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SCIENTIFIC RESULTS OF ATLANTIS CRUISE 151 TO THE MEDITERRANEAN --ETC(U)
SEP 48 M J POLLAK, D F BUMPUS, R B ABEL

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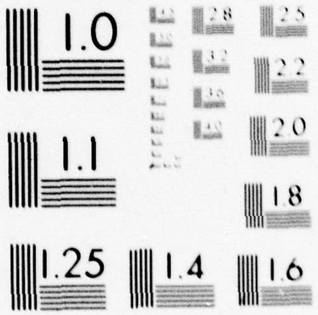

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WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole, Massachusetts

COLUMBIA UNIVERSITY
HUDSON LABORATORIES
CONTRACT N6-ONR-27135

(9) Preliminary Report on the

102297

(6) Scientific Results of

ATLANTIS Cruise 151 to the Mediterranean Area.

9/48

by

Scientific Staff for the Cruise

(10) M. J. Pollak,
D. F. Bumpus,
R. B. Abel,
N. Corwin
F. J. Mather

(11) September 1948

(12) 69

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(B)

1. Introduction

by

M. J. Pollak

On 18 June 1948 the R. V. ATLANTIS returned to Woods Hole after completion of Cruise 151 to the Mediterranean and Aegean Seas. This cruise, lasting over six months, was the longest one in her career, as well as the first one into European waters since her maiden voyage from Copenhagen to Woods Hole.

The observational program throughout the trip was so heavy that little time remained for a thorough study of the collected material. Some of the data, such as salinity samples and wave records, would not even be processed until the ship reached Woods Hole. However, in expectation of the usual time lag before the issuance of the final results, it seemed worth while to compile an informal preliminary report on the accomplishments of the cruise. This idea was carried out, on the return trip, by the scientific staff under the supervision of D. F. Bumpus, who had become scientist-in-charge when the writer left the ship at Gibraltar. The present paper is the edited version of the resulting "Homeward Bound Report." In view of the limitations already mentioned, it can do little more than indicate the types and quantities of observations made and those general features of the region which became apparent after a rough analysis of the data aboard ship.

Since the time available for the cruise was far too short to cover the Mediterranean area in its entirety, the major effort was devoted to those regions where modern oceanographic observations were sparsest. These were, primarily, the Aegean Sea and the Mediterranean east of the Straits of Sicily but exclusive of the Adriatic Sea.

One of the factors contributing to the success of the cruise was the excellent and continuous cooperation given the scientific staff by Captain A. K. Lane of the ATLANTIS and by his officers and men.

It is also a pleasure to acknowledge the courtesies and assistance rendered the ATLANTIS by the British authorities throughout the Mediterranean and, in particular, by Dr. J. N. Carruthers of the Oceanographical Branch, Hydrographic Department of the British Admiralty whose brief stay aboard the ship was thoroughly enjoyed by all hands.

Thanks are furthermore due to the personnel of the Greek Hydrographic Office, to members of the Greek Hydrobiological Institute of the Athens Academy, to the American Naval Attache at Athens and to the Hydrographic Institute of Genoa, Italy for their generosity in furnishing us data, charts and general information that might prove of value in our work.

During the planning stage of the cruise advice and assistance had been furnished us by the U. S. Hydrographic Office and by the Department of State through the Office of Near Eastern and African Affairs.

2. Hydrographic Observations

by

D. F. Bumpus

Hydrographic observations, consisting of Nansen bottle stations and bathythermograph lowerings, were made throughout the cruise. The geographical distribution of these observations is shown below.

	Hydrographic Stations	Bathythermograms
Atlantic Ocean	29	1100
Mediterranean Sea	67	850
Aegean Sea	29	800
Total for Cruise 151 - - - -	- 125	- - - - - - - 2750

