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IR NO. 67-98

INFORMAL REPORT

AN ANALYSIS OF SELECTED SIGMA-t SURFACES IN THE INDIAN OCEAN

NOVEMBER 1967

NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

INFORMAL REPORT

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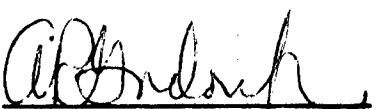
ABSTRACT

An analysis was made of interpolated values on six sigma-t surfaces beginning with 26.6 and ending with 27.6. The levels are spaced at increments of 0.2 unit of sigma-t. For each sigma-t surface three charts are drawn showing the mean depth, mean temperature, and mean salinity of the surface.

These analyses will be published at some future date in the U. S. Naval Oceanographic Office "Oceanographic Atlas of the Indian Ocean, Section II, Physical Properties." Data used in this report were published in NODC Publication G-12, "Indian Ocean Atlas, Interpolated Values of Depth, Salinity and Temperature on Selected Sigma-t Surfaces."

This Information Report was prepared by Douglas R. Hamilton and Paul E. LaViolette of the Environment Branch, Oceanographic Analysis Division, Marine Sciences Department.

This manuscript has been reviewed and is approved for release as an UNCLASSIFIED Informal Report.



A. R. GORDON, JR.
Division Director

ACKNOWLEDGMENTS

This report is a product of the Physical Properties Section, Environment Branch, Oceanographic Analysis Division. The data were based on NODC Publication G-12. The authors wish to acknowledge especially the efforts of Miss Sandra Seim and Mr. Arnold Akanovich for their help in the extensive cross checking necessary.

INFORMAL REPORT

An Analysis of Selected Sigma-t Surfaces in the Indian Ocean

by

Douglas R. Hamilton

and

Paul E. LaViolette

November 1967

NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D.C., 20390

CONTENTS

LIST OF FIGURES

AN ANALYSIS OF SELECTED SIGMA-t SURFACES IN THE INDIAN OCEAN

INTRODUCTION

The depths of the various water masses beneath the sea surface are controlled by their density characteristics. These water masses, identifiable by their temperature-salinity (T-S) relationships, spread both horizontally and vertically through the ocean along definite density surfaces (see Figure 1). As an addition to the three-dimensional presentation to be used in "Oceanographic Atlas of the Indian Ocean, Section II, Physical Properties," the figures used in this report show the depth of selected sigma-t surfaces, as well as the temperature and salinity distributions along these surfaces.

BACKGROUND

While the Physical Properties Section of the Oceanographic Analysis Division is engaged in the final analysis of its section of the Indian Ocean atlas*, the production timing does not allow the inclusion of all recent International Indian Ocean Expedition data. To offset this deficiency, the analysis of the data available was done in a manner best described as continuous. That is, each dimension being analyzed was compared to the other dimensions as well as to itself. For example, the various depth levels of the horizontal charts were compared to one another and then to the vertical traces and vertical cross sections. Charts of water shallower than 300 meters are being done seasonally. Thus, the analysis is continuous in three dimensions: Horizontally, vertically, and temporally.

*The U. S. Naval Oceanographic Office is currently producing a series of oceanographic atlases of the oceans of the world. A list of completed oceanographic atlases or sections may be found in the Appendix.

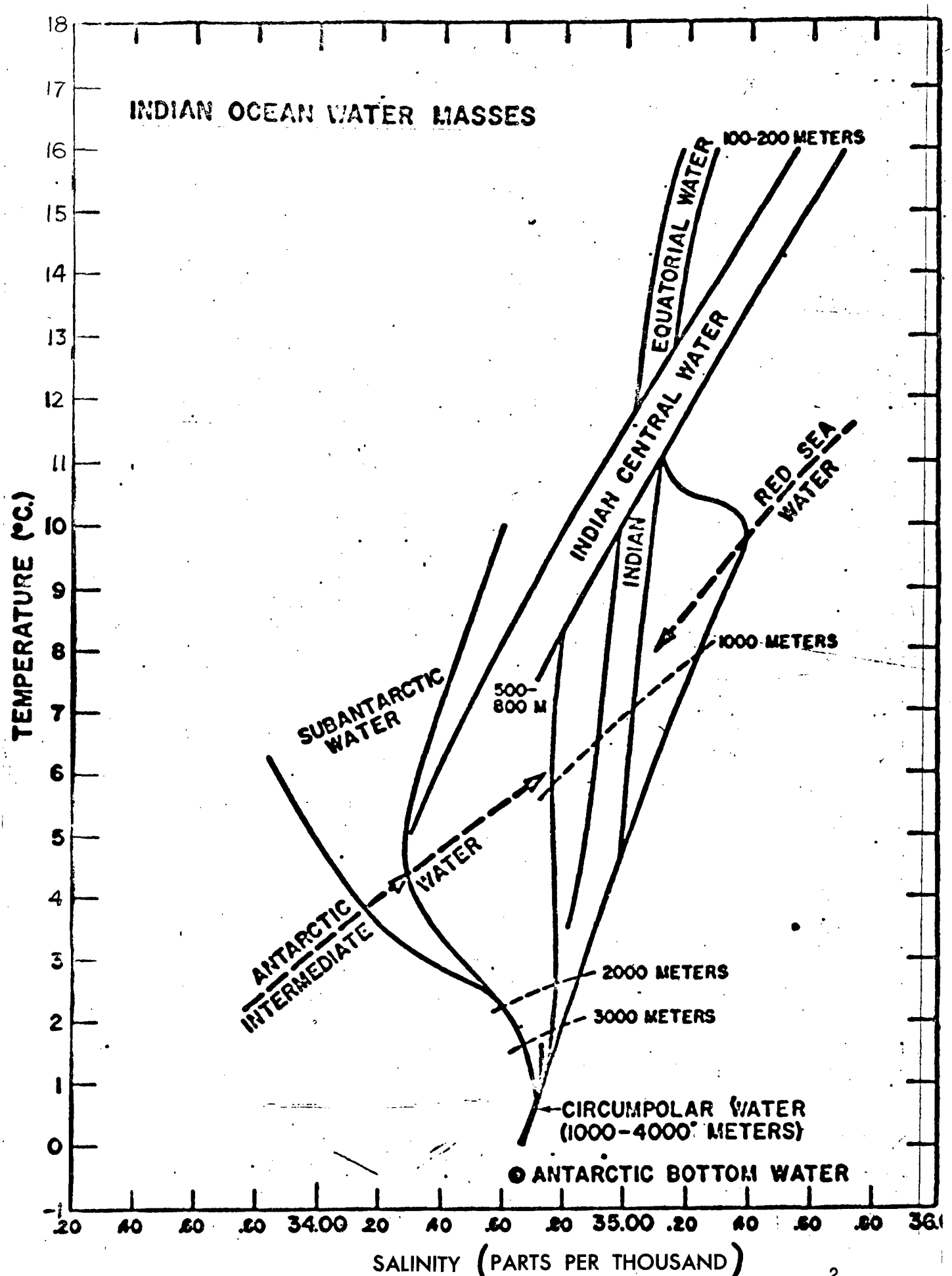


Figure 1 Indian Ocean Water Masses

In order to enhance the display of the temperature, salinity, and density distributions, the sigma-t surfaces shown in this report are to be included in the atlas. As with each of the horizontal charts, cross sections, and vertical traces, the analyzed sigma-t surfaces have been checked for continuity and tied with the other dimensional presentations.

THE DATA AND THEIR ANALYSIS

The data used as a basis for the analysis of these figures are from National Oceanographic Data Center (NODC) Publication G-12, "Indian Ocean Atlas, Interpolated Values of Depth, Salinity, and Temperature on Selected Sigma-t Surfaces." Therein, approximately 1,700 oceanographic stations, spanning a period of about 60 years, were used. The approximate seasonal distribution of these data is as follows:

January through March	540
April through June	425
July through September	290
October through December	440
	1,695

All available pre-1959 Indian Ocean station data considered to be "oceanographically plausible" were included, as well as approximately 250 International Indian Ocean Expedition stations.

The methods of interpolation used by NODC to determine data values are described in the introduction to Publication G-12. In addition, the data used in this report and in the Indian Ocean atlas were smoothed by rigorously cross checking the depth, temperature, and salinity analyses of each sigma-t level with each other and with the sigma-t levels above and below. The final analyses were then

compared to the horizontal and vertical sections of the Indian Ocean atlas for continuity. Thus, much of the original data were re-evaluated and some omitted in the final analysis.

The charts present interpolated values on six sigma-t surfaces from 26.6 through 27.6, spaced at increments of 0.2. For each sigma-t surface, three charts are included showing the mean depth, mean temperature, and mean salinity of the surface.

The depth of each sigma-t surface is given in 100-meter intervals.* Temperature values are in two degree Fahrenheit (°F.) intervals* except on the 27.6 sigma-t surface where the interval is one degree Fahrenheit (°F). Salinity is in parts per thousand (‰) with intermediate isohalines at 0.1 and 0.2 intervals where space and data permit.

In the Gulfs of Oman and Aden, however, gradients of all three parameters are strong and sometimes isolines are omitted to avoid crowding.

APPLICATION

A general picture of the dynamic structure of the Indian Ocean may be obtained by studying these sigma-t surfaces and comparing them with horizontal and vertical charts of the ocean.

*Conversion tables for meters to feet and for Fahrenheit to Celsius are given in the Appendix.

26.6 Sigma-t Surface

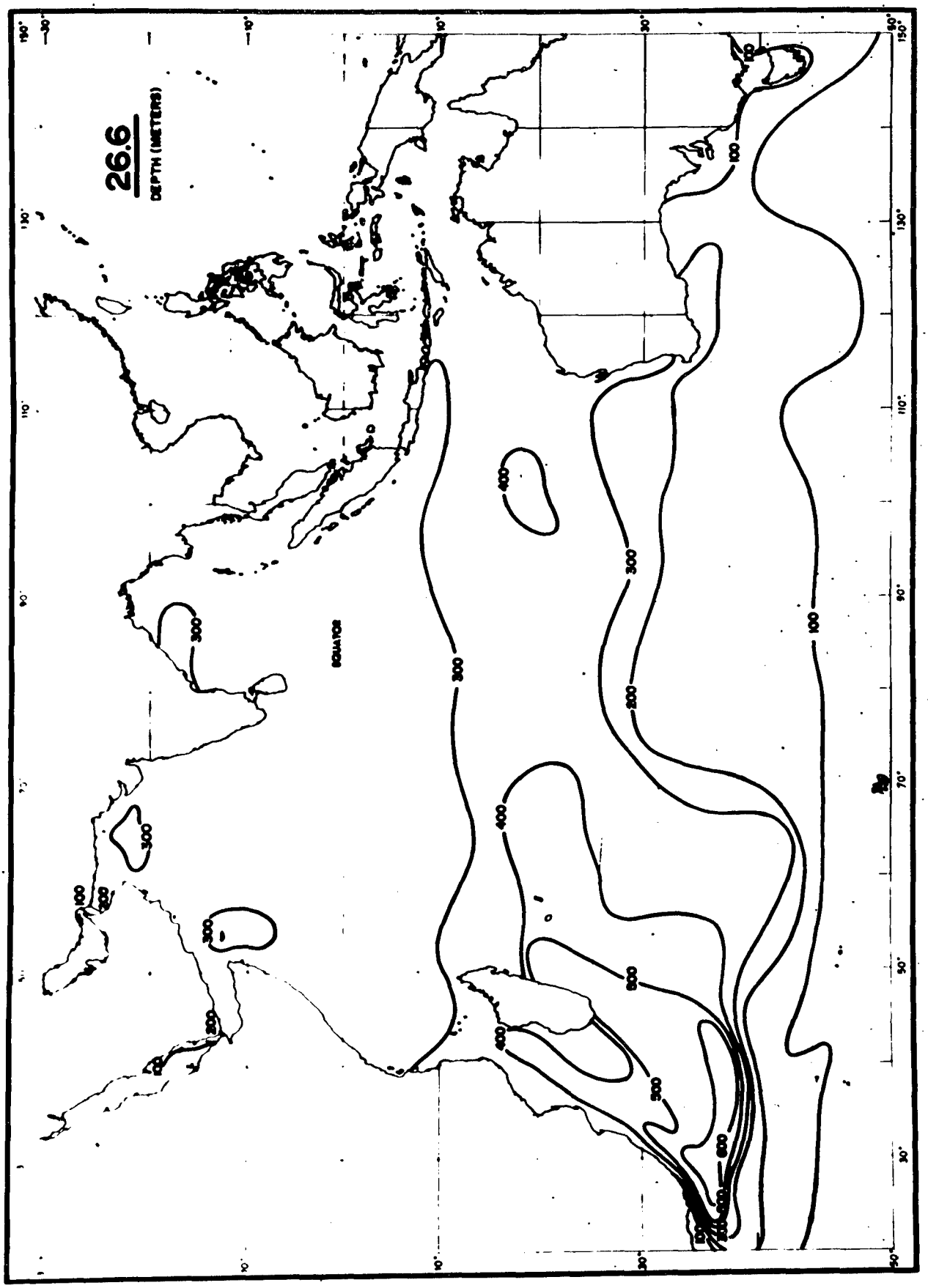


Figure 2 26.6 Sigma-t Surface, Depth (meters)

