.4	0.5	0.3	-0.2	0.1
A	-3.0	0.1	-0.2	-0.3	-0.5	-0.7	-0.4	1.2	0.1	0.2	0.4	0.1
1980 U	0.1	0.7	-0.2	0.3	-0.2	-0.7	-1.7	-1.1	-0.7	-0.9	-0.3	0.1
A	0.3	0.4	-0.3	0.2	-0.5	-0.6	-1.7	-1.3	-1.1	-0.7	-0.1	0.2
1981 U	0.5	0	-0.2	-0.3	0.3	0.6	-0.4	-0.4	-0.1	0.6	1.4	0.5
A	0.6	0	-0.2	-0.5	0.2	0.4	-	-	-	-	-	-
1982 U	-0.6	-0.2	1.2	1.1	-1.1	1.1	0.3	0.3	2.2	1.4	1.8	1.4
A	-	-	-	-	-	-	-	-	-	-	-	-

Appendix table 13. Monthly and annual mean sea surface temperatures (°C) and anomalies (A), Amphitrite Point, 1934-83.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1934									12.3	10.4	10.1	9.0	-
A									-0.5	-1.1	0.2	0.4	-
1935	7.3	7.6	7.4	8.8	9.9	11.6	12.7	12.6	12.7	11.2	8.1	8.4	9.8
A	-0.2	0.1	-0.7	-0.4	-0.6	0	0.1	-0.6	-0.1	-0.3	-0.8	-0.2	-0.4
1936	8.0	6.6	7.6	8.6	10.4	13.7	14.3	14.6	12.9	11.7	9.1	8.4	10.4
A	0.5	-0.9	-0.5	-0.6	-0.1	2.1	1.7	1.4	0.1	0.2	0.8	-0.2	0.2
1937	6.9	6.3	8.1	9.2	10.3	11.7	12.2	12.9	11.7	11.0	10.4	9.1	9.9
A	-0.6	-1.2	0	0	-0.2	0.1	-0.4	-0.3	-1.1	-0.5	0.5	0.5	-0.3
1938	8.3	6.8	7.9	9.2	10.0	10.9	11.3	12.1	12.2	11.6	9.7	8.2	9.8
A	0.8	-0.7	-0.2	0	-0.5	-0.7	-1.3	-1.1	-0.6	0.1	-0.2	-0.4	-0.4
1939	7.9	6.7	-	-	-	-	-	13.7	12.3	10.9	10.6	10.1	-
A	-0.4	-0.8	-	-	-	-	-	0.5	-0.5	-0.6	0.7	1.5	-
1940	8.7	8.7	9.2	11.1	11.7	11.9	12.4	13.3	13.0	12.4	10.9	9.2	11.0
A	1.2	1.2	1.1	1.9	1.2	0.3	-0.2	0.1	0.2	0.9	1.0	0.6	0.8
1941	8.4	9.1	9.9	11.2	12.4	13.1	14.1	13.1	13.5	12.2	10.9	9.7	11.4
A	0.9	1.6	1.8	2.0	1.9	1.5	1.5	-0.1	0.7	0.7	1.0	1.1	1.2
1942	7.6	8.1	8.0	9.6	11.1	12.1	14.7	14.2	13.3	11.5	9.4	8.0	10.6
A	0.1	0.6	-0.1	0.4	0.6	0.5	2.1	1.0	0.5	0	-0.5	-0.6	0.4
1943	6.6	6.7	7.4	9.6	10.0	11.4	12.4	13.0	13.0	11.6	10.2	9.2	10.1
A	-0.9	-0.8	-0.7	0.4	-0.5	-0.2	-0.2	-0.2	0.2	0.1	0.3	0.6	-0.1
1944	8.4	7.7	8.1	9.4	10.7	10.7	12.0	13.4	12.8	12.1	11.4	9.5	10.5
A	0.9	0.2	0	0.2	0.2	-0.9	-0.6	0.2	0	0.6	1.5	0.9	0.3
1945	9.0	8.7	8.7	9.1	11.4	10.9	11.9	12.6	11.9	10.6	8.4	7.6	10.1
A	1.5	1.2	0.6	-0.1	0.9	-0.7	-0.7	-0.6	-0.9	-0.9	-1.5	-1.0	-0.1
1946	7.9	7.4	8.1	8.8	10.4	12.6	12.7	12.9	12.1	10.4	8.2	7.2	9.9
A	0.4	-0.1	0	-0.4	-0.1	1.0	0.1	-0.3	-0.7	-1.1	-1.7	-1.4	-0.3
1947	6.5	6.8	7.8	9.3	10.3	12.4	13.3	14.3	12.6	11.3	10.3	8.4	10.3
A	-1.0	-0.7	-0.3	0.1	-0.2	0.8	0.7	1.1	-0.2	-0.2	0.4	-0.2	0.1
1948	7.6	6.9	7.2	8.1	10.1	11.6	12.8	13.3	13.0	10.9	8.5	6.7	9.7
A	0.1	-0.6	-0.9	-1.1	-0.4	0	0.2	0.1	0.2	-0.6	-1.4	-1.9	-0.5
1949	5.2	5.4	7.1	8.6	10.9	10.6	11.9	13.2	12.1	10.1	9.8	8.5	9.4
A	-2.3	-2.1	-1.0	-0.6	0.4	-1.0	-0.7	0	-0.7	-1.4	-0.1	-0.1	-0.8
1950	5.2	5.8	7.1	8.2	8.8	11.3	11.4	12.1	11.9	11.0	9.8	9.0	9.3
A	-2.3	-1.7	-1.0	-1.0	-1.7	-0.3	-1.2	-1.1	-0.9	-0.5	-0.1	0.4	-0.9
1951	8.2	7.3	7.1	9.2	9.9	11.1	(12.6)	13.4	12.2	11.5	9.8	8.4	9.8
A	0.7	-0.2	-1.0	0	-0.6	-0.5	-	0.2	-0.6	0	-0.1	-0.2	-0.4
1952	6.9	7.3	7.9	8.7	10.4	11.3	12.2	13.1	12.6	11.5	9.2	8.2	9.9
A	-0.6	-0.2	-0.2	-0.5	-0.1	-0.3	-0.4	-0.1	-0.2	0	-0.7	-0.4	-0.3
1953	8.2	8.4	8.6	9.2	11.2	11.4	11.9	13.2	13.2	11.9	10.8	9.6	10.6
A	0.7	0.9	0.5	0	0.7	-0.2	-0.7	0	0.4	0.4	0.9	1.0	0.4
1954	8.9	7.9	8.0	8.4	9.6	11.2	12.4	12.9	12.6	11.3	11.2	9.9	10.3
A	1.4	0.4	-0.1	-0.8	-0.9	-0.4	-0.2	-0.3	-0.2	-0.2	1.3	1.3	0.1
1955	8.4	7.6	7.4	8.0	8.8	10.4	11.6	11.8	11.8	10.8	8.6	7.4	9.3
A	0.9	0.1	-0.7	-1.2	-1.7	-1.2	-1.0	-1.4	-1.0	-0.7	-1.3	-1.2	-0.9
1956	7.0	(7.5)	(8.1)	8.3	8.8	10.0	12.3	12.7	12.1	11.1	9.5	7.9	9.9
A	-0.5	-	-	-0.9	-1.7	-1.6	-0.3	-0.5	-0.7	-0.4	-0.4	-0.7	-0.3