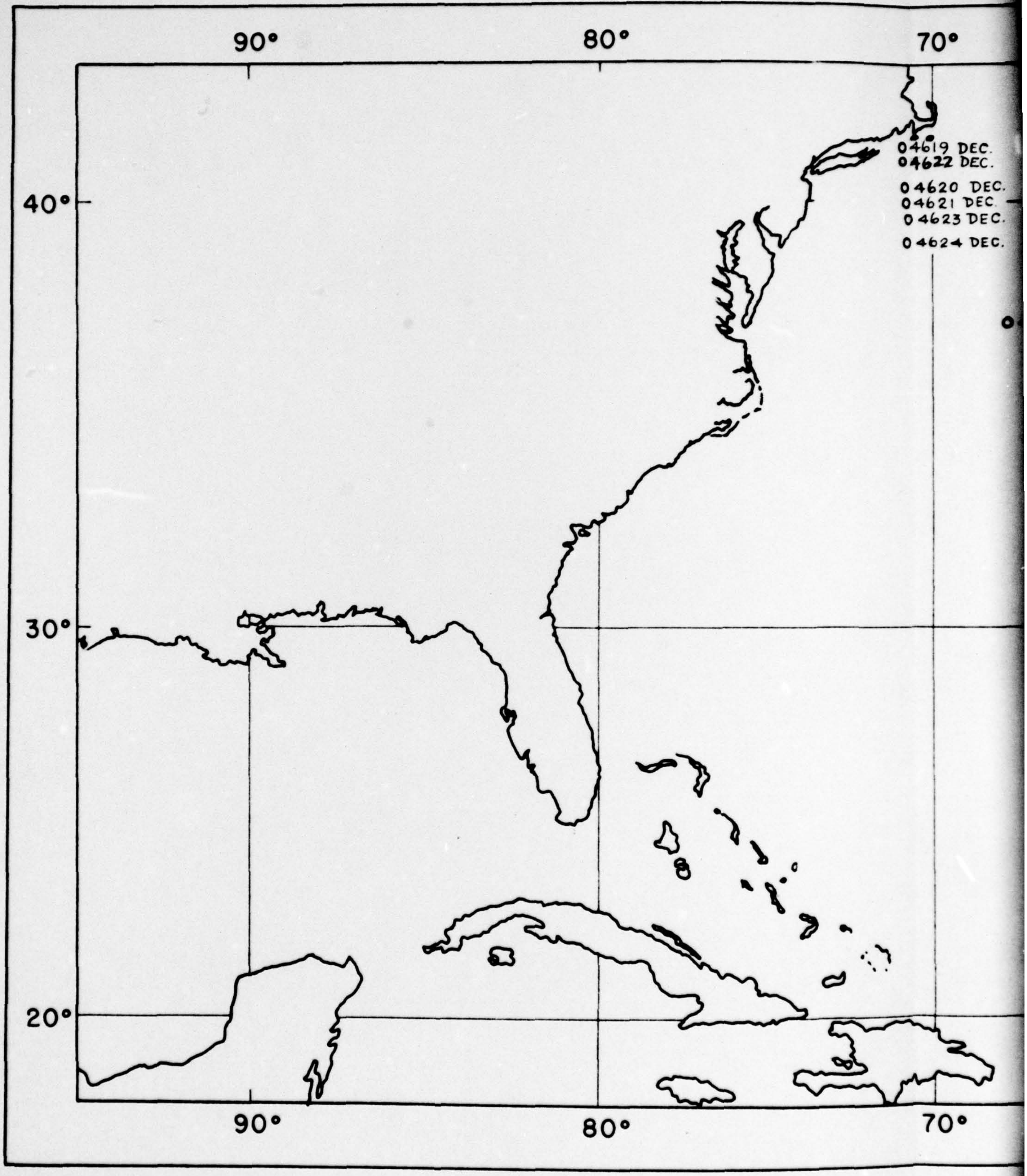
Bathythermograms were generally obtained at hourly intervals while the ship was under way. A majority of the lowerings were made with a 900 foot instrument. Shallower instruments were used when in shoal water and to obtain more details of surface temperature gradients.

Figures 2.1 and 2.2 show the positions and dates of all hydrographic stations.

x x x x x x

The temperature distribution in the Mediterranean Sea is characterized by a shallow thermocline about 500 meters deep in the eastern basin but only 100 meters deep in the western basin, with a very weak gradient extending somewhat below 1000 meters. Below these layers the temperature increases, probably adiabatically, about 0.01°C per 100 meters. The temperature of the minimum layer in the eastern Mediterranean is slightly less than 13.55°C whereas in the western Mediterranean it is about 12.92°C. Surface temperatures were about 15°C in January and 17°C in April and May.