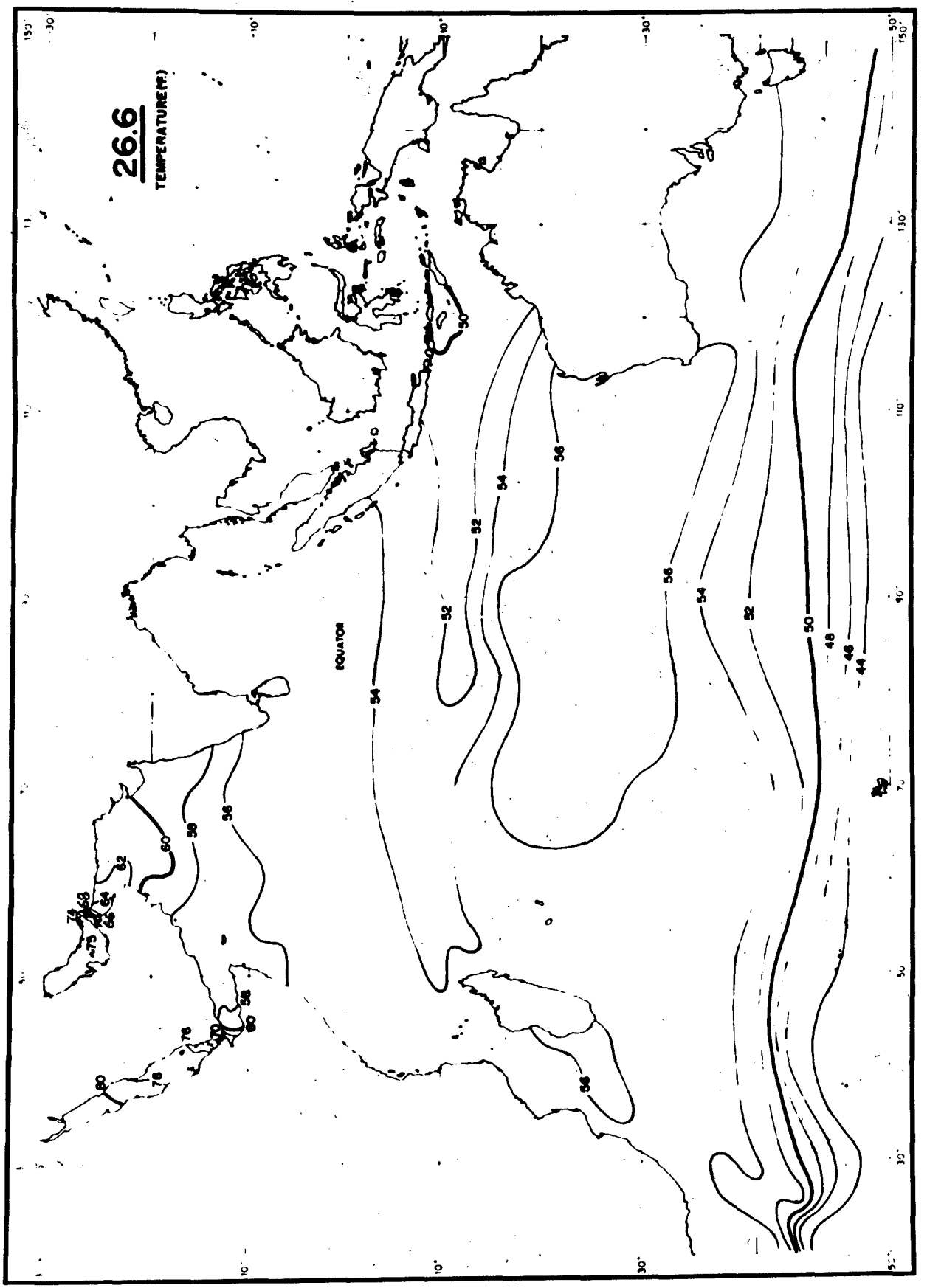


Figure 3 26.6 Sigma-t Surface, Mean Temperature (°F.)

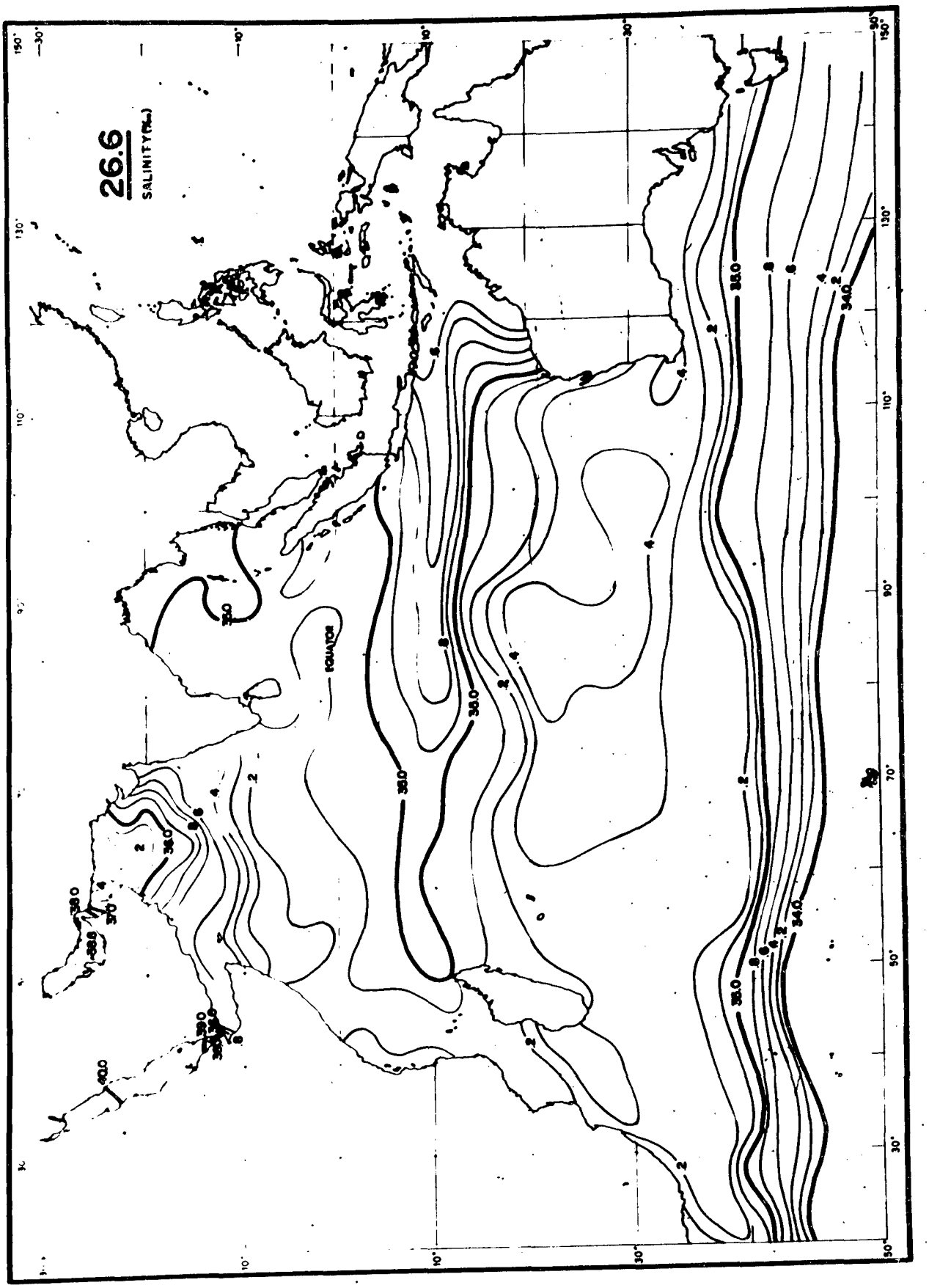


Figure 4 26.6 Sigma-t Surface, Mean Salinity (parts per thousand)

26.8 Sigma-t Surface

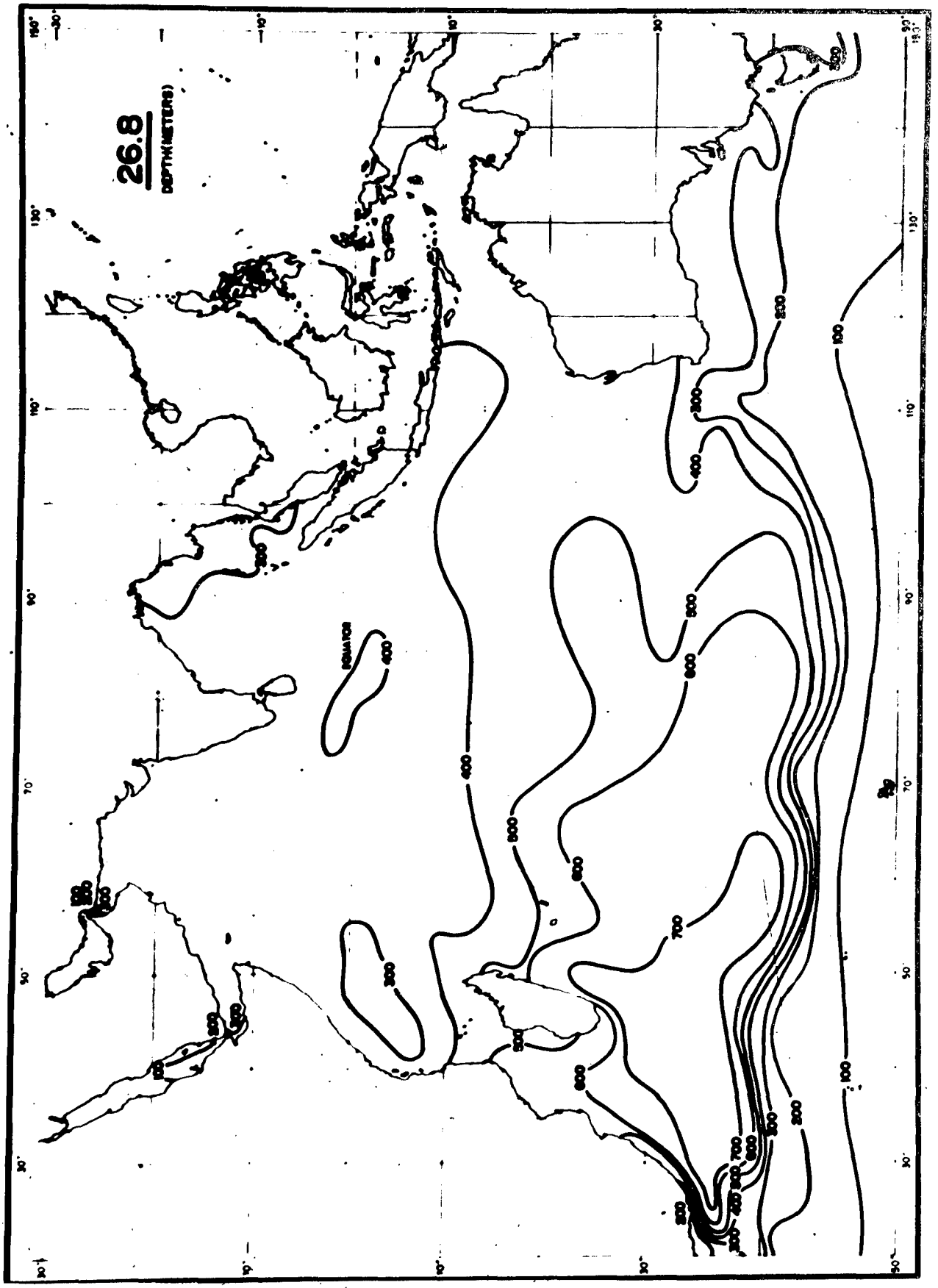


Figure 5 26.8 Sigma-t Surface, Depth (meters)