Appendix table 13 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1957	6.4	6.3	7.3	8.9	10.6	11.5	12.8	13.8	14.1	12.2	11.1	9.6	10.3
A	-1.1	-1.2	-0.8	-0.3	0.1	-0.1	0.2	0.6	1.3	0.7	1.1	1.0	0.1
1958	8.8	9.4	9.3	10.4	12.2	13.7	14.8	14.6	13.3	11.3	9.9	8.9	11.3
A	1.3	1.9	1.2	1.2	1.3	2.1	2.2	1.4	0.5	-0.2	0	0.3	1.1
1959	8.1	7.9	8.4	9.6	10.7	12.1	12.3	12.9	13.0	11.3	9.1	8.3	10.3
A	0.6	0.4	0.3	0.4	0.2	0.5	-0.3	-0.3	0.2	-0.2	-0.8	-0.3	0.1
1960	7.2	7.9	7.7	9.7	11.0	10.8	11.2	13.3	13.4	11.7	11.1	9.3	10.3
A	-0.3	0.4	-0.4	0.5	0.5	-0.8	-1.4	0.1	0.6	0.2	1.2	0.7	0.1
1961	8.6	8.9	9.0	9.5	11.2	11.8	14.1	13.7	12.7	10.4	8.4	7.2	10.4
A	1.1	1.4	0.9	0.3	0.7	0.2	1.5	0.5	-0.1	-1.1	-1.5	-1.4	0.2
1962	7.1	7.8	7.6	9.4	10.6	11.1	11.2	13.1	13.1	12.7	12.0	10.3	10.5
A	-0.4	0.3	-0.5	0.2	0.1	-0.5	-1.4	-0.1	0.3	1.2	1.1	1.7	0.3
1963	8.1	8.8	8.6	10.1	11.9	11.3	13.5	14.2	14.3	13.3	11.3	9.9	11.3
A	0.6	1.3	0.5	0.9	1.4	-0.3	1.9	1.0	1.5	1.8	1.4	1.3	1.1
1964	(7.5)	8.7	8.7	8.9	9.2	11.3	12.7	13.2	12.7	11.3	8.9	7.8	10.1
A	-	1.2	0.6	-0.3	-0.7	-0.3	0.1	0	-0.1	-0.2	-1.0	-0.8	-0.1
1965	7.2	7.3	8.2	8.7	9.9	11.1	11.7	12.9	12.7	11.6	11.1	9.8	10.2
A	-0.3	-0.2	0.1	-0.5	-0.6	-0.5	-0.9	-0.3	-0.1	0.1	1.2	1.2	0
1966	(7.5)	8.5	8.1	9.6	10.0	11.7	12.3	12.2	12.4	11.3	9.9	9.2	10.2
A	-	1.0	0	0.4	-0.5	0.1	-0.3	-1.0	-0.4	-0.2	0	0.6	0
1967	8.4	8.4	7.9	9.1	10.1	11.9	12.7	13.2	13.3	12.6	11.3	8.7	10.6
A	0.9	0.9	-0.2	-0.1	-0.4	0.3	0.1	0	0.5	1.1	1.4	0.1	0.4
1968	7.4	7.4	8.7	9.1	10.6	11.7	12.4	12.9	12.6	10.8	10.4	8.5	10.2
A	-0.1	-0.1	0.6	-0.1	0.1	0.1	-0.2	-0.3	-0.2	-0.7	0.5	-0.1	0
1969	6.6	6.4	7.9	9.3	11.4	12.8	12.3	12.9	12.2	12.0	10.6	9.4	10.3
A	-0.9	-1.1	-0.2	0.1	0.9	1.2	-0.3	-0.3	-0.6	-0.5	0.7	0.8	0.1
1970	8.3	8.8	9.1	9.5	10.2	11.2	12.4	12.5	12.3	10.6	9.6	7.9	10.2
A	0.8	1.3	1.0	0.3	-0.3	-0.4	-0.2	-0.7	-0.5	-1.1	-0.3	-0.7	0
1971	7.5	7.4	7.0	8.6	9.8	11.8	12.8	13.6	13.4	11.1	9.2	7.7	10.1
A	0	-0.1	-1.1	-0.6	-0.7	0.2	0.2	0.4	0.6	-0.4	-0.7	-0.9	-0.1
1972	6.4	5.9	7.9	8.4	10.3	11.4	13.0	13.8	12.4	10.5	9.2	7.9	9.8
A	-1.1	-1.6	-0.2	-0.8	-0.2	-0.2	0.4	0.6	-0.4	-1.0	-0.7	-0.7	-0.4
1973	6.9	7.3	8.5	9.4	10.4	11.6	12.4	12.8	12.6	11.3	9.1	8.8	10.2
A	-0.6	-0.2	0.4	0.2	-0.1	0	-0.2	-0.4	-0.2	-0.2	-0.8	0.2	0
1974	7.3	7.6	7.7	9.0	10.0	10.7	13.0	14.0	13.4	11.2	9.4	9.1	10.3
A	-0.2	0.1	-0.4	-0.2	-0.5	-0.9	0.4	0.8	0.6	-0.3	-0.5	0.5	0.1
1975	7.6	6.7	7.6	8.8	10.4	10.8	12.0	12.6	13.2	11.6	9.9	8.4	10.0
A	0.1	-0.8	-0.5	-0.4	-0.1	-0.8	-0.6	-0.6	0.4	0.1	0	-0.2	-0.2
1976	7.5	7.3	7.1	8.8	9.9	10.8	12.9	12.5	12.9	11.4	10.2	8.9	10.1
A	0	-0.2	-1.0	-0.4	-0.6	-0.8	0.3	-0.7	0.1	-0.1	0.3	0.3	-0.1
1977	7.8	8.4	8.6	9.7	10.7	11.9	11.9	14.4	13.4	11.9	9.3	8.3	10.6
A	0.3	0.9	0.5	0.5	0.2	0.3	-0.7	1.2	0.6	0.4	-0.6	-0.3	0.4
1978	8.2	8.8	9.1	10.1	11.1	13.7	13.3	13.1	14.2	12.4	8.1	6.9	10.8
A	0.7	1.3	1.0	0.9	0.6	2.1	0.7	-0.1	1.4	0.9	-1.8	-1.7	0.6
1979	5.9	6.1	(8.1)	9.3	11.5	11.6	13.6	14.0	14.9	12.4	10.6	9.7	10.6
A	-1.6	-1.4	-	0.1	1.0	0	1.0	0.8	2.1	0.9	0.7	1.1	0.4

Appendix table 13 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1980	7.6	8.1	8.7	10.1	11.3	12.1	12.7	13.4	12.9	12.1	11.1	9.3	10.8
A	0.1	0.6	0.6	0.9	0.8	0.5	0.1	0.2	0.1	0.6	1.2	0.7	0.6
1981	9.6	9.0	9.7	10.0	11.4	12.5	13.4	13.8	13.3	12.5	11.2	9.2	11.3
A	2.1	1.5	1.6	0.8	0.9	0.9	0.8	0.6	0.5	1.0	1.3	0.6	1.1
1982	7.7	7.4	8.2	9.2	10.2	11.5	12.4	13.4	13.7	11.8	10.3	9.0	10.4
A	0.2	-0.1	0.1	0	-0.3	0.1	0.2	0.2	0.9	0.3	0.4	0.4	0.2
1983	8.9	9.5	10.6	11.4	12.9	12.7	13.9	14.2	13.5	11.4			
A	1.4	2.0	2.5	2.2	2.4	1.1	1.3	1.0	0.7	-0.1			
Mean 1935-79	7.5	7.5	8.1	9.2	10.5	11.6	12.6	13.2	12.8	11.5	9.9	8.6	10.2
Std Dev	0.9	1.0	0.7	0.7	0.8	0.8	0.9	0.7	0.7	0.7	1.0	0.9	0.5

Appendix table 14. Monthly and annual mean sea surface temperatures (°C) and anomalies (A), Kains Island, 1935-83.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1935	7.1	7.7	7.6	8.6	9.8	11.6	12.3	12.3	12.6	10.9	8.2	8.2	9.7
A	-0.4	0.3	-0.1	0	-0.3	0.1	-0.3	-0.9	-0.4	-0.5	-1.3	-0.1	-0.3
1936	7.6	6.6	7.0	8.2	10.3	12.9	15.4	13.8	12.2	11.6	9.1	8.3	10.2
A	0.1	-0.8	-0.7	-0.4	0.2	1.4	2.8	0.6	-0.8	0.2	-0.4	0	0.2
1937	6.6	6.3	7.6	8.5	10.3	11.6	12.5	13.3	12.9	11.3	9.9	9.3	10.0
A	-0.9	-1.1	-0.1	-0.1	0.2	0.1	-0.1	0.1	-0.1	-0.1	0.4	1.0	0
1938	8.3	7.6	8.3	9.4	10.5	11.4	12.1	12.3	13.8	11.9	8.9	7.4	10.1
A	0.8	0.2	0.6	0.8	0.4	-0.1	-0.5	-0.9	0.8	0.5	-0.6	-0.9	0.1
1939	7.1	6.2	7.6	7.6	10.2	10.6	12.8	13.6	13.2	10.8	10.5	10.2	10.0
A	-0.4	-1.2	-0.1	-1.0	0.1	-0.9	0.2	0.4	0.2	-0.6	1.0	1.9	0
1940	9.8	8.9	9.1	10.3	11.2	12.8	12.9	14.2	14.3	12.5	10.7	9.6	11.3
A	2.3	1.5	1.4	1.7	1.1	1.3	0.3	1.0	1.3	1.1	1.2	1.3	1.3
1941	8.8	8.9	10.1	10.9	11.4	13.2	14.1	14.2	13.9	12.1	10.6	8.8	11.4
A	1.3	1.5	2.4	2.3	1.3	1.7	1.5	1.0	0.9	0.7	1.1	0.5	1.4
1942	8.8	8.7	8.4	9.4	10.8	12.2	13.6	13.7	12.6	11.9	9.1	7.7	10.5
A	1.3	1.3	0.7	0.8	0.7	0.7	1.0	0.5	-0.4	0.5	-0.4	-0.6	0.5
1943	6.6	7.1	7.6	8.9	10.0	11.6	12.6	13.3	13.0	11.6	9.9	8.9	10.1
A	-0.9	-0.3	-0.1	0.3	-0.1	0.1	0	0.1	0	0.2	0.4	0.6	0.1
1944	8.2	8.2	8.2	8.9	10.2	11.7	12.7	13.1	13.1	12.6	10.5	9.8	10.6
A	0.7	0.8	0.5	0.3	0.1	0.2	0.1	-0.1	0.1	1.2	1.0	1.5	0.6
1945	9.7	8.7	8.2	8.6	9.7	10.8	11.8	12.3	11.3	10.7	8.1	7.2	9.7
A	2.2	1.3	0.5	0	-0.4	-0.7	-0.8	-0.9	-1.7	-0.7	-1.4	-1.1	-0.3
1946	7.4	7.1	7.5	7.9	10.2	12.0	13.2	13.0	12.6	10.5	8.0	6.8	9.7
A	-0.1	-0.3	-0.2	-0.7	0.1	0.5	0.6	-0.2	-0.4	-0.9	-1.5	-1.5	-0.3
1947	6.2	6.6	7.8	8.8	10.3	12.2	13.7	12.9	12.8	11.2	9.7	8.8	10.1
A	-1.3	-0.8	0.1	0.2	0.2	0.7	1.1	-0.3	-0.2	-0.2	0.2	0.5	0.1
1948	7.7	7.2	7.3	8.2	10.0	11.7	12.3	12.7	12.7	11.0	8.9	7.1	9.7
A	0.2	-0.2	-0.4	-0.4	-0.1	0.2	-0.3	-0.5	-0.3	-0.4	-0.6	-1.2	-0.3
1949	6.3	5.8	6.9	8.1	10.1	10.8	12.3	13.7	12.8	11.2	10.0	8.2	9.7
A	-1.2	-1.6	-0.8	-0.5	0	-0.7	-0.3	0.5	-0.2	-0.2	0.5	-0.1	-0.3
1950	6.2	5.6	6.6	7.4	8.7	11.2	12.2	13.3	12.4	11.0	8.9	9.3	9.4
A	-1.3	-1.8	-1.1	-1.2	-1.4	-0.3	-0.4	0.1	-0.6	-0.4	-0.6	1.0	-0.6
1951	7.9	7.3	7.3	8.4	10.5	10.6	12.6	12.8	12.2	11.9	9.8	8.3	9.9
A	0.4	-0.1	-0.4	-0.2	0.4	-0.9	0	-0.4	-0.8	0.5	0.3	0	-0.1
1952	7.1	7.0	7.6	8.0	9.3	10.3	11.1	12.8	12.4	11.9	10.1	8.4	9.7
A	-0.4	-0.4	-0.1	-0.6	-0.8	-1.2	-1.5	-0.4	-0.6	0.5	0.6	0.1	-0.3
1953	7.8	7.9	8.0	8.7	10.1	11.2	12.9	12.7	13.6	11.3	10.1	9.3	10.3
A	0.3	0.5	0.3	0.1	0	-0.3	0.3	-0.5	0.6	-0.1	0.6	1.0	0.3
1954	7.8	7.6	7.8	8.4	9.8	11.4	11.7	12.4	14.2	11.4	10.5	9.2	10.2
A	0.3	0.2	0.1	-0.2	-0.3	-0.1	-0.9	-0.8	1.2	0	1.0	0.9	0.2
1955	8.6	8.0	7.1	7.9	9.1	10.1	11.9	11.9	12.2	10.4	8.1	6.4	9.3
A	1.1	0.6	-0.6	-0.7	-1.0	-1.4	-0.7	-1.3	-0.8	-1.0	-1.4	-1.9	-0.7
1956	6.3	6.3	6.6	7.9	9.6	11.2	12.0	13.1	13.6	11.2	9.3	7.9	9.6
A	-1.2	-1.1	-1.1	-0.7	-0.5	-0.3	-0.6	-0.1	0.6	-0.2	-0.2	-0.4	-0.4