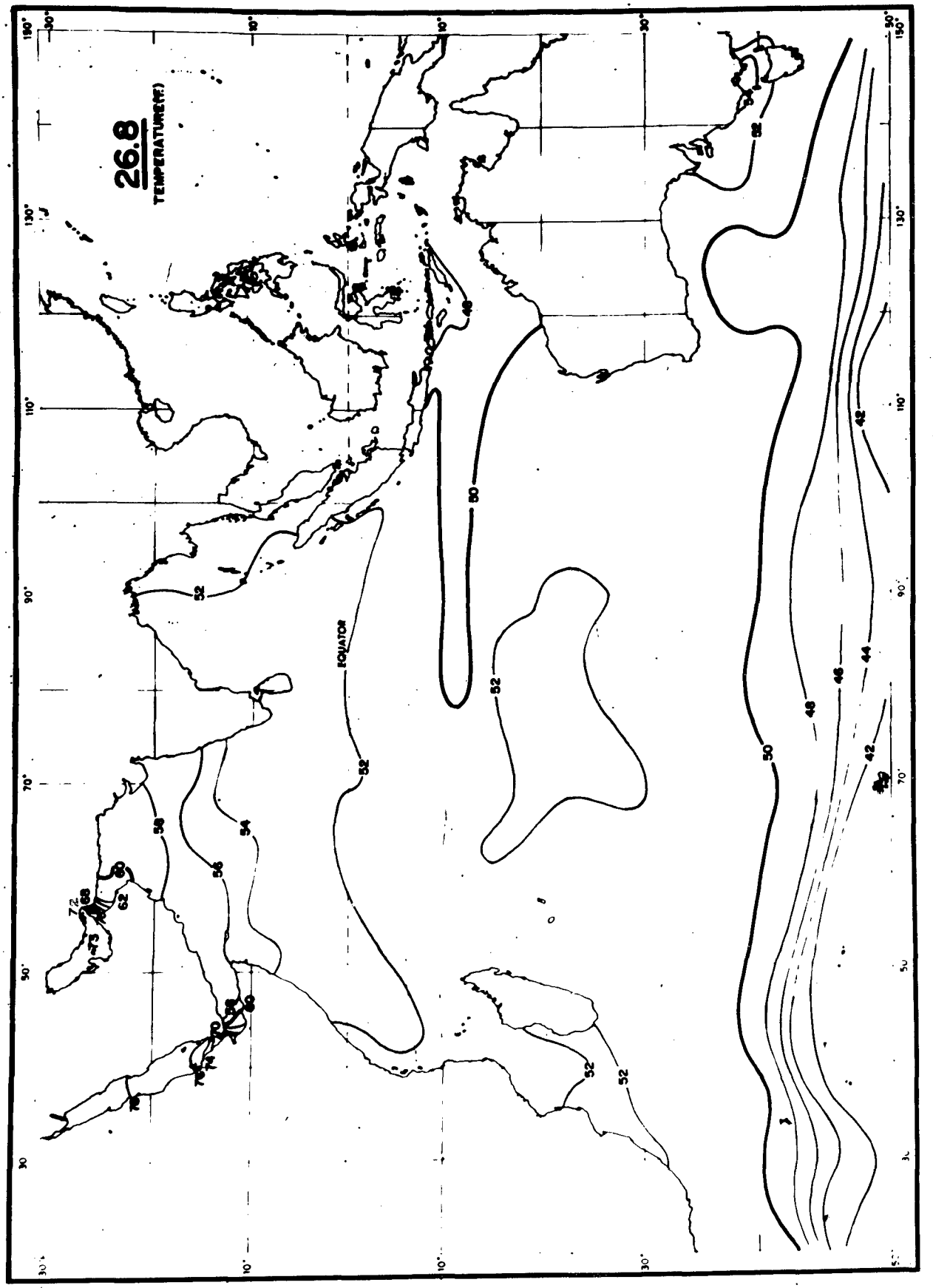


Figure 6 26.8 Sigma-t Surface, Mean Temperature (°F.)

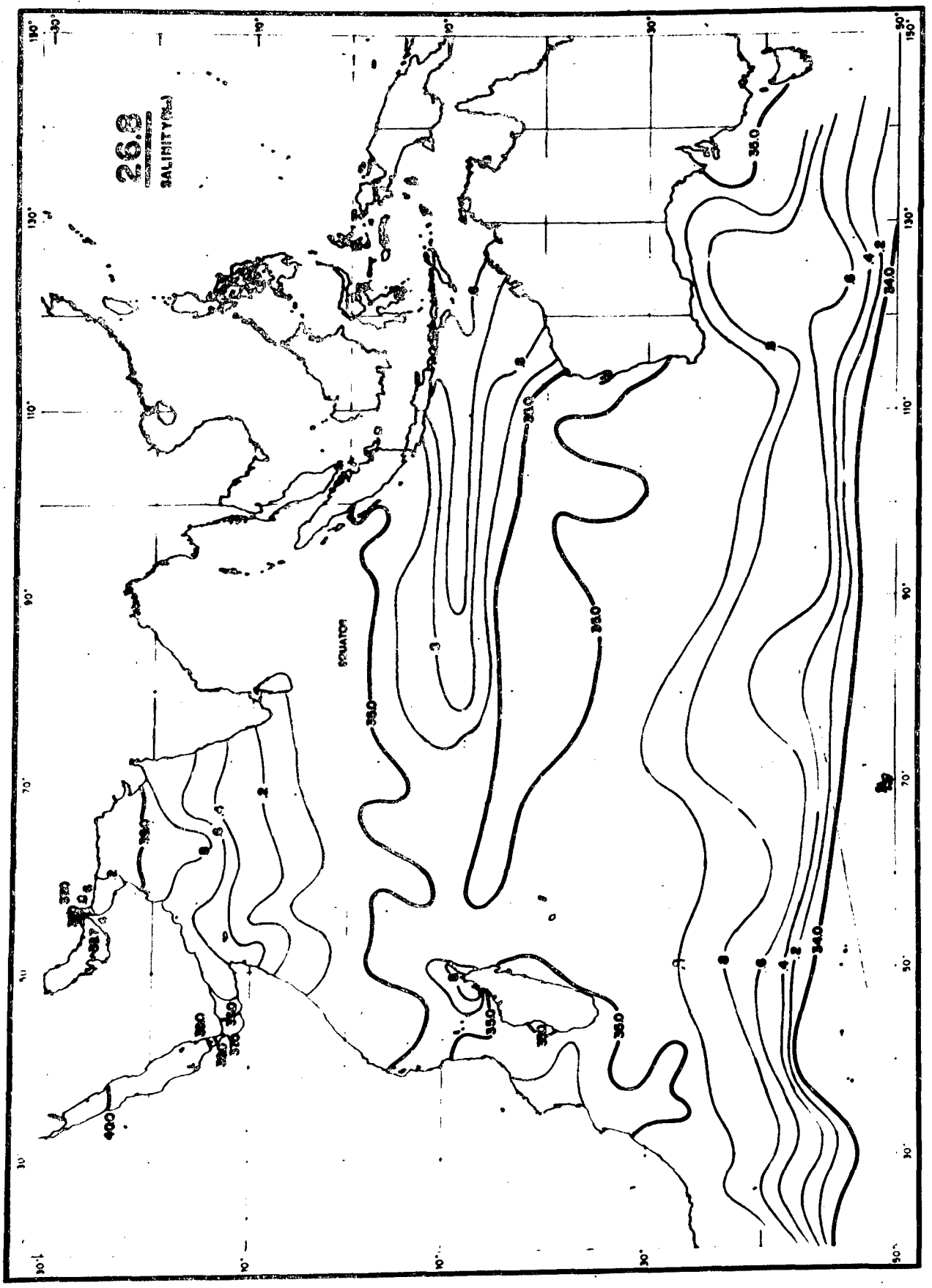


Figure 7 26.8 Sigma-t Surface, Mean Salinity (parts per thousand)

27.0 Sigma-t Surface

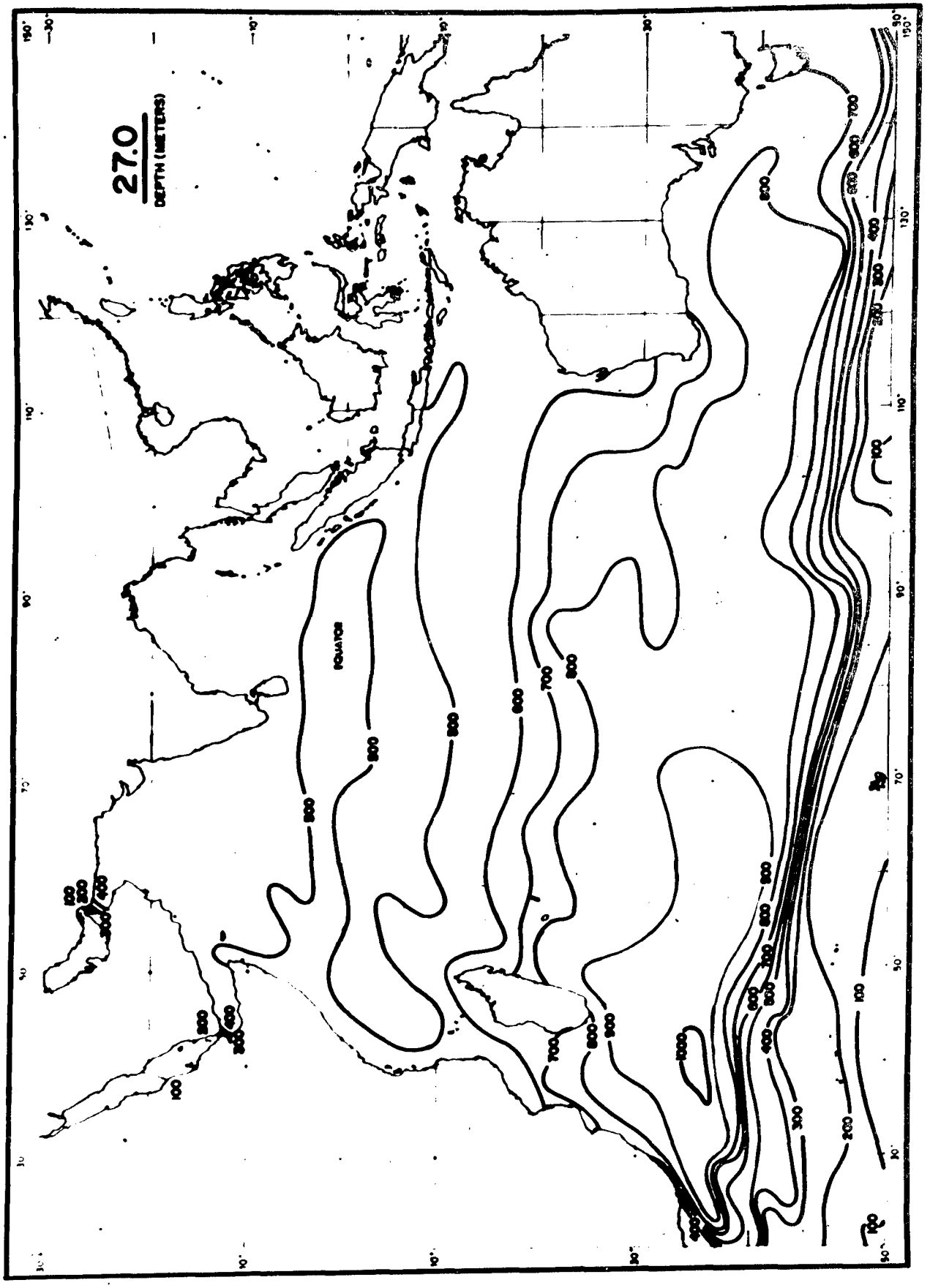


Figure 8 27.0 Sigma-t Surface, Depth (meters)

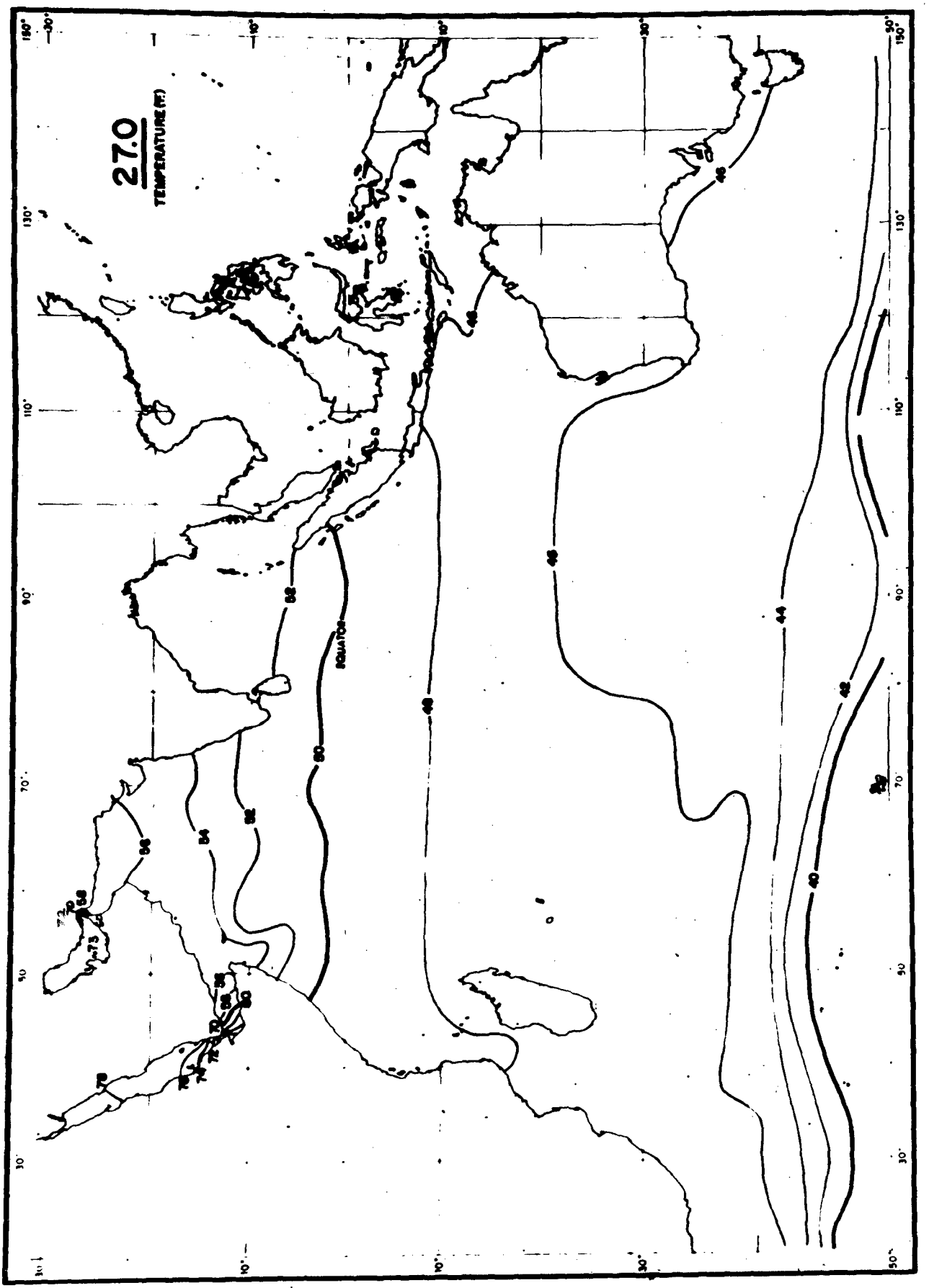


Figure 9 27.0 Sigma-t Surface, Mean Temperature (°F.)

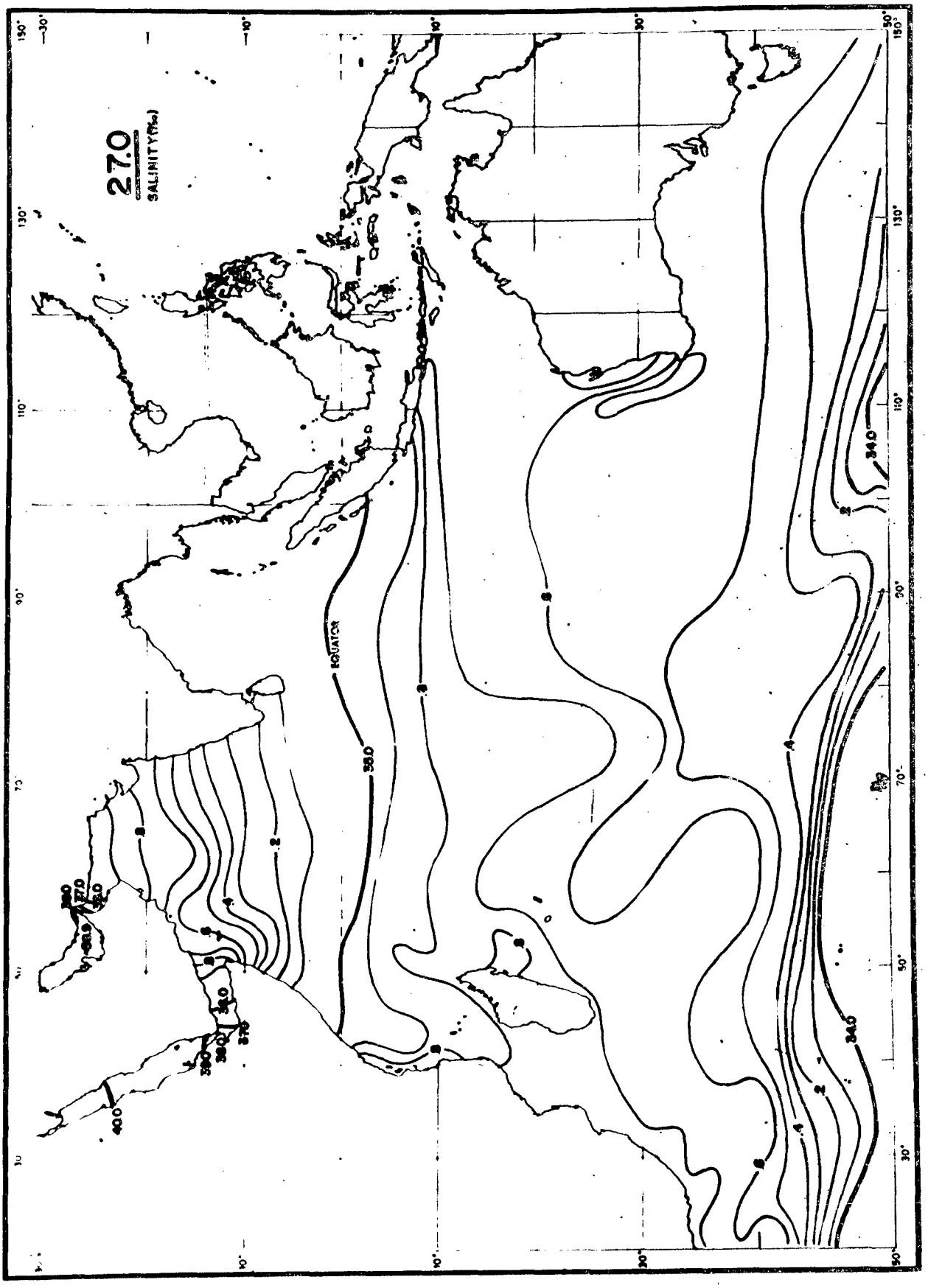


Figure 10 27.0 Sigma-t Surface, Mean Salinity (parts per thousand)

27.2 Sigma-t Surface

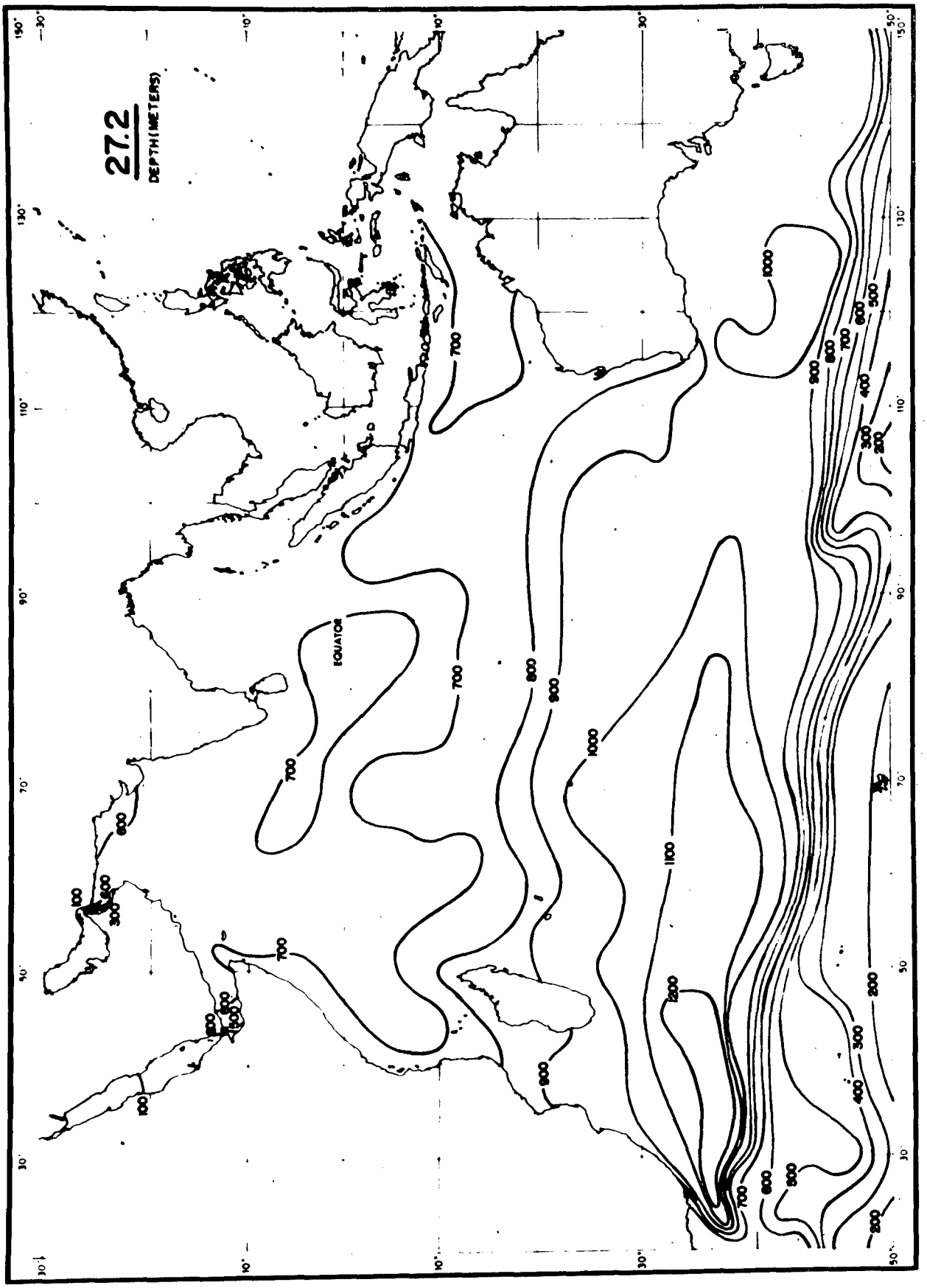


Figure 11 27.2 Sigma-t Surface, Depth (meters)