Appendix table 14 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1957	6.8	6.7	6.9	8.3	10.4	12.1	13.1	14.8	13.6	11.9	10.3	9.3	10.3
A	-0.7	-0.7	-0.8	-0.3	0.3	0.6	0.5	1.6	0.6	0.5	0.8	1.0	0.3
1958	8.8	9.1	8.2	9.7	11.2	13.0	13.1	13.4	13.1	11.2	9.4	8.4	10.8
A	1.3	1.7	0.5	1.1	1.1	1.5	0.5	0.2	0.1	-0.2	-0.1	0.1	0.8
1959	7.7	7.7	7.9	8.6	10.3	11.7	12.6	12.1	12.9	11.4	9.0	(8.4)	10.0
A	0.2	0.3	0.2	0	0.2	0.2	0	-1.1	-0.1	0	-0.5	-	0
1960	7.2	7.6	7.3	8.6	10.2	10.8	11.4	13.1	12.7	11.2	9.6	8.6	9.8
A	-0.3	0.2	-0.4	0	0.1	-0.7	-1.2	-0.1	-0.3	-0.2	0.1	0.3	-0.2
1961	8.3	8.3	8.4	9.6	10.9	12.5	13.7	13.8	13.1	10.3	8.3	7.2	10.3
A	0.8	0.9	0.7	1.0	0.8	1.0	1.1	0.6	0.1	-1.1	-1.2	-1.1	0.3
1962	7.1	7.4	7.4	8.8	9.7	11.6	12.3	12.9	12.2	11.4	10.4	9.1	10.0
A	-0.4	0	-0.3	0.2	-0.4	0.1	-0.3	-0.3	-0.8	0	0.9	0.8	0
1963	8.6	8.6	8.2	9.2	10.9	11.7	13.1	14.0	15.5	13.4	10.6	9.8	11.1
A	1.1	1.2	0.5	0.6	0.8	0.2	0.5	0.8	2.5	2.0	1.1	1.5	1.1
1964	8.8	8.6	8.3	8.7	9.3	(11.5)	12.7	13.3	11.9	11.1	9.1	7.6	10.1
A	1.3	1.2	0.6	0.1	-0.8	-	0.1	0.1	-1.1	-0.3	-0.4	-0.7	0.1
1965	6.5	6.8	7.7	8.4	9.6	10.6	12.4	13.9	11.4	10.7	9.9	9.0	9.7
A	-1.0	-0.6	0	-0.2	-0.5	-0.9	-0.2	0.7	-1.6	-0.7	0.4	0.7	-0.3
1966	8.3	8.3	7.9	8.9	9.7	11.2	12.7	12.6	13.3	11.4	9.0	8.1	10.1
A	0.8	0.9	0.2	0.3	-0.4	-0.3	0.1	-0.6	0.3	0	-0.5	-0.2	0.1
1967	7.8	7.7	7.8	8.7	10.5	11.6	13.1	14.1	14.9	12.7	10.6	8.5	10.6
A	0.3	0.3	0.1	0.1	0.4	0.1	0.5	0.9	1.9	1.3	1.1	0.2	0.6
1968	7.4	7.1	8.2	8.4	10.6	12.1	13.1	13.3	13.1	10.6	9.4	8.1	10.1
A	-0.1	-0.3	0.5	-0.2	0.5	0.6	0.5	0.1	0.1	-0.8	-0.1	-0.2	0.1
1969	6.7	6.3	7.5	8.2	10.1	12.4	12.1	12.6	13.3	11.4	10.2	8.8	9.8
A	-0.8	-1.1	-0.2	-0.4	0	0.9	-0.5	-0.6	-0.7	0	0.7	0.5	-0.2
1970	7.4	7.8	8.1	8.3	9.4	10.7	11.6	12.2	11.4	9.9	8.2	6.4	9.3
A	-0.1	0.4	0.4	-0.3	-0.7	-0.8	-1.0	-1.0	-1.6	-1.5	-1.3	-1.9	-0.7
1971	6.0	6.6	6.7	7.7	9.1	10.9	12.3	14.3	13.0	10.9	8.4	6.9	9.4
A	-1.5	-0.8	-1.0	-0.9	-1.0	-0.6	-0.3	1.1	0	-0.5	-1.1	-1.4	-0.6
1972	5.8	5.8	6.6	7.6	9.5	11.3	12.9	13.2	11.6	10.0	8.6	7.2	9.2
A	-1.7	-1.6	-1.1	-1.0	-0.6	-0.2	0.3	0	-1.4	-1.4	-0.9	-1.1	-0.8
1973	6.6	6.7	7.6	8.8	10.2	10.8	11.7	12.2	13.2	11.1	8.0	7.4	9.6
A	-0.9	-0.7	-0.1	0.2	0.1	-0.7	-0.9	-1.0	0.2	-0.3	-1.5	-0.9	-0.4
1974	6.4	7.3	7.4	8.6	9.9	10.9	12.7	12.6	13.9	11.3	9.3	8.4	9.9
A	-1.1	-0.1	-0.3	0	-0.2	-0.6	0.1	-0.6	0.9	-0.1	-0.2	0.1	-0.1
1975	7.3	6.7	7.1	8.2	9.8	10.4	12.6	12.1	11.9	10.9	8.9	7.8	9.5
A	-0.2	-0.7	-0.6	-0.4	-0.3	-1.1	0	-1.1	-1.1	-0.5	-0.6	-0.5	-0.5
1976	7.2	6.9	7.2	8.3	9.7	10.7	12.3	12.9	13.8	12.0	9.9	8.8	10.0
A	-0.3	-0.5	-0.3	-0.3	-0.4	-0.8	-0.3	-0.3	0.8	0.6	0.4	0.5	0
1977	8.2	8.6	8.4	9.2	10.3	11.4	12.6	13.7	13.2	11.8	9.3	8.0	9.8
A	0.7	1.2	0.7	0.6	0.2	-0.1	0	0.5	0.2	0.4	-0.2	-0.3	-0.2
1978	7.8	8.4	8.9	10.0	10.7	12.7	12.6	14.1	14.2	12.8	9.8	8.2	10.8
A	0.3	1.0	1.2	1.4	0.6	1.2	0	0.9	1.2	1.4	0.3	-0.1	0.8
1979	6.7	6.5	7.7	8.8	10.8	11.7	13.4	14.2	14.9	12.5	10.4	9.4	10.6
A	-0.8	-0.9	0	0.2	0.7	0.2	0.8	1.0	1.9	1.1	0.9	1.1	0.6