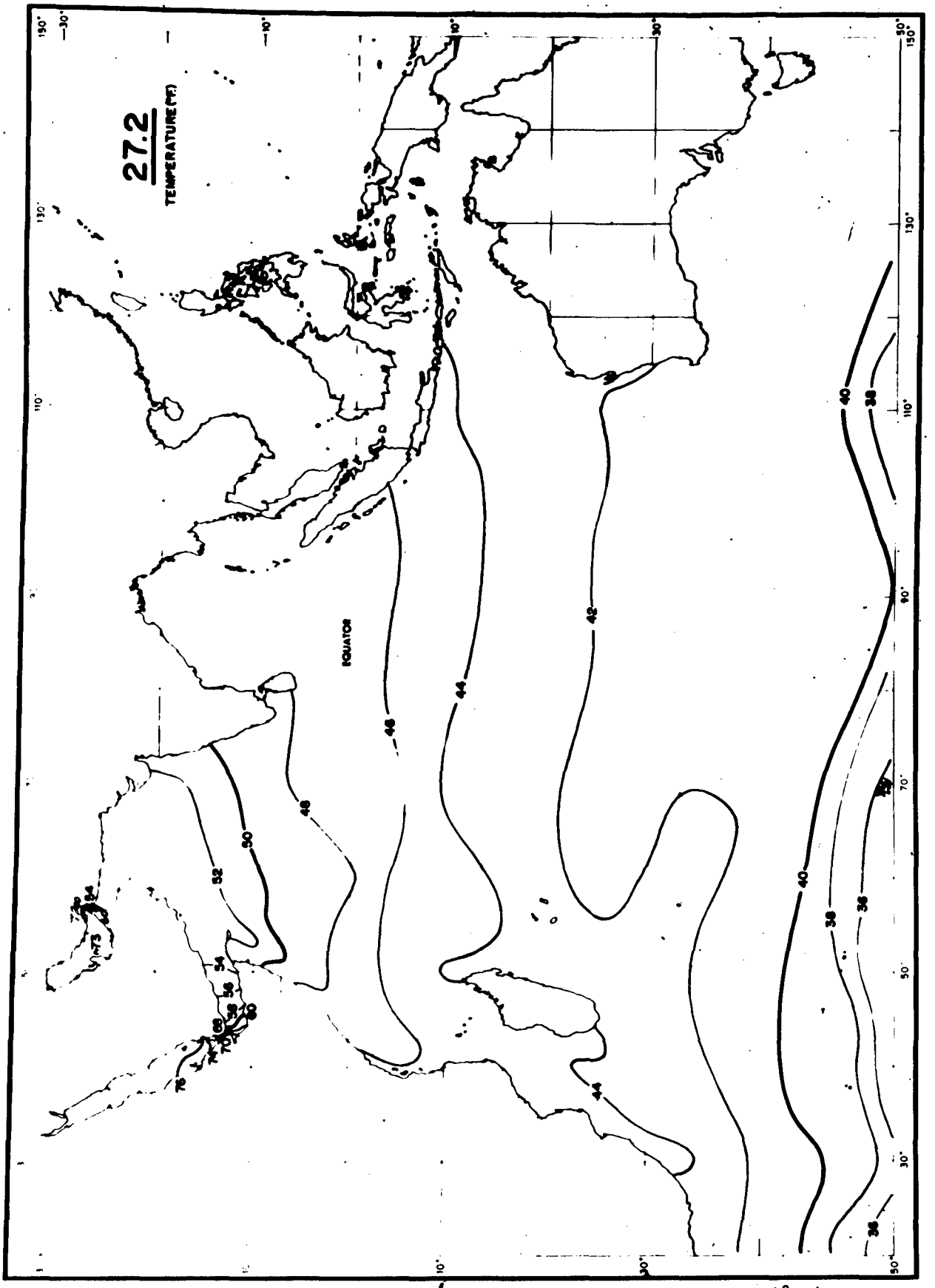


Figure 12 27.2 Sigma-t Surface, Mean Temperature (°F.)

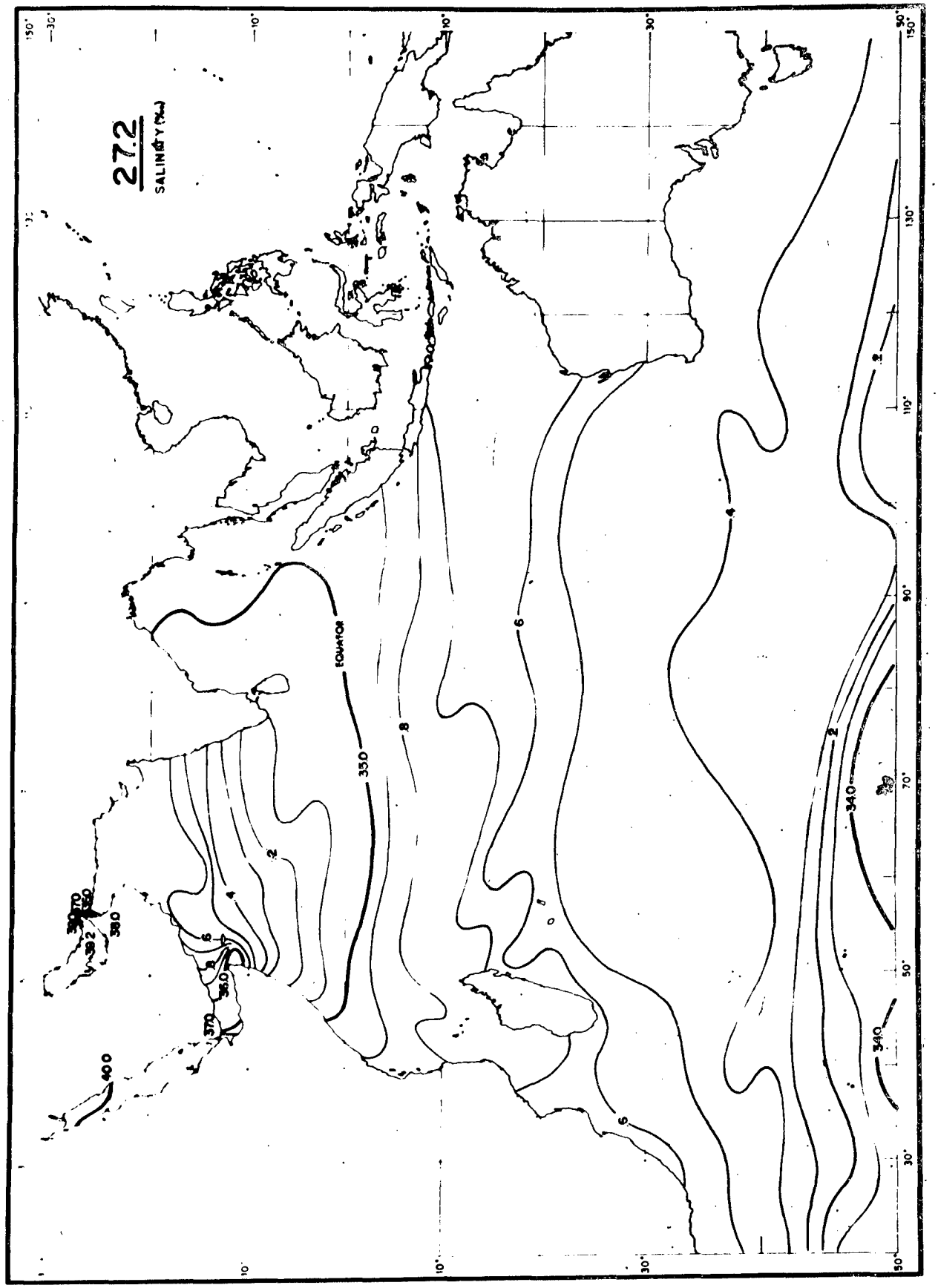


Figure 13 27.2 Sigma-t Surface, Mean Salinity (parts per thousand)

27.4 Sigma-t Surface

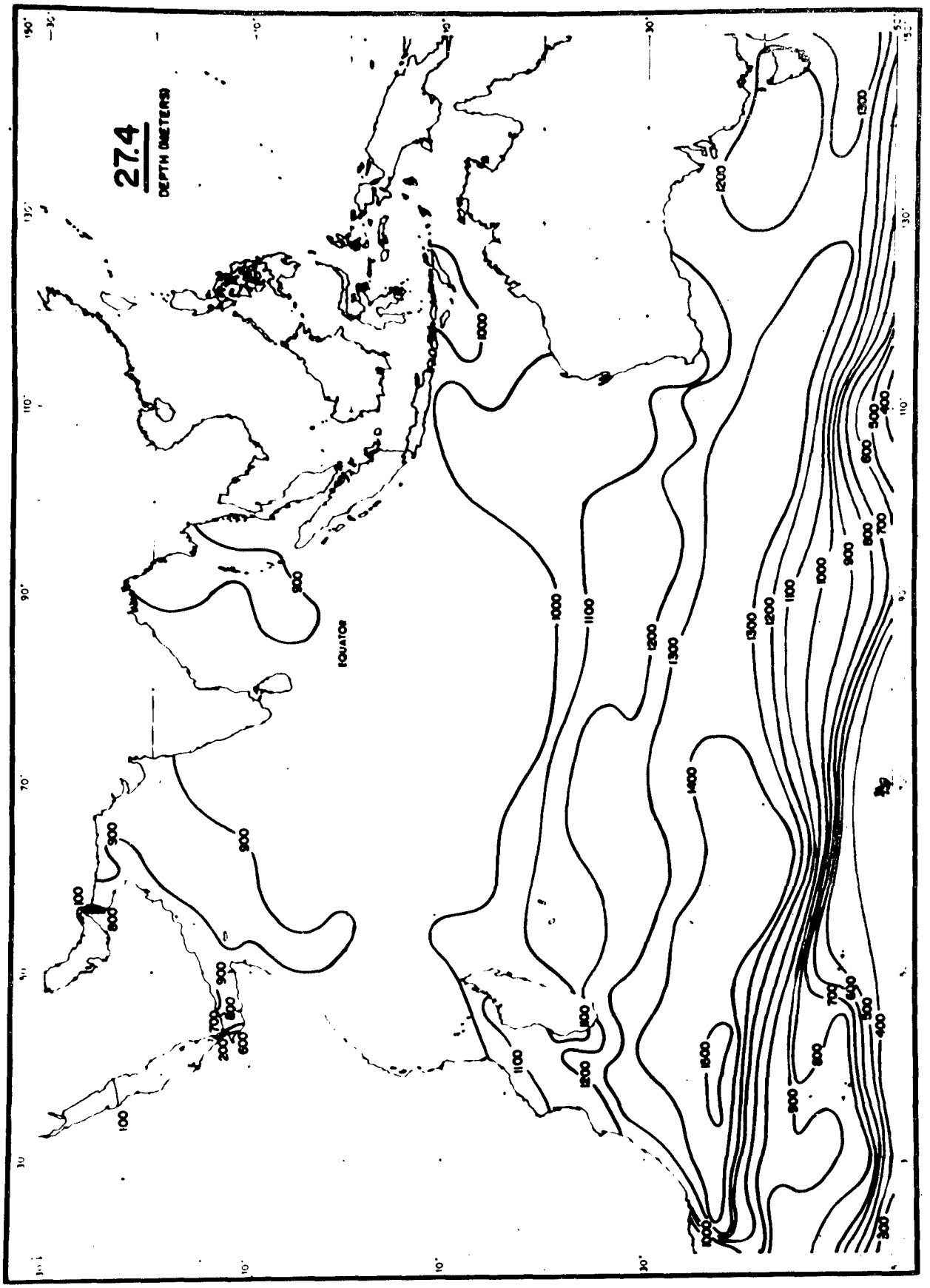


Figure 14 27.4 Sigma-t Surface, Depth (meters)

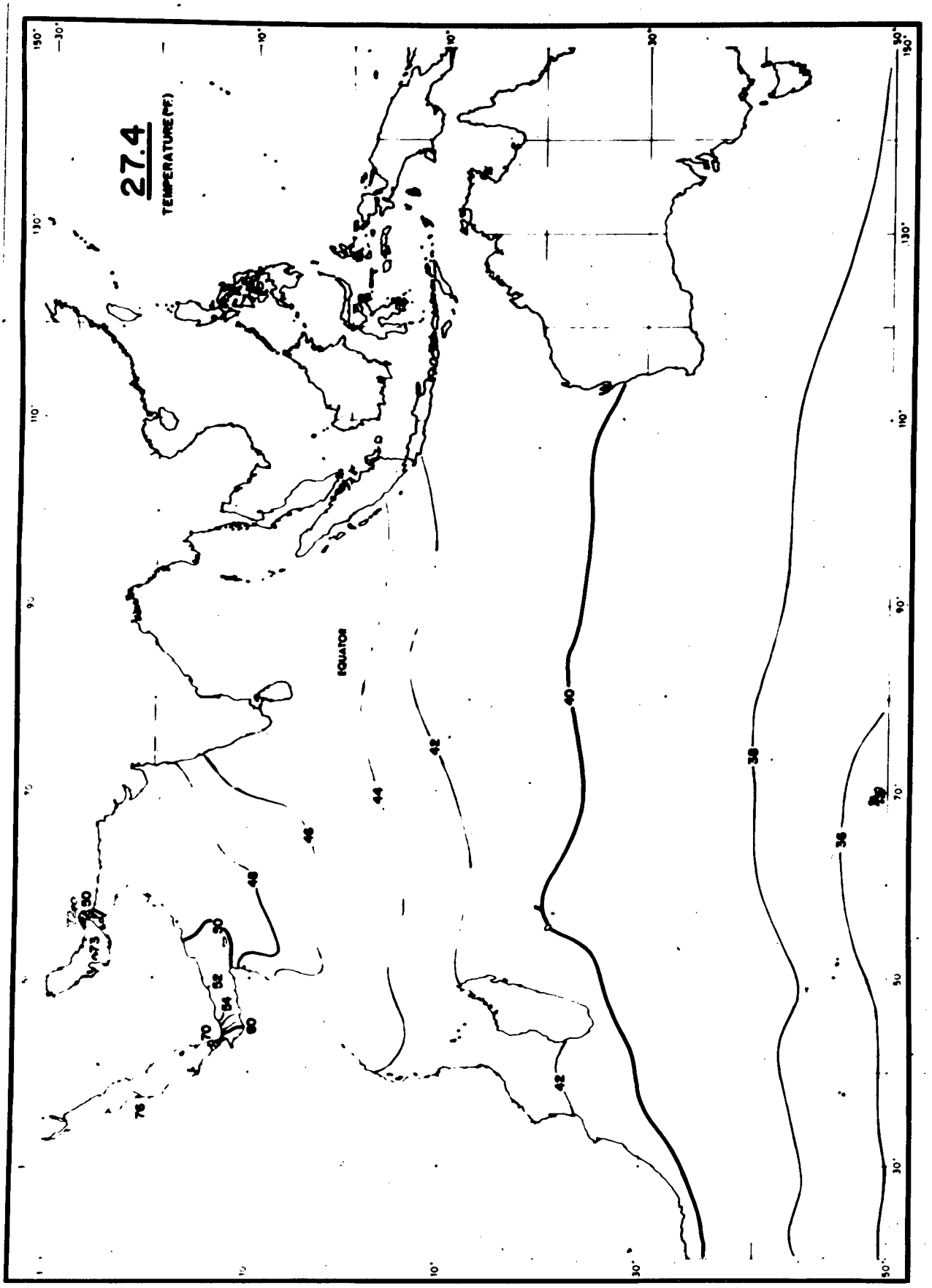


Figure 15 27.4 Sigma-t Surface, Mean Temperature (°F.)

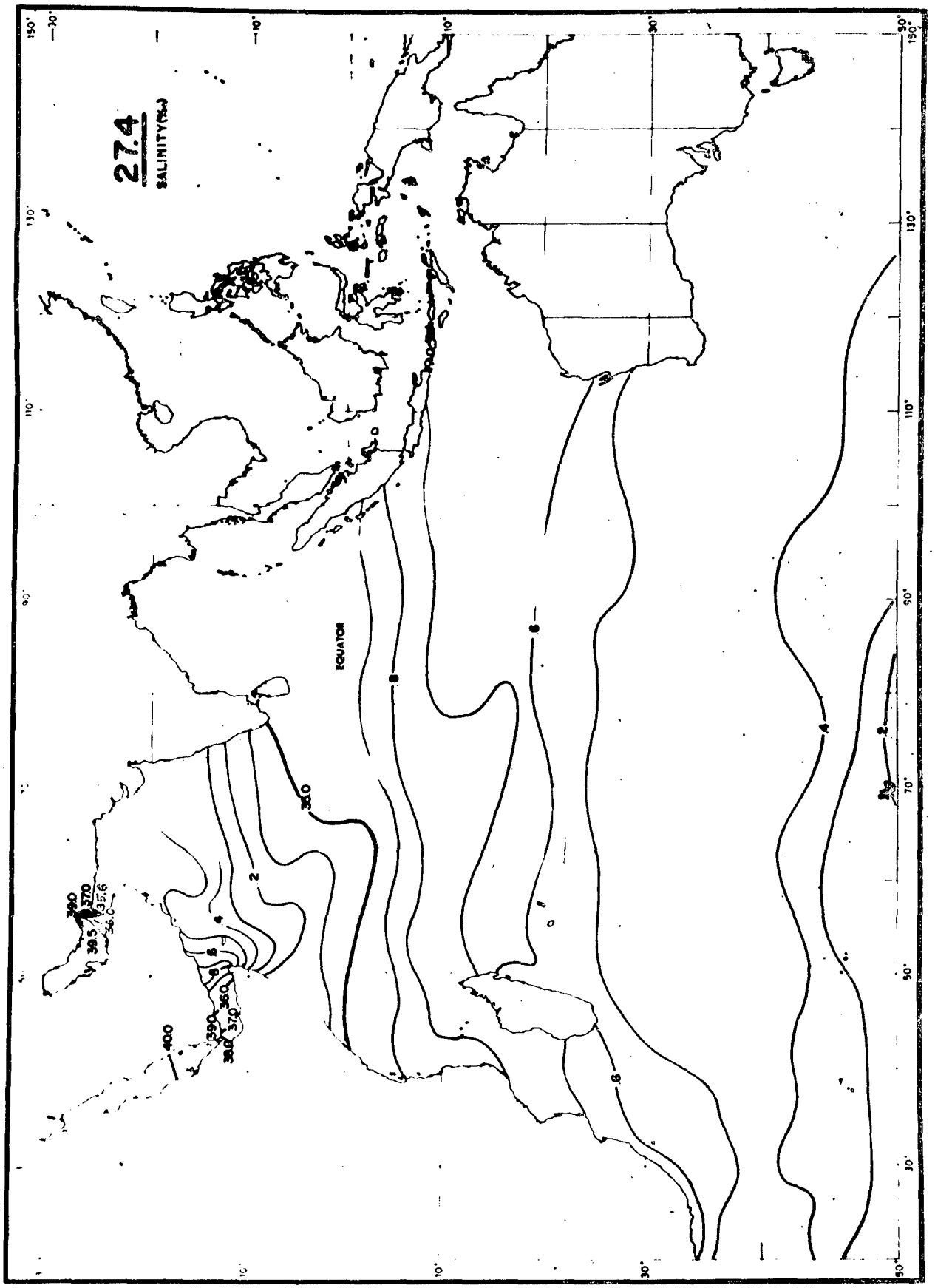


Figure 16 27.4 Sigma-t Surface, Mean Salinity (parts per thousand)

27.6 Sigma-t Surface

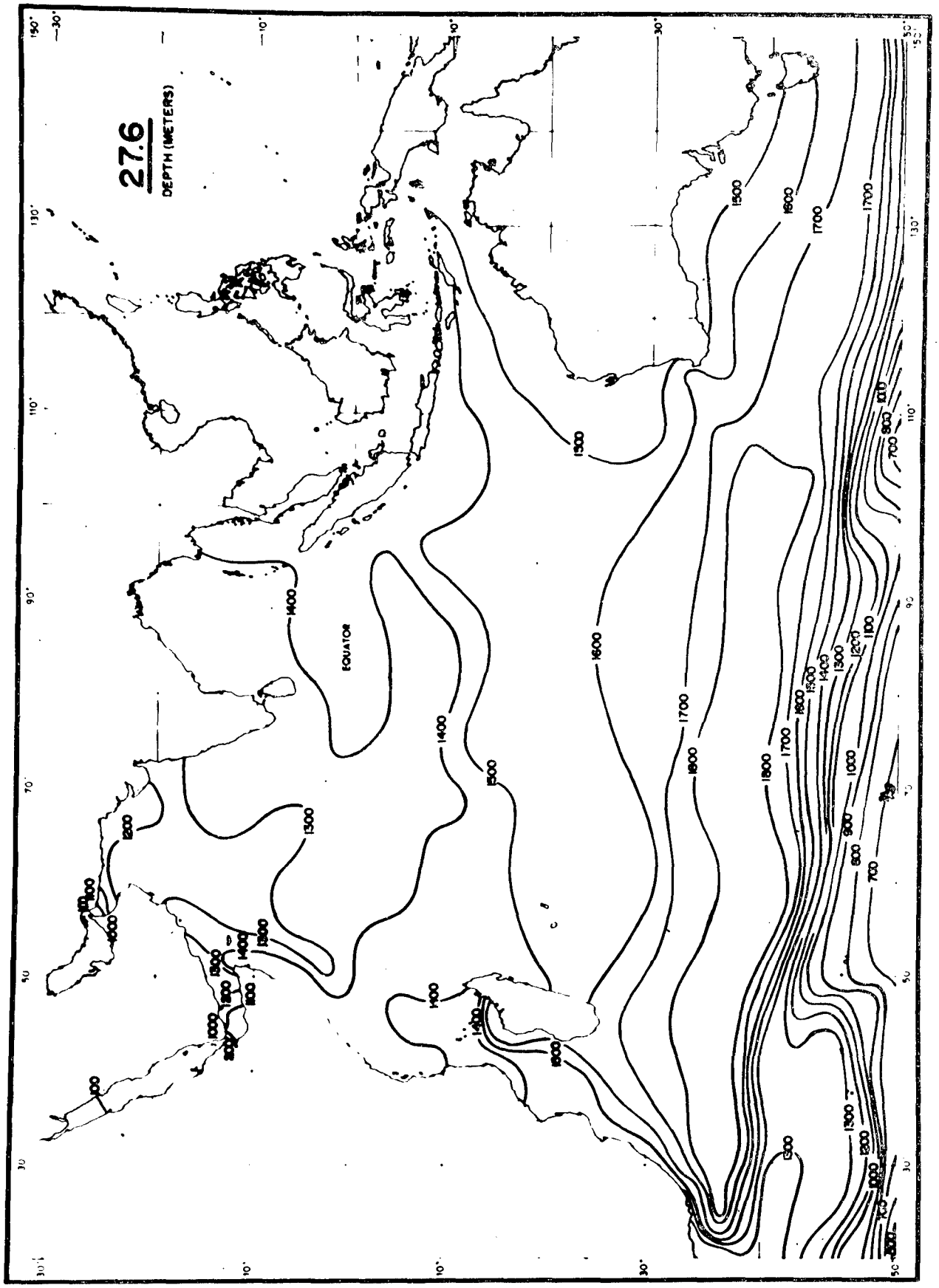


Figure 17 27.6 Sigma-t Surface, Depth (meters)