Appendix table 14 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1980	8.1	8.2	8.7	9.1	10.8	12.2	13.3	12.3	12.5	12.4	10.6	9.2	10.6
A	0.6	0.8	1.0	0.5	0.7	0.7	0.7	-0.9	-0.5	1.0	1.1	0.9	0.6
1981	9.4	8.9	9.2	9.7	10.8	12.7	13.2	13.0	14.3	11.5	10.3	8.9	11.0
A	1.9	1.5	1.5	1.1	0.7	1.2	0.6	-0.2	1.3	-0.1	0.8	0.6	1.0
1982	7.4	7.3	7.8	8.5	9.9	11.8	12.8	13.4	(13.0)	11.2	9.2	8.4	10.1
A	-0.1	-0.1	0.1	-0.1	-0.2	0.3	0.2	0.3	-	-0.2	-0.3	0.1	0.1
1983	8.4	8.6	9.5	10.5	12.2	12.9	14.5	14.5	13.9	11.4			
A	0.9	1.2	1.8	1.9	2.1	1.4	1.9	1.3	0.9	0			
Mean 1935-79	7.5	7.4	7.7	8.6	10.1	11.5	12.6	13.2	13.0	11.4	9.5	8.3	10.0
Std Dev	1.0	0.9	0.7	0.7	0.6	0.8	0.8	0.7	0.9	0.7	0.8	0.9	0.5

Appendix table 15. Number of standard deviations in the monthly and annual sea surface temperature anomalies, Amphitrite Point (A) and Kains Island (K), 1935-82.

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1935	A	-0.2	0.1	-1.0	-0.6	-0.7	0	0.1	-0.9	-0.1	-0.4	-0.8	-0.2	-0
	K	-0.4	0.3	-0.1	0	-0.5	0.1	-0.4	-1.3	-0.4	-0.7	-1.6	-0.1	-0.6
1936	A	0.6	-0.9	-0.7	-0.9	-0.1	2.6	1.9	2.0	0.1	0.3	0.8	-0.2	0.4
	K	0.1	-0.9	-1.0	-0.6	0.3	1.7	3.5	0.9	-0.9	0.3	-0.5	0	0.4
1937	A	-0.7	-1.2	0	0	-0.2	0.1	-0.4	-0.4	-1.6	-0.7	0.5	0.6	-0.6
	K	-0.9	-1.2	-0.1	-0.1	0.3	0.1	-0.1	0.1	-0.1	-0.1	0.5	1.1	0
1938	A	0.9	-0.7	-0.3	0	-0.6	-0.9	-1.4	-1.6	-0.9	0.1	-0.2	-0.4	-0.8
	K	0.8	0.2	0.9	1.1	0.7	-0.1	-0.6	-1.3	0.9	0.7	-0.7	-1.0	0.2
1939	A	-0.4	-0.8	-	-	-	-	-	0.7	-0.7	-0.9	0.7	1.7	-
	K	-0.4	-1.3	-0.1	-1.4	0.2	-1.1	0.2	0.6	0.2	-0.9	1.2	2.1	0
1940	A	1.3	1.2	1.6	2.7	1.5	0.4	-0.2	0.1	0.3	1.3	1.0	0.7	1.6
	K	2.3	1.7	2.0	2.4	1.8	1.6	0.4	1.4	1.4	1.6	1.5	1.4	2.6
1941	A	1.0	1.6	2.6	2.9	2.4	1.9	1.7	-0.1	1.0	1.0	1.0	1.2	2.4
	K	1.3	1.7	3.4	3.3	2.2	2.1	1.9	1.4	1.0	1.0	1.4	0.6	2.8
1942	A	0.1	0.6	-0.1	0.6	0.7	0.6	2.3	1.4	0.7	0	-0.5	-0.7	0.8
	K	1.3	1.4	1.0	1.1	1.2	0.9	1.2	0.7	-0.4	0.7	-0.5	-0.7	1.0
1943	A	-1.0	-0.8	-1.0	0.6	-0.6	-0.2	-0.2	-0.3	0.3	0.1	0.3	0.7	-0.2
	K	-0.9	-0.3	-0.1	0.4	-0.2	0.1	0	0.1	0	0.3	0.5	0.7	0.2
1944	A	1.0	0.2	0	0.3	0.2	-1.1	-0.7	0.3	0	0.9	1.5	1.0	0.6
	K	0.7	0.9	0.7	0.4	0.2	0.2	0.1	-0.1	0.1	1.7	1.2	1.7	1.2
1945	A	1.7	1.2	0.9	-0.1	1.1	-0.9	-0.8	-0.9	-1.3	-1.3	-1.5	-1.1	-0.2
	K	2.2	1.4	0.7	0	-0.7	-0.9	-1.0	-1.3	-1.9	-1.0	-1.7	-1.2	-0.6
1946	A	0.4	-0.1	0	-0.6	-0.1	1.2	0.1	-0.4	-1.0	-1.6	-1.7	-1.6	-0.6
	K	-0.1	-0.3	-0.3	-1.0	0.2	0.6	0.7	-0.3	-0.4	-1.3	-1.9	-1.7	-0.6
1947	A	-1.1	-0.7	-0.4	0.1	-0.2	1.0	0.8	1.6	1.6	-0.3	0.4	-0.2	0.2
	K	-1.3	-0.9	0.1	0.3	0.3	0.9	1.4	-0.4	-0.2	-0.3	0.2	0.6	0.2
1948	A	0.1	-0.6	-1.3	-1.6	-0.5	0	0.2	0.1	0.3	-0.9	-1.4	-2.1	-1.0
	K	0.2	-0.2	-0.6	-0.6	-0.2	0.2	-0.4	-0.7	-0.3	-0.6	-0.7	-1.3	-0.6
1949	A	-2.6	-2.1	-1.4	-0.8	0.5	-1.2	-0.8	0	-1.0	-2.0	-0.1	-0.1	-1.6
	K	-1.2	-1.8	-1.1	-0.7	0	-0.9	-0.4	0.7	-0.2	-0.3	0.6	-0.1	-0.6
1950	A	-2.6	-1.7	-1.4	-1.4	-2.1	-0.4	-1.3	-1.6	-1.3	-0.7	-0.1	0.4	-1.8
	K	-1.3	-2.0	-1.6	-1.7	-2.3	-0.4	-0.5	0.1	-0.7	-0.6	-0.7	1.1	-1.2
1951	A	0.8	-0.2	-1.4	0	-0.7	-0.6	0	0.3	-0.9	0	-0.1	-0.2	-0.8
	K	0.4	-0.1	-0.6	-0.3	0.7	-1.1	0	-0.6	-0.9	0.7	0.4	0	-0.2
1952	A	-0.7	-0.2	-0.3	-0.7	-0.1	-0.4	-0.4	-0.1	-0.3	0	-0.7	-0.4	-0.6
	K	-0.4	-0.4	-0.1	-0.9	-1.3	-1.5	-1.9	-0.6	-0.7	0.7	0.7	0.1	-0.6
1953	A	0.8	0.9	0.7	0	0.9	-0.2	-0.8	0	0.6	0.6	0.9	1.1	0.8
	K	0.3	0.6	0.4	0.1	0	-0.4	0.4	-0.7	0.7	-0.1	0.7	1.1	0.6
1954	A	1.6	0.4	-0.1	-1.1	-1.1	-0.5	-0.2	-0.4	-0.3	-0.3	1.3	1.4	0.2
	K	0.3	0.2	0.1	-0.3	-0.5	-0.1	-1.1	-1.1	1.3	0	1.2	1.0	0.4
1955	A	1.0	0.1	-1.0	-1.7	-2.1	-1.5	-1.1	-2.0	-1.4	-1.0	-1.3	-1.3	-1.8
	K	1.1	0.7	-0.9	-1.0	-1.7	-1.7	-0.9	-1.9	-0.9	-1.4	-1.7	-2.1	-1.4
1956	A	-0.6	-	-	-1.3	-2.1	-2.0	-0.3	-0.7	-1.0	-0.6	-0.4	-0.8	-0.6
	K	-1.2	-1.2	-1.6	-1.0	-0.8	-0.4	-0.7	-0.1	0.7	-0.3	-0.2	-0.4	-0.8
1957	A	-1.2	-1.2	-1.1	-0.4	0.1	-0.1	0.2	0.9	1.9	1.0	1.1	1.1	0.2
	K	-0.7	-0.8	-1.1	-0.4	0.5	-0.7	0.6	2.3	0.7	0.7	1.0	1.1	0.6

Appendix table 15 (cont'd)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1958	A	1.4	1.9	1.7	1.7	1.6	2.6	2.4	2.0	0.7	-0.3	0	0.3	2.2
	K	1.3	1.9	0.7	1.6	1.8	1.9	0.6	0.3	0.1	-0.3	-0.1	0.1	1.6
1959	A	0.7	0.4	0.4	0.6	0.2	0.6	-0.3	-0.4	0.3	-0.3	-0.8	-0.3	0.2
	K	0.2	0.3	0.3	0	0.3	0.2	0	-1.6	-0.1	0	-0.6	0	0.4
1960	A	-0.3	0.4	-0.6	0.7	0.6	-1.0	-1.6	0.1	0.9	0.3	1.2	0.8	0.2
	K	-0.3	0.2	-0.6	0	0.2	-0.9	-1.5	-0.1	-0.3	-0.3	0.1	0.3	-0
1961	A	1.2	1.4	1.3	0.4	0.9	0.2	1.7	0.7	-0.1	-1.6	-1.5	-1.6	0.4
	K	0.8	1.0	2.4	1.4	1.3	1.2	1.4	0.9	0.1	-1.6	-1.5	-1.2	0.6
1962	A	-0.4	0.3	-0.7	0.3	0.1	-0.6	-1.6	-0.1	0.4	1.7	1.1	1.9	0.6
	K	-0.4	0	-0.4	0.3	-0.7	0.1	-0.4	-0.4	-0.9	0	1.1	0.9	0
1963	A	0.7	1.3	0.7	1.3	1.7	-0.4	2.1	1.4	2.1	2.6	1.4	1.4	2.2
	K	1.1	1.3	0.7	0.9	1.3	0.2	0.6	1.1	2.8	2.9	1.4	1.7	2.2
1964	A	-	1.2	0.9	-0.4	-0.9	-0.4	0.1	0	-0.1	-0.3	-1.0	-0.9	-0.2
	K	1.3	1.3	0.9	0.1	-1.3	-	0.1	0.1	-1.2	-0.4	-0.5	-0.8	-0.2
1965	A	-0.3	-0.2	0.1	-0.7	-0.7	-0.6	1.0	-0.4	-0.1	0.1	1.2	1.3	0
	K	-1.0	-0.7	0	-0.3	-0.8	-1.1	-0.2	1.0	-1.8	-1.0	0.5	0.8	-0.6
1966	A	-	1.0	0	0.6	-0.6	0.1	-0.3	-1.4	-0.6	-0.3	0	0.7	0.4
	K	0.8	1.0	0.3	0.4	-0.7	-0.4	0.1	-0.9	0.3	0	-0.6	-0.2	0.1
1967	A	1.0	0.9	-0.3	-0.1	-0.5	0.4	0.1	0	0.7	1.6	1.4	0.1	0.8
	K	0.3	0.3	0.1	0.1	0.7	0.1	0.6	1.3	2.1	1.9	1.4	0.2	1.2
1968	A	-0.1	-0.1	0.9	-0.1	0.1	0.1	-0.2	-0.4	-0.3	-1.0	0.5	-0.1	0
	K	-0.1	-0.3	0.7	-0.3	0.8	0.7	0.6	0.1	0.1	-1.1	-0.1	-0.2	1.0
1969	A	-1.0	-1.1	-1.6	0.1	1.1	1.5	-0.3	-0.4	-0.9	-0.7	0.7	0.9	0.2
	K	-0.8	-1.2	-0.3	-0.6	0	1.1	-0.6	-0.9	-0.8	0	0.9	0.6	-0.4
1970	A	0.9	1.3	1.4	0.4	-0.4	-0.5	-0.2	-1.0	-0.7	-1.6	-0.3	-0.8	0
	K	-0.1	0.4	0.6	-0.4	-1.2	-1.0	-1.2	-1.4	-1.8	-2.1	-1.6	-2.1	-1.4
1971	A	0	-0.1	-1.6	-0.9	-0.9	0.2	0.2	0.6	0.9	-0.6	-0.7	-1.0	-0.2
	K	-1.5	-0.9	-1.4	-1.3	-1.7	-0.7	-0.4	1.6	0	-0.7	-1.4	-1.6	-1.2
1972	A	-1.2	-1.6	-0.3	-1.1	-0.2	-0.2	0.4	0.9	-0.6	-1.4	-0.7	-0.8	-0.8
	K	-1.7	-1.8	-1.6	-1.4	-1.0	-0.2	0.4	0	-1.6	-2.0	-1.1	-1.2	-1.6
1973	A	-0.7	-0.2	0.6	0.3	-0.1	0	-0.2	-0.6	-0.3	-0.3	-0.8	0.2	0
	K	-0.9	-0.8	-0.1	0.3	0.2	-0.9	-1.1	-1.4	0.2	-0.4	-1.9	-1.0	-0.8
1974	A	-0.2	0.1	-0.6	-0.3	-0.6	-1.1	0.4	1.1	0.9	-0.4	-0.5	0.6	-0.2
		-1.1	-0.1	-0.4	0	-0.3	-0.7	0.1	-0.9	1.0	-0.1	-0.2	0.1	-0.2
1975	A	0.1	-0.8	-0.7	-0.6	-0.1	-1.0	-0.7	-0.9	0.6	0.1	0	-0.2	-0.4
	K	-0.2	-0.8	-0.9	-0.6	-0.4	-1.4	0	-1.6	-1.2	-0.7	-0.7	-0.6	-1.0
1976	A	0	-0.2	-1.4	-0.6	-0.7	-1.0	0.3	-1.0	0.1	-0.1	0.3	0.3	-0.2
	K	-0.3	-0.6	-0.7	-0.4	-0.7	-1.0	-0.4	-0.4	0.9	0.9	0.5	0.6	0
1977	A	0.3	0.9	0.7	0.7	0.2	0.4	-0.8	1.7	0.9	0.6	-0.6	-0.3	0.8
	K	0.7	1.3	1.0	0.9	0.3	-0.1	0	0.7	0.2	0.6	-0.2	-0.3	-0.4
1978	A	0.8	1.3	1.4	1.3	0.7	2.6	0.8	-0.1	2.0	1.3	-1.8	-1.9	1.2
	K	0.3	1.1	1.7	2.0	1.0	1.5	0	1.3	1.3	2.0	0.4	-0.1	1.6
1979	A	-1.8	-1.4	-	0.1	1.2	0	1.1	1.1	3.0	1.3	0.7	1.2	0.8
	K	-0.8	-1.0	0	0.3	1.2	0.2	1.0	1.4	2.1	1.6	1.1	1.2	1.2
1980	A	0.1	0.6	0.9	1.3	1.0	0.6	0.1	0.3	0.1	0.9	1.2	0.8	1.2
	K	0.6	0.9	1.4	0.7	1.2	0.9	0.9	-1.3	-0.6	1.4	1.4	1.0	1.2

Appendix table 15 (cont'd)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1981	A	2.3	1.5	2.3	1.1	1.1	1.1	0.9	0.9	0.7	1.4	1.3	0.7	2.2
	K	1.9	1.7	2.1	1.6	1.2	1.5	0.7	-0.3	1.4	-0.1	1.0	0.7	2.0
1982	A	0.2	-0.1	0.6	0	-0.4	0.1	0.2	0.3	1.3	0.4	0.4	0.4	0.4
	K	-0.1	-0.1	0.1	-0.1	-0.3	0.4	0.2	0.4	-	-0.3	-0.4	0.1	0.2
Std Dev	A	0.9	1.0	0.7	0.7	0.8	0.8	0.9	0.7	0.7	0.7	1.0	0.9	0.5
Std Dev	K	1.0	0.9	0.7	0.7	0.6	0.8	0.8	0.7	0.9	0.7	0.8	0.9	0.5

Appendix table 16. Monthly and annual surface salinity (°/oo) anomalies (A) and number of standard deviations (N) in the anomalies, Amphitrite Point, 1935-82.