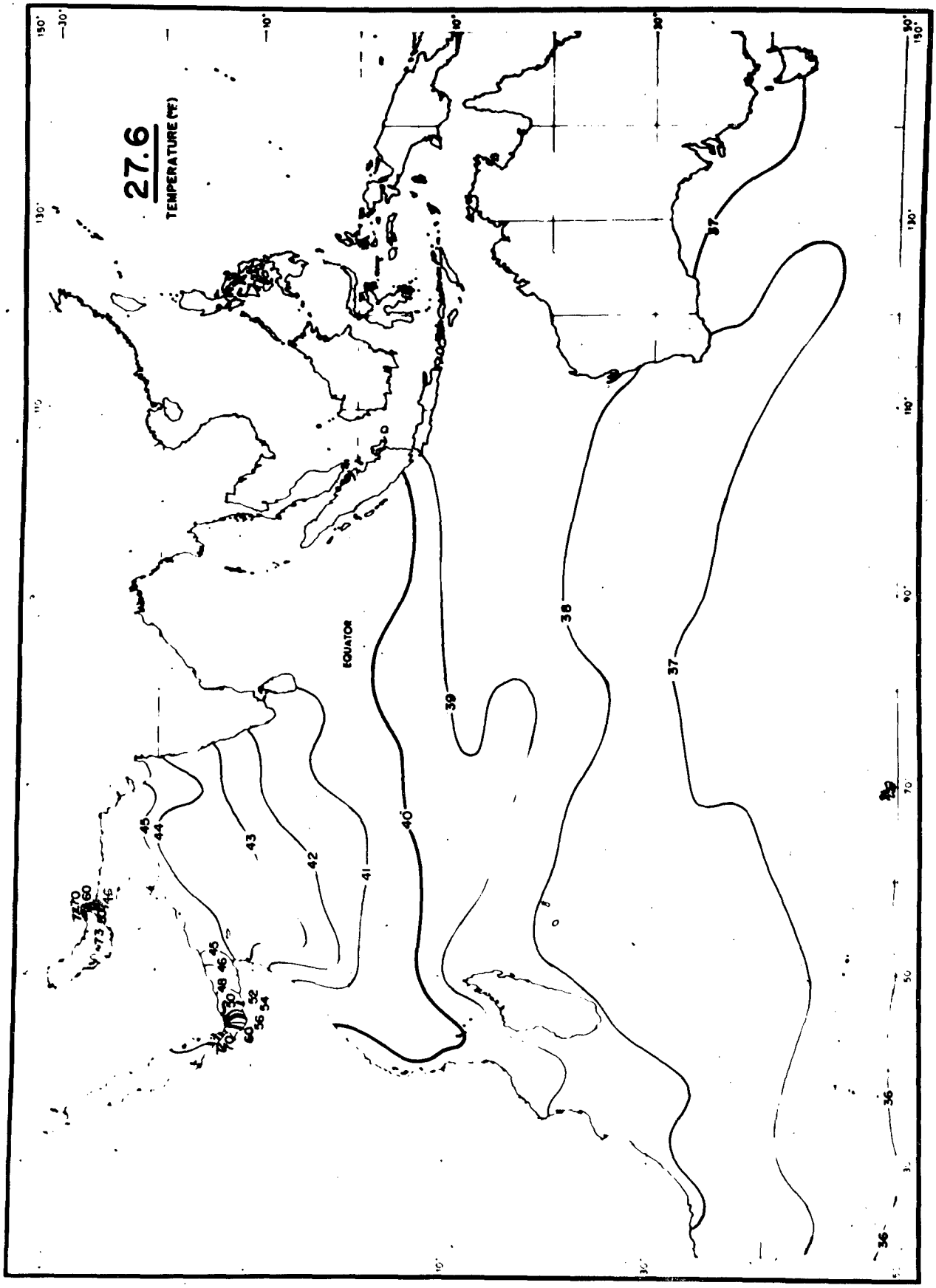


Figure 18 27.6 Sigma-t Surface, Mean Temperature (°F.)

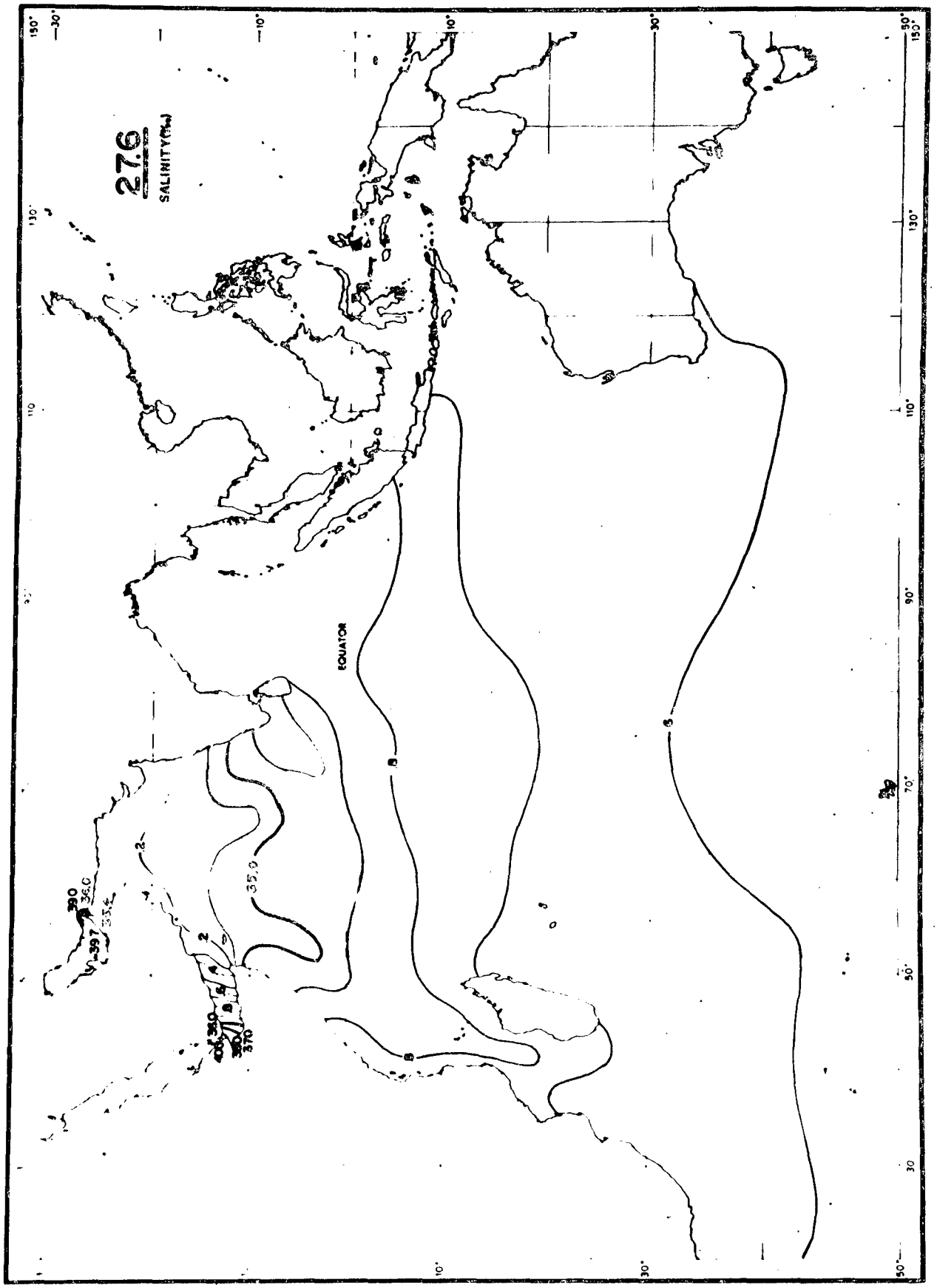


Figure 19 27.6 Sigma-t Surface, Mean Salinity (parts per thousand)

APPENDIX

I Conversion Tables
  (a) Meters to feet
  (b) Fahrenheit to Celsius

II List of Published Oceanographic Atlases and Sections of Atlases

III Distribution of Oceanographic Atlases (Figure 20)

(a) Meters to Feet

Meters	0	1	2	3	4	5	6	7	8	9
0	0.0	3.3	6.6	9.8	13.1	16.4	19.7	23.0	26.2	29.5
10	32.8	36.1	39.4	42.7	45.9	49.2	52.5	55.8	59.1	62.3
20	65.6	68.9	72.2	75.5	78.7	82.0	85.3	88.6	91.9	95.1
30	98.4	101.7	105.0	108.3	111.5	114.8	118.1	121.4	124.7	128.0
40	131.2	134.5	137.8	141.1	144.4	147.6	150.9	154.2	157.5	160.8
50	164.0	167.3	170.6	173.9	177.2	180.4	183.7	187.0	190.3	193.6
60	196.8	200.1	203.4	206.7	210.0	213.3	216.5	219.8	223.1	226.4
70	229.7	232.9	236.2	239.5	242.8	246.1	249.3	252.6	255.9	259.2
80	262.5	265.7	269.0	272.3	275.6	278.9	282.2	285.4	288.7	292.0
90	295.3	298.6	301.8	305.1	308.4	311.7	315.0	318.2	321.5	324.8
100	328.1	331.4	334.6	337.9	341.2	344.5	347.8	351.0	354.3	357.6
110	360.9	364.2	367.5	370.7	374.0	377.3	380.6	383.9	387.1	390.4
120	393.7	397.0	400.3	403.5	406.8	410.1	413.4	416.7	419.9	423.2
130	426.5	429.8	433.1	436.4	439.6	442.9	446.2	449.5	452.8	456.0
140	459.3	462.6	465.9	469.2	472.4	475.7	479.0	482.3	485.6	488.8
150	492.1	495.4	498.7	502.0	505.2	508.5	511.8	515.1	518.4	521.7
160	524.9	528.2	531.5	534.8	538.1	541.3	544.6	547.9	551.2	554.5
170	557.7	561.0	564.3	567.6	570.9	574.1	577.4	580.7	584.0	587.3
180	590.5	593.8	597.1	600.4	603.7	607.0	610.2	613.5	616.8	620.1
190	623.4	626.6	629.9	633.2	636.5	639.8	643.0	646.3	649.6	652.9
200	656.2	659.4	662.7	666.0	669.3	672.6	675.9	679.1	682.4	685.7
210	689.0	692.3	695.5	698.8	702.1	705.4	708.7	711.9	715.2	718.5
220	721.8	725.1	728.3	731.6	734.9	738.2	741.5	744.7	748.0	751.3
230	754.6	757.9	761.2	764.4	767.7	771.0	774.3	777.6	780.8	784.1
240	787.4	790.7	794.0	797.2	800.5	803.8	807.1	810.4	813.6	816.9
250	820.2	823.5	826.8	830.1	833.3	836.6	839.9	843.2	846.5	849.7
260	853.0	856.3	859.6	862.9	866.1	869.4	872.7	876.0	879.3	882.5
270	885.8	889.1	892.4	895.7	898.9	902.2	905.5	908.8	912.1	915.4
280	918.6	921.9	925.2	928.5	931.8	935.0	938.3	941.6	944.9	948.2
290	951.4	954.7	958.0	961.3	964.6	967.8	971.1	974.4	977.7	981.0