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1935	A	-1.32	-1.09	-0.68	0.10	1.20	0.23	-0.04	0.21	0.05	0.84	1.49	1.03	0.16
	N	-1.5	-1.1	-0.6	0.1	1.5	0.3	0	0.3	0.1	0.8	1.4	1.2	0.4
1936	A	0.08	1.61	-0.60	1.11	0.29	-1.51	-1.60	0.17	0.07	0.72	2.33	1.21	0.47
	N	0.1	1.6	-0.6	1.1	0.4	-2.0	-1.8	0.3	0.1	0.7	2.3	1.4	1.2
1937	A	2.02	1.85	-0.02	-0.02	-0.28	-0.78	0.42	-0.32	0.69	-0.17	-0.67	0.29	0.23
	N	2.4	1.8	0	0	-0.3	-1.0	0.5	-0.5	0.9	-0.2	-0.6	0.3	0.6
1938	A	0.15	-0.05	0.11	-0.93	-0.02	1.08	0.89	0.79	1.15	1.22	1.46	0.05	0.65
	N	0.2	0	0.1	-1.0	0	1.4	1.0	1.3	1.5	1.2	1.4	0.1	1.7
1939	A	-0.66	-0.22	-	-	-	-	-	0.09	0.39	0.92	-1.98	0.28	-
	N	-0.8	-0.2	-	-	-	-	-	0.1	0.5	0.9	-1.9	0.3	-
1940	A	0.27	-0.38	-1.04	0.21	-0.39	0.86	0.51	0.44	0.10	-0.93	0.02	0.39	-0.06
	N	0.3	-0.4	-1.0	0.2	-0.5	1.1	0.6	0.7	0.1	-0.9	0	0.4	-0.1
1941	A	0.10	-0.10	-0.21	1.12	-1.24	0.01	0.56	0.73	-0.44	-1.10	-0.04	-0.43	-0.10
	N	0.1	-0.1	-0.2	1.1	-1.5	0	0.6	1.2	-0.6	-1.1	0	-0.5	-0.3
1942	A	-0.15	0.42	0.45	0.33	0.05	-0.14	-0.62	0.43	0.78	0.18	-0.25	-0.88	0.12
	N	-0.2	0.4	0.4	0.3	0	-0.2	-0.7	0.7	1.0	0.2	-0.2	-1.0	0.3
1943	A	0.91	0.47	0.54	-0.10	0.25	0.54	0.75	0.06	0.21	0.48	0.95	0.96	0.33
	N	1.1	0.5	0.5	-0.1	0.3	0.7	0.8	0.1	0.3	0.5	0.9	1.1	0.8
1944	A	0.66	1.36	1.39	0.55	0.83	1.54	1.49	1.12	0.63	0.88	-1.33	0.54	0.79
	N	0.8	1.4	1.3	0.6	1.0	2.0	1.7	1.8	0.8	0.9	-1.3	0.6	2.0
1945	A	0.61	0.89	0.91	0.79	-0.64	0.79	0.67	0.86	0.08	0.77	0.22	0.13	0.50
	N	0.7	0.9	0.8	0.8	-0.8	1.0	0.8	1.4	0.1	0.8	0.2	0.1	1.3
1946	A	-0.65	-0.09	-0.87	-1.21	0.16	-0.36	-0.73	-0.06	0.31	0.74	1.51	-0.43	-0.23
	N	-0.8	-0.1	-0.8	-1.2	0.2	-0.5	-0.8	-0.1	0.4	0.7	1.5	-0.5	-0.6
1947	A	0	-0.46	0.10	0.02	0.16	0.81	-1.54	0.08	0.58	-0.47	0.18	0.58	0.08
	N	0	-0.5	0.1	0	0.2	1.0	-1.7	0.1	0.8	-0.5	0.2	0.7	0.2
1948	A	-0.35	-0.51	0.50	-0.02	-1.52	-0.29	-0.43	-0.56	-2.40	-0.50	0.39	0.09	-0.48
	N	-0.4	-0.5	0.5	0	-1.9	-0.4	-0.5	-0.9	-3.2	-0.5	0.4	0.1	-1.2
1949	A	1.36	1.65	-0.44	-0.29	-1.14	0.52	0.74	-0.80	0.44	0.59	0.55	0.42	0.30
	N	1.6	1.6	-0.4	-0.3	-1.4	0.7	0.8	-1.3	0.6	0.6	0.5	0.5	0.8
1950	A	0.86	-1.63	-2.31	-1.41	-0.21	-0.71	-0.47	-0.38	0.32	-0.51	-1.69	-1.29	-0.88
	N	1.0	-1.6	-2.1	-1.4	-0.3	-0.9	-0.5	-0.6	0.4	-0.5	-1.6	-1.5	-2.3
1951	A	-0.46	-1.48	0.48	1.23	0.75	0.72	-	0.79	0.90	0.75	0.64	1.15	0.46
	N	-0.5	-1.5	0.4	1.3	0.9	-0.9	-	1.3	1.2	0.7	0.6	1.3	1.2
1952	A	1.44	-1.28	1.11	1.06	0.19	-0.26	0.43	0.24	0.72	1.46	0.97	0.34	0.53
	N	1.7	-1.3	1.0	1.1	0.2	-0.3	0.5	0.4	1.0	1.5	0.9	0.4	1.4
1953	A	-0.45	-0.65	1.39	1.00	-0.76	0.36	0.31	-0.59	0.09	-0.50	-0.32	0.10	-0.01
	N	-0.5	-0.6	1.3	1.0	-0.9	0.5	0.3	-0.9	0.1	-0.5	-0.3	0.1	0
1954	A	0.64	-0.19	-0.88	0.71	1.47	0.04	-1.26	-0.95	-0.40	0.34	-1.14	-1.86	-0.40
	N	0.7	-0.2	-0.8	0.7	1.8	0	-1.4	-1.5	-0.5	0.3	-1.1	-2.1	-1.0
1955	A	0.66	0.95	2.19	-0.22	0.72	-0.11	0.14	-0.22	0.23	0.29	-0.38	0.20	0.36
	N	0.8	0.9	2.0	-0.2	0.9	-0.1	0.2	-0.3	0.3	0.3	-0.4	0.2	0.9
1956	A	-0.65	-	-	0.41	0.26	-2.20	-0.56	0.03	0.33	-1.39	-1.14	-0.27	-0.34
	N	-0.8	-	-	0.4	0.3	-2.9	-0.6	0	0.4	-1.4	-1.1	-0.3	-0.9
1957	A	0.44	1.40	-1.15	-0.15	0.04	-0.11	-0.94	-0.65	-0.93	1.35	0.87	0.06	0.01
	N	0.5	1.4	-1.1	-0.1	0	-0.1	-1.1	-1.0	-1.3	1.3	0.8	0.1	0

Appendix table 16 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1958 A	-1.28	-0.80	-1.19	-0.56	0.59	0.34	0.35	0.23	-0.77	-0.26	-0.38	-1.40	-0.44
N	-1.5	-0.8	-1.1	-0.6	0.7	0.4	0.4	0.4	-1.0	-0.3	-0.4	-1.6	-1.1
1959 A	-0.03	-0.04	-0.38	-0.23	-0.19	-0.71	0.34	0.32	-1.51	0.62	0.96	-0.35	-0.02
N	0	0	-0.3	-0.2	-0.2	-0.9	0.4	0.5	-2.0	0.6	0.9	-0.4	0
1960 A	0.70	-0.21	0.76	-2.30	-2.05	-0.19	0.77	-0.27	-0.42	-0.31	-0.33	-0.19	-0.35
N	0.8	-0.2	-0.7	-2.4	-2.6	-0.2	0.9	-0.4	-0.6	-0.3	-0.3	-0.2	-0.9
1961 A	-0.72	0	-1.09	-0.25	-1.02	0.03	-0.22	0.38	0.09	0.38	0.73	-1.28	-0.42
N	-0.8	0	-1.0	-0.3	-1.3	0	-0.2	0.6	0.1	0.4	0.7	-1.4	-1.1
1962 A	-1.01	0.13	1.61	0.44	-0.54	0.52	1.10	-1.00	0.34	-1.05	0.66	-0.30	-0.04
N	-1.2	0.1	1.5	0.4	-0.7	0.7	1.2	-1.6	0.5	-1.0	0.6	-0.3	-0.1
1963 A	0.55	-0.14	0.16	-0.82	0.11	0.82	-0.27	0.26	0.41	-0.33	-1.16	-1.32	-0.15
N	0.6	-0.1	0.1	-0.8	0.1	1.1	-0.3	0.4	0.5	-0.3	-1.1	-1.5	-0.4
1964 A	-	2.12	1.70	1.74	0.05	-0.18	-2.54	-1.04	-0.57	0	0.77	1.21	0.39
N	-	2.1	1.6	1.8	0.06	-0.2	-2.9	-1.7	-0.8	0	0.7	1.4	1.0
1965 A	-0.97	-0.60	0.59	1.33	0.71	0.99	1.19	0.56	0.77	-3.00	-0.97	-0.06	0.04
N	-1.1	-0.6	0.5	1.4	0.9	1.3	1.3	0.9	1.0	-3.0	-0.9	-0.1	0.1
1966 A	-	0.42	-1.00	0.04	1.23	-0.41	0.20	0.19	-0.13	-0.35	0.40	-1.94	-0.09
N		0.4	-0.9	0.04	1.5	-0.5	0.2	0.3	-0.2	-0.3	0.4	-2.2	-0.2
1967 A	-1.51	-0.48	-0.91	-0.51	0.40	0.14	0.38	0.40	0.03	-0.06	0.53	1.16	-0.30
N	-1.8	-0.5	-0.8	-0.5	0.50	0.2	0.4	0.6	0	-0.1	0.5	1.3	-0.8
1968 A	-1.09	-0.15	-2.04	0.46	0.29	-0.25	-0.19	-0.93	-1.42	-1.01	-0.61	-0.56	-0.63
N	-1.3	-0.1	-1.9	0.5	0.4	-0.3	-0.2	-1.5	-1.9	-1.0	-0.6	-0.6	-1.6
1969 A	-0.15	-0.44	-0.25	-1.59	-0.66	-0.57	0.34	0.24	-1.68	-0.67	-1.14	0.83	-0.49
N	-0.2	-0.4	0.2	-1.6	-0.8	-0.7	0.4	0.4	-2.3	-0.7	-1.1	0.9	-1.3
1970 A	0.81	-0.66	-0.04	0.95	0.52	1.27	0.76	0.70	-0.98	1.08	1.12	0.32	0.73
N	0.9	-0.7	0	1.0	0.6	1.6	0.9	1.1	1.3	1.1	1.1	0.4	1.9
1971 A	-1.05	-1.00	-0.73	-0.11	-0.09	-1.25	-0.52	-0.51	-1.38	-0.94	-1.08	-0.13	-0.77
N	-1.2	-1.0	-0.7	-0.1	-0.1	-1.6	-0.6	-0.8	-1.9	-0.9	-1.0	-0.1	-2.0
1972 A	0.6	-1.1	-3.8	-1.5	-0.4	0.2	2.0	-0.1	0	1.1	0.7	0.6	-0.5
N	0.7	-1.0	-3.5	-1.5	-0.5	0.3	2.3	-0.2	0	1.1	0.7	0.7	-1.3
1973 A	-0.8	0.3	0.1	1.0	0.4	-1.1	0.3	0.6	0.6	0.1	-0.5	-0.7	0
N	-0.9	0.3	0.1	1.0	0.5	-1.4	0.3	1.0	0.8	0.1	-0.5	-0.8	0
1974 A	-0.4	-2.0	-1.8	-1.3	-1.4	-0.5	-1.6	-0.1	-0.4	0.8	0.3	-0.5	-0.8
N	-0.5	-2.0	-1.7	-1.3	-1.7	-0.6	-1.8	-0.2	-0.5	0.8	0.3	-0.6	-2.0
1975 A	0.2	-0.3	-0.4	0.7	0.4	0.1	0.6	-0.9	-0.5	-1.3	-1.7	-0.5	-0.3
N	0.2	-0.3	-0.4	0.7	0.5	0.1	0.7	-1.4	-0.7	-1.3	-1.6	-0.6	-0.8
1976 A	-1.4	-0.5	-1.3	-0.6	-0.2	-0.6	-1.1	-1.4	-1.3	-0.4	0.2	0.4	-0.7
N	-1.6	-0.5	-1.2	-0.6	-0.2	-0.8	-1.2	-2.3	-1.8	-0.4	0.2	0.4	-1.8
1977 A	0.7	0.7	-0.2	-0.3	-0.3	-0.3	0.7	0.3	0	1.0	-0.6	-1.2	0
N	0.8	0.7	-0.2	-0.3	-0.4	-0.4	0.8	0.5	0	1.0	-0.6	-1.4	0
1978 A	-0.3	0.1	0.5	0.2	-0.1	-0.8	0.8	-0.1	-1.7	0.5	0.4	1.9	0.1
N	-0.3	0.1	0.5	0.2	-0.1	-1.0	0.9	-0.2	-2.3	0.5	0.4	2.2	0.3
1979 A	2.3	0	-0.7	1.0	0.6	0.6	0.3	-0.4	-0.6	0.9	0.7	0.6	0.5
N	2.7	0	-0.7	1.0	0.7	0.8	0.3	-0.6	-0.8	0.9	0.7	0.7	1.3
1980 A	-	-	-	-0.1	-0.2	0	-0.1	-0.8	-0.7	0.7	-0.7	-1.6	-
N	-	-	-	-0.1	-0.2	0	-0.1	-1.3	-0.9	0.7	-0.7	-1.8	-

Appendix table 16 (cont'd)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1981 A	-0.3	-0.1	-0.4	-0.6	-0.9	-1.4	-0.3	-0.6	-0.7	-0.5	-1.1	-0.3	-0.6
N	-0.3	-0.1	-0.4	-0.6	-1.1	-1.8	-0.3	-1.0	-0.9	-0.5	-1.1	-0.3	-1.5
1982 A	0	-1.5	-1.1	-1.9	0	0	-0.5	-0.3	-0.9	-0.2	-0.8	0.3	-0.6
N	0	-1.5	-1.1	-2.0	0	0	-0.6	-0.5	-1.2	-0.2	-0.8	0.3	-1.5
Mean 1935-1970	28.53	28.62	28.98	29.41	30.28	30.80	30.86	31.00	30.63	29.52	28.93	28.44	29.67
Std Dev	0.85	1.00	1.08	0.97	0.80	0.77	0.88	0.62	0.74	1.00	1.03	0.88	0.39

Appendix table 17. Monthly and annual surface salinity °/oo anomalies (A) and the number of standard deviations (N) in the anomalies, Kains Island, 1935-82.

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1935	A	-0.40	-1.53	-0.73	0.28	0.74	0.10	0.12	0.53	0.62	1.01	1.21	1.15	0.32
	N	-0.5	-1.6	-1.0	0.4	1.25	0.2	0.2	1.2	1.0	0.9	1.2	1.1	0.8
1936	A	0.82	1.85	0.02	0.54	0.18	0.38	-1.94	-0.54	0.17	1.54	0.97	1.46	0.37
	N	1.0	1.9	0	0.8	0.3	0.8	-3.5	-1.2	0.3	1.4	1.0	1.4	0.9
1937	A	1.67	1.56	0.27	-0.56	-1.13	-0.02	-0.20	-0.41	0.05	0.83	=0.34	0.53	0.19
	N	2.0	1.6	0.4	-0.8	-1.9	0	-0.4	-0.9	0.1	0.7	-0.3	0.5	0.5
1938	A	-0.20	0.30	0.09	-0.01	0.79	0.90	0.92	0.61	0.58	0.80	0.25	0.43	0.46
	N	-0.2	0.3	0.1	0	1.3	2.0	1.7	1.4	0.9	0.7	0.2	0.4	1.2
1939	A	-0.87	0.43	0.86	0.60	-	-	0.04	0.45	0.12	0.96	-1.67	-2.66	-0.29
	N	-1.0	0.4	1.1	0.9	-	-	0.1	1.0	0.2	0.8	-1.7	-2.6	-0.7
1940	A	-0.16	-0.34	-1.16	-0.26	-0.32	0.43	0.39	-0.22	0.10	=1.17	0.01	0.31	-0.20
	N	-0.2	-0.4	-1.5	-0.4	-0.54	1.9	0.7	-0.5	0.2	=1.0	0	0.3	-0.5
1941	A	-0.50	-1.53	-0.06	0.45	0.26	0.16	0.26	0.51	0.10	0.05	0.24	-0.58	-0.05
	N	-0.6	-1.6	-0.1	0.7	0.4	0.4	0.5	1.2	0.2	0	0.2	-0.6	-0.1
1942	A	0.80	0.69	-0.38	-0.32	-0.33	-0.12	0.28	0.62	0.88	1.04	0.91	-0.13	0.33
	N	1.0	0.7	-0.5	-0.5	-0.6	-0.3	0.5	1.4	1.4	0.9	0.9	-0.1	0.8
1943	A	0.60	0.55	0.57	-0.16	0.01	0.31	0.42	0.44	0.2	0.98	0.94	1.47	0.54
	N	0.7	0.6	0.7	-0.2	0	0.7	0.8	1.0	0.5	0.9	0.9	1.4	1.4
1944	A	-0.11	0.95	1.54	1.41	1.17	1.01	0.74	0.43	0.37	-0.54	-0.76	0.85	0.60
	N	-0.1	1.0	2.0	2.1	2.0	2.2	1.3	1.0	0.6	-0.5	-0.8	0.8	1.5
1945	A	0.51	1.02	0.59	0.38	0.30	0.08	0.50	0.56	0.50	0.46	0.78	0.22	0.58
	N	0.6	1.1	0.8	0.6	0.5	0.2	0.9	1.3	0.8	.4	0.8	0.2	1.5
1946	A	-0.85	-0.35	-1.31	-0.60	-0.47	-0.30	-0.38	0.05	0.29	0.80	1.58	0.36	0.10
	N	-1.0	-0.4	-1.7	-0.9	-0.8	-0.7	-0.7	0.1	0.5	0.7	1.6	0.3	0.3
1946	A	0.13	-0.55	0.39	0.49	-0.04	0.14	-0.69	-0.16	0.50	-0.56	-0.15	0.84	0.03
	N	0.2	-0.6	0.5	0.7	-0.1	0.3	-1.2	-0.4	0.8	-0.5	-0.1	0.8	0.1
1948	A	-0.33	0.79	0.58	0.51	0.03	-0.15	0.20	0.02	-1.40	-1.74	0.08	0.34	0
	N	-0.4	0.8	0.8	0.8	0	-0.3	0.4	0	-2.2	-1.5	0.1	0.3	0
1949	A	0.97	1.55	0.43	-0.46	-0.66	0.07	0.32	-0.49	0.21	0.94	1.07	0.47	0.37
	N	1.2	1.6	0.6	-0.7	-1.1	0.2	0.6	-1.1	0.3	0.8	1.1	0.4	0.9
1950	A	2.20	0.29	-0.90	-1.20	-0.65	-0.47	-0.19	-0.30	-0.21	-0.03	-1.00	-0.79	-0.27
	N	2.6	0.3	-1.2	-1.8	-1.1	-1.0	-0.3	-0.7	-0.3	0	-1.0	-0.8	-0.7
1951	A	0.06	-0.25	0.73	1.17	0.79	0.50	0.84	0.57	0.81	1.56	1.48	1.08	0.78
	N	0.1	-0.3	1.0	1.8	1.3	1.1	1.5	1.3	1.3	1.4	1.5	1.0	2.0
1952	A	1.15	-1.11	0.44	-0.83	-0.79	-0.45	-0.11	0.29	0.30	1.06	1.07	0.52	0.13
	N	1.4	-1.2	0.6	-1.2	-1.3	-1.0	-0.2	0.7	0.5	0.9	1.1	0.5	0.3
1953	A	0.43	-1.18	0	0.07	-0.03	-0.13	-0.08	-0.12	-0.53	-0.69	-1.92	-0.85	-0.42
	N	0.5	-1.2	0	0.1	0	-0.3	-.15	-0.5	-0.8	-0.6	-1.9	-0.8	-1.1
1954	A	0.1	-0.03	-0.53	0.37	0.90	-0.12	-0.59	-0.12	-0.48	-0.39	-1.04	-1.36	-0.25
	N	0.4	0	-0.7	0.6	1.5	-0.3	-1.1	-0.3	-0.8	-0.3	-1.0	-1.3	-0.6
1955	A	-0.33	0.61	1.41	1.08	0.63	0.34	0.14	-0.16	0.12	0.10	0.89	0.81	0.47
	N	-0.4	0.6	1.9	1.6	1.1	0.8	0.2	-0.4	0.2	0.1	0.9	0.8	1.2
1956	A	0.08	0.49	0.12	-0.13	0.42	-0.11	-0.21	0.20	0.49	0.10	-0.08	-0.07	0.11
	N	0.1	0.5	0.2	-0.2	0.7	-0.2	-0.4	0.4	0.8	0.1	-0.1	-0.1	0.3
1957	A	0.47	1.38	0.47	-0.01	0.19	0.06	0.65	-0.78	-0.19	0.40	0.45	-0.37	0.20
	N	0.6	1.4	0.6	0	0.3	0.1	-1.2	-1.8	-0.3	0.3	0.4	-0.4	0.5
1958	A	-1.24	-0.52	-0.63	-0.17	0.54	0.65	0.75	0.19	-0.37	-0.56	0.29	-0.25	-0.11
	N	-1.5	-0.5	-0.8	-0.3	0.9	1.4	1.4	0.4	-0.6	-0.5	0.3	-0.2	-0.3