Meters	00	10	20	30	40	50	60	70	80	90
300	984.2	1,017.1	1,049.9	1,082.7	1,115.5	1,148.3	1,181.1	1,213.9	1,246.7	1,279.5
400	1,312.3	1,345.1	1,377.9	1,410.8	1,443.6	1,476.4	1,509.2	1,542.0	1,574.8	1,607.6
500	1,640.4	1,673.2	1,706.0	1,738.8	1,771.6	1,804.5	1,837.3	1,870.1	1,902.9	1,935.7
600	1,968.5	2,001.3	2,034.1	2,066.9	2,099.7	2,132.5	2,165.3	2,198.2	2,231.0	2,263.8
700	2,296.6	2,329.4	2,362.2	2,395.0	2,427.8	2,460.6	2,493.4	2,526.2	2,559.0	2,591.9
800	2,624.7	2,657.5	2,690.3	2,723.1	2,755.9	2,788.7	2,821.5	2,854.3	2,887.1	2,919.9
900	2,952.7	2,985.6	3,018.4	3,051.2	3,084.0	3,116.8	3,149.6	3,182.4	3,215.2	3,248.0

Meters	000	100	200	300	400	500	600	700	800	900
1,000	3,281	3,609	3,937	4,265	4,593	4,921	5,249	5,577	5,905	6,234
2,000	6,562	6,890	7,218	7,546	7,874	8,202	8,530	8,858	9,186	9,514
3,000	9,842	10,171	10,499	10,827	11,155	11,483	11,811	12,139	12,467	12,795
4,000	13,123	13,451	13,779	14,108	14,436	14,764	15,092	15,420	15,748	16,076
5,000	16,404	16,732	17,060	17,388	17,716	18,045	18,373	18,701	19,028	19,357
6,000	19,685	20,013	20,341	20,669	20,997	21,325	21,653	21,982	22,310	22,638
7,000	22,966	23,294	23,622	23,950	24,278	24,606	24,934	25,262	25,590	25,919
8,000	26,247	26,575	26,903	27,231	27,559	27,887	28,215	28,543	28,871	29,199
9,000	29,527	29,856	30,184	30,512	30,840	31,168	31,496	31,824	32,152	32,480

(b) Temperature Conversions-Fahrenheit to Celsius

°F.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
30	−1. 11	−1. 06	−1. 00	−0. 94	−0. 89	−0. 83	−0. 78	−0. 72	−0. 67	−0. 61
31	−. 56	−. 50	−. 44	−. 39	−. 33	−. 28	−. 22	−. 17	−. 11	−. 06
32	. 00	. 06	. 11	. 17	. 22	. 28	. 33	. 39	. 44	. 50
33	. 56	. 61	. 67	. 72	. 78	. 83	. 89	. 94	1. 00	1. 06
34	1. 11	1. 17	1. 22	1. 28	1. 33	1. 39	1. 44	1. 50	1. 56	1. 61
35	1. 67	1. 72	1. 78	1. 83	1. 89	1. 94	2. 00	2. 06	2. 11	2. 17
36	2. 22	2. 28	2. 33	2. 39	2. 44	2. 50	2. 56	2. 61	2. 67	2. 72
37	2. 78	2. 83	2. 89	2. 94	3. 00	3. 06	3. 11	3. 17	3. 22	3. 28
38	3. 33	3. 39	3. 44	3. 50	3. 56	3. 61	3. 67	3. 72	3. 78	3. 83
39	3. 89	3. 94	4. 00	4. 06	4. 11	4. 17	4. 22	4. 28	4. 33	4. 39
40	4. 44	4. 50	4. 56	4. 61	4. 67	4. 72	4. 78	4. 83	4. 89	4. 94
41	5. 00	5. 06	5. 11	5. 17	5. 22	5. 28	5. 33	5. 39	5. 44	5. 50
42	5. 56	5. 61	5. 67	5. 72	5. 78	5. 83	5. 89	5. 94	6. 00	6. 06
43	6. 11	6. 17	6. 22	6. 28	6. 33	6. 39	6. 44	6. 50	6. 56	6. 61
44	6. 67	6. 72	6. 78	6. 83	6. 89	6. 94	7. 00	7. 06	7. 11	7. 17
45	7. 22	7. 28	7. 33	7. 39	7. 44	7. 50	7. 56	7. 61	7. 67	7. 72
46	7. 78	7. 83	7. 89	7. 94	8. 00	8. 06	8. 11	8. 17	8. 22	8. 28
47	8. 33	8. 39	8. 44	8. 50	8. 56	8. 61	8. 67	8. 72	8. 78	8. 83
48	8. 89	8. 94	9. 00	9. 06	9. 11	9. 17	9. 22	9. 28	9. 33	9. 39
49	9. 44	9. 50	9. 56	9. 61	9. 67	9. 72	9. 78	9. 83	9. 89	9. 94
50	10. 00	10. 06	10. 11	10. 17	10. 22	10. 28	10. 33	10. 39	10. 44	10. 50
51	10. 56	10. 61	10. 67	10. 72	10. 78	10. 83	10. 89	10. 94	11. 00	11. 06
52	11. 11	11. 17	11. 22	11. 28	11. 33	11. 39	11. 44	11. 50	11. 56	11. 61
53	11. 67	11. 72	11. 78	11. 83	11. 89	11. 94	12. 00	12. 06	12. 11	12. 17
54	12. 22	12. 28	12. 33	12. 39	12. 44	12. 50	12. 56	12. 61	12. 67	12. 72
55	12. 78	12. 83	12. 89	12. 94	13. 00	13. 06	13. 11	13. 17	13. 22	13. 28
56	13. 33	13. 39	13. 44	13. 50	13. 56	13. 61	13. 67	13. 72	13. 78	13. 83
57	13. 89	13. 94	14. 00	14. 06	14. 11	14. 17	14. 22	14. 28	14. 33	14. 39
58	14. 44	14. 50	14. 56	14. 61	14. 67	14. 72	14. 78	14. 83	14. 89	14. 94
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63	17. 22	17. 28	17. 33	17. 39	17. 44	17. 50	17. 56	17. 61	17. 67	17. 72
64	17. 78	17. 83	17. 89	17. 94	18. 00	18. 06	18. 11	18. 17	18. 22	18. 28
65	18. 33	18. 39	18. 44	18. 50	18. 56	18. 61	18. 67	18. 72	18. 78	18. 83
66	18. 89	18. 94	19. 00	19. 06	19. 11	19. 17	19. 22	19. 28	19. 33	19. 39
67	19. 44	19. 50	19. 56	19. 61	19. 67	19. 72	19. 78	19. 83	19. 89	19. 94
68	20. 00	20. 06	20. 11	20. 17	20. 22	20. 28	20. 33	20. 39	20. 44	20. 50
69	20. 56	20. 61	20. 67	20. 72	20. 78	20. 83	20. 89	20. 94	21. 00	21. 06
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72	22. 22	22. 28	22. 33	22. 39	22. 44	22. 50	22. 56	22. 61	22. 67	22. 72
73	22. 78	22. 83	22. 89	22. 94	23. 00	23. 06	23. 11	23. 17	23. 22	23. 28
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78	25. 56	25. 61	25. 67	25. 72	25. 78	25. 83	25. 89	25. 94	26. 00	26. 06
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80	26. 67	26. 72	26. 78	26. 83	26. 89	26. 94	27. 00	27. 06	27. 11	27. 17
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84	28. 89	28. 94	29. 00	29. 06	29. 11	29. 17	29. 22	29. 28	29. 33	29. 39

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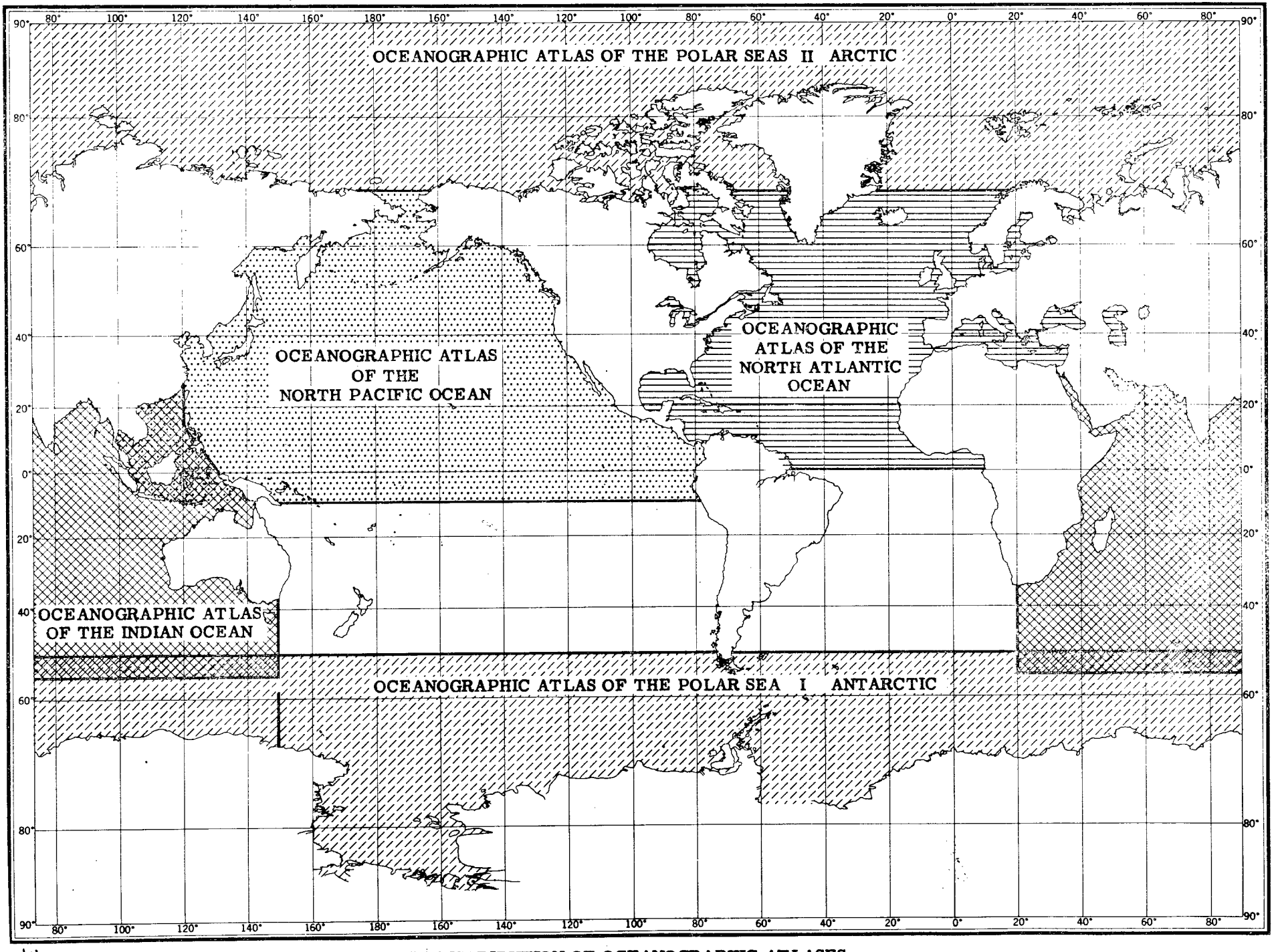

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1. ORIGINATING ACTIVITY *(Corporate author)*

Naval Oceanographic Office
Washington, D.C. 20390

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

AN ANALYSIS OF SELECTED SIGMA-t SURFACES IN THE INDIAN OCEAN

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Informal Report (IR 67-98)

5. AUTHOR(S) *(First name, middle initial, last name)*

Douglas R. Hamilton and Paul E. LaViolette

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
November 1967	36	none

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	IR 67-98
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	none

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13. ABSTRACT

An analysis was made of interpolated values on six sigma-t surfaces beginning with 26.6 and ending with 27.6. The levels are spaced at increments of 0.2 unit of sigma-t. For each sigma-t surface three charts are drawn showing the mean depth, mean temperature, and mean salinity of the surface.

These analyses will be published at some future date in the U.S. Naval Oceanographic Office "Oceanographic Atlas of the Indian Ocean, Section II, Physical Properties" on the basis of data published in NODC Publication G-12, "Indian Ocean Atlas, Interpolated Values of Depth, Salinity, and Temperature on Selected Sigma-t Surfaces."

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Sigma-t						
Indian Ocean						
Temperature						
Salinity						
Density						
Physical Properties						