Appendix table 17 (cont'd)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1959	A	-0.58	0.49	-0.95	-0.08	-0.33	-0.53	-0.22	0.11	0.04	0.91	1.20	0.25	0.03
	N	-0.7	0.5	-1.2	-0.1	-0.6	1.2	-0.4	0.2	0.1	0.8	1.2	0.2	0.1
1960	A	0.46	0.24	0.25	-0.89	-1.05	-1.11	0.05	-0.40	-0.49	-0.05	-0.42	0.37	-0.25
	N	0.5	0.2	0.3	-1.3	-1.8	-2.5	0.1	-0.9	-0.8	0	-0.4	0.4	-0.6
1961	A	-0.38	-1.30	-1.70	-0.41	-0.04	-0.34	-0.08	0.27	-0.16	0.13	0.67	0.71	-0.21
	N	-0.5	-1.4	-2.2	-0.6	-0.1	-0.8	-0.1	0.6	-0.2	0.1	0.7	0.7	-0.5
1962	A	-0.51	0.20	1.23	0.43	-0.29	0.11	0.49	-0.10	0.64	-2.83	-1.11	-3.59	-0.49
	N	-0.6	0.2	1.6	0.6	-0.5	0.2	0.9	-0.2	1.0	-2.5	-1.1	-3.4	-1.3
1963	A	-0.27	-0.45	-0.06	0.22	-0.72	-0.06	-0.25	-0.03	-0.63	-1.48	-1.93	-0.29	-0.44
	N	-0.3	-0.5	-0.1	0.3	-1.2	-0.1	-0.4	-0.1	-1.0	-1.3	-1.9	-0.3	-1.1
1964	A	-0.92	-0.84	0.04	0.44	0.68	0.12	-0.67	-1.00	-0.34	-1.10	0	0.02	-0.21
	N	-1.1	-0.9	0	0.7	1.1	0.3	-1.2	-2.3	0.5	-1.0	0	0	-0.5
1965	A	0.31	-1.00	0.27	0.73	0.16	0.74	0.78	0.59	1.12	-1.15	-0.43	-0.30	0.15
	N	0.4	-1.0	0.4	1.1	0.3	1.6	1.4	1.3	1.8	-1.0	-0.4	-0.3	0.4
1966	A	-1.42	-0.43	-0.53	-0.45	0.27	0.01	-0.13	-0.18	-0.15	-0.24	-0.23	-0.58	-0.34
	N	-1.7	-0.4	-0.7	-0.7	0.5	0	-0.2	-0.4	-0.2	-0.2	-0.2	-0.6	-0.9
1967	A	-1.58	-1.95	-0.44	-0.15	-0.53	-0.26	-0.21	-0.24	-1.79	-2.35	-0.79	-0.45	-0.89
	N	-1.9	-2.0	-0.6	-0.2	-0.9	-0.6	-0.4	-0.5	-2.8	-2.1	-0.8	-0.4	-2.3
1968	A	-0.78	-0.39	-1.04	-0.78	0.11	0.03	-0.29	-0.30	-1.04	-1.66	-1.43	-0.71	-0.69
	N	-0.9	-0.4	-1.4	-1.2	0.2	0.1	-0.5	-0.7	-1.6	-1.5	-1.4	-0.7	-1.8
1969	A	0.86	0.42	0.20	-1.62	-0.62	-0.74	-0.28	-0.86	-0.63	0	-0.93	-0.16	-0.39
	N	1.0	0.4	0.3	-2.4	-1.0	-1.6	-0.5	-1.9	-1.0	0	-0.9	-0.1	-1.0
1970	A	0.50	0.38	-01.11	0.30	-0.05	0.66	0.08	0.50	0.70	1.50	1.86	1.82	-0.23
	N	0.6	0.4	-0.1	0.4	-0.1	1.5	0.1	1.1	1.1	1.3	1.9	1.7	-0.6
1971	A	-0.04	-1.10	0.02	-0.52	0.16	0.37	-0.20	-0.21	-1.17	-0.89	-1.81	0.73	-0.36
	N	-0	-1.2	0	-0.8	0.3	0.8	-0.4	-0.5	-1.9	-0.8	1.8	0.7	-0.9
1972	A	1.1	0.6	-1.5	-1.8	-0.9	-0.1	0.4	0.1	0.1	1.5	1.0	1.0	0.2
	N	1.3	0.6	-2.0	-2.7	-1.5	-0.2	0.7	0.2	0.2	1.3	1.0	1.0	0.5
1973	A	-0.4	-0.2	0	0.2	0.1	-0.1	0.2	0.6	0.7	0.4	0.8	-0.3	0.2
	N	-0.5	-0.2	0	0.3	0.2	-0.2	0.4	1.4	1.1	0.3	0.8	-0.3	0.5
1974	A	-0.2	-0.8	-1.0	-1.2	-0.8	-0.2	-0.2	0.3	0.4	1.5	1.3	0.6	0
	N	-0.2	-0.8	-1.3	-1.8	-1.4	-0.4	-0.4	0.7	0.6	1.3	1.3	0.6	0
1975	A	0.2	1.2	0	0.9	1.1	0.9	0.8	-0.1	0.7	0.6	-1.7	0.4	0.5
	N	0.2	1.3	0	1.4	1.9	2.0	1.4	-0.2	1.1	0.5	-1.7	0.4	1.3
1976	A	-0.3	-0.4	-0.1	-0.5	-0.6	-1.3	-0.9	-0.5	-0.8	-0.8	0.4	-0.5	-0.3
	N	-0.4	-0.4	-0.1	-0.8	-1.0	-2.9	-1.6	-1.1	-1.3	-0.7	0.4	-0.5	-0.8
1977	A	1.0	0.8	-0.5	0.5	0.5	0.6	0.5	0.5	0.3	0.9	-0.4	0.3	0.4
	N	1.2	0.8	-0.7	0.8	0.8	1.3	0.9	1.1	0.5	0.8	-0.4	0.3	1.0
1978	A	0.5	0.5	-0.2	0.3	0.8	0.5	0.9	0.1	-0.3	-0.3	0	1.9	0.4
	N	0.6	0.5	-0.3	0.4	1.4	1.1	1.6	0.2	-0.5	-0.3	0	1.8	1.0
1979	A	1.8	1.4	0	1.0	1.7	0.9	0.7	0.6	-0.2	0.7	0.9	0	0.8
	N	2.2	1.5	0	1.5	2.9	2.0	1.3	1.4	-0.3	0.6	0.9	0	2.0
1980	A	-0.5	0.1	0	-0.4	-0.7	-0.1	-0.4	-0.3	-1.0	0.1	-0.9	-1.4	-0.4
	N	-0.6	0.1	0	-0.6	-1.2	-0.2	-0.7	-0.7	-1.6	0.1	-0.9	-1.4	-1.3
1981	A	-1.4	-1.1	-1.3	-0.5	-1.6	-1.6	-1.1	-0.5	-0.9	-1.3	-2.0	-	-1.1
	N	-1.7	-1.2	-1.7	-0.8	-2.7	-3.6	-2.0	-1.1	-1.4	-1.1	-2.0	-	-2.8
1982	A	-0.9	-1.5	-1.4	-1.1	-1.1	-0.3	-0.4	-0.7	-	-0.3	-0.8	-0.1	-0.7
	N	-1.1	-1.6	-1.8	-1.7	-1.9	-0.7	-0.7	-1.6	-	-0.3	-0.8	-0.1	-1.9
Mean 1935-1970		29.19	29.29	29.83	30.08	30.60	31.34	31.69	31.96	31.57	30.25	29.42	28.84	30.33
Std Dev		0.83	0.95	0.76	0.66	0.59	0.45	0.55	0.44	0.63	1.13	1.00	1.04	0.39