Figure 2.3 depicts a January temperature section from Gibraltar to the Aegean Sea, Figure 2.4 an April-May section from the Syrian coast to Gibraltar. In the former, the shape of the 13.5° isotherm west of the Straits of Sicily points to the possibility of a slow westerly set through the Straits. The bubble of less than 13°C water which appears at a depth of 200 meters in both sections (near Stations 4641 and 4731 respectively) may indicate a counter clockwise circulation in this basin, resulting in a southerly set between the Spanish coast and the Balearic Islands. No final conclusions can be drawn about the circulation of the Mediterranean Sea until the salinity samples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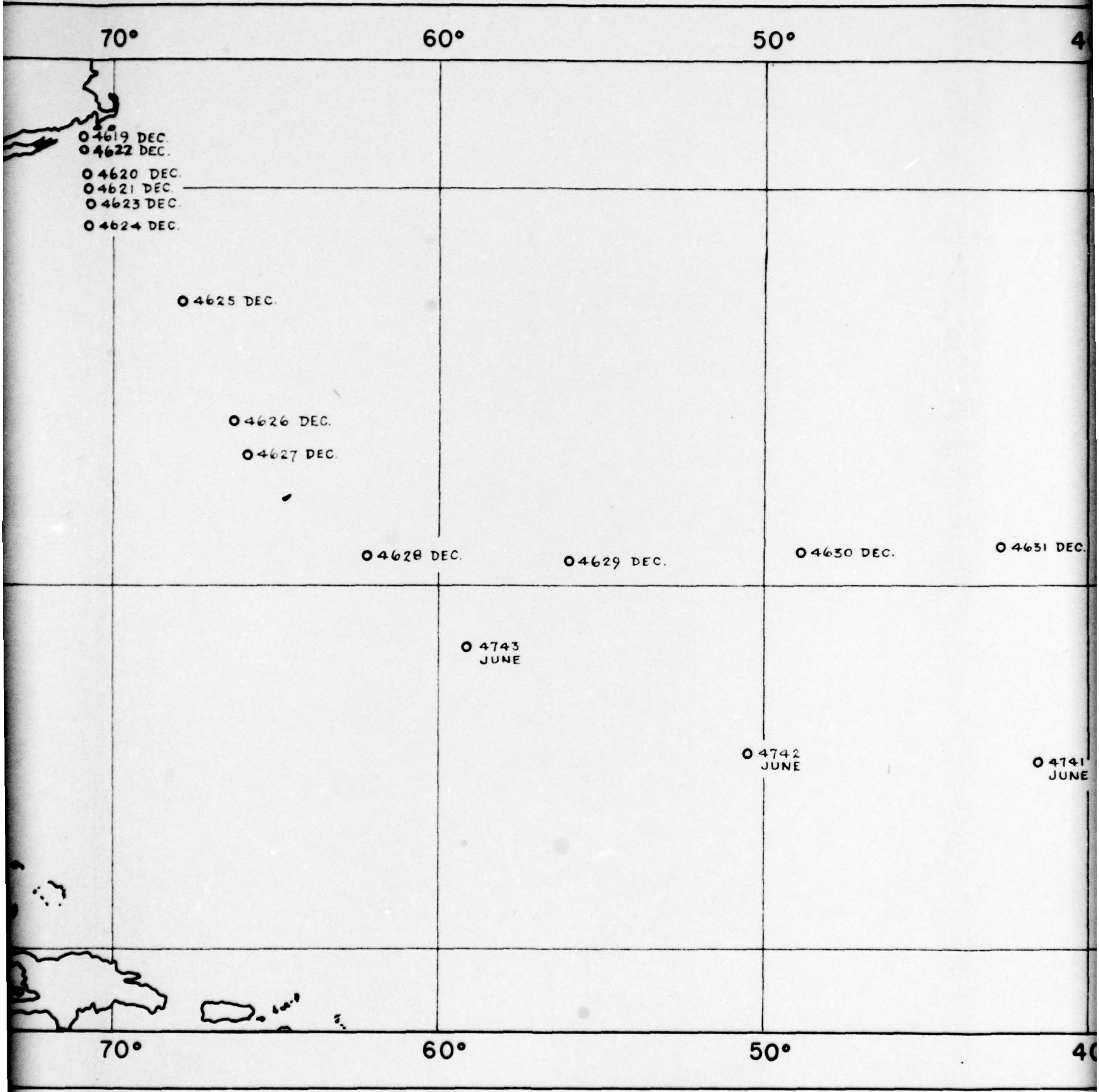
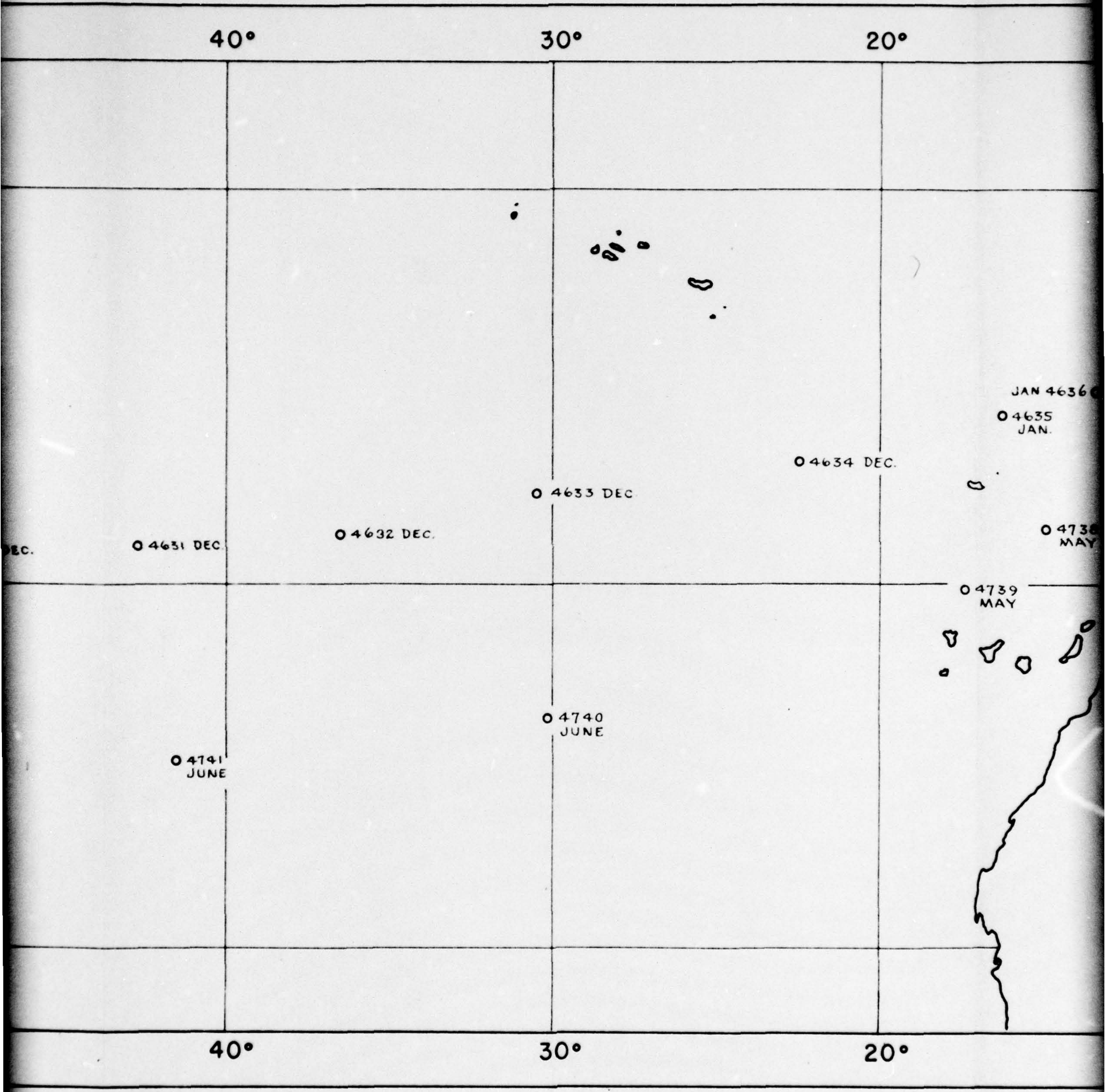
90°
80°
70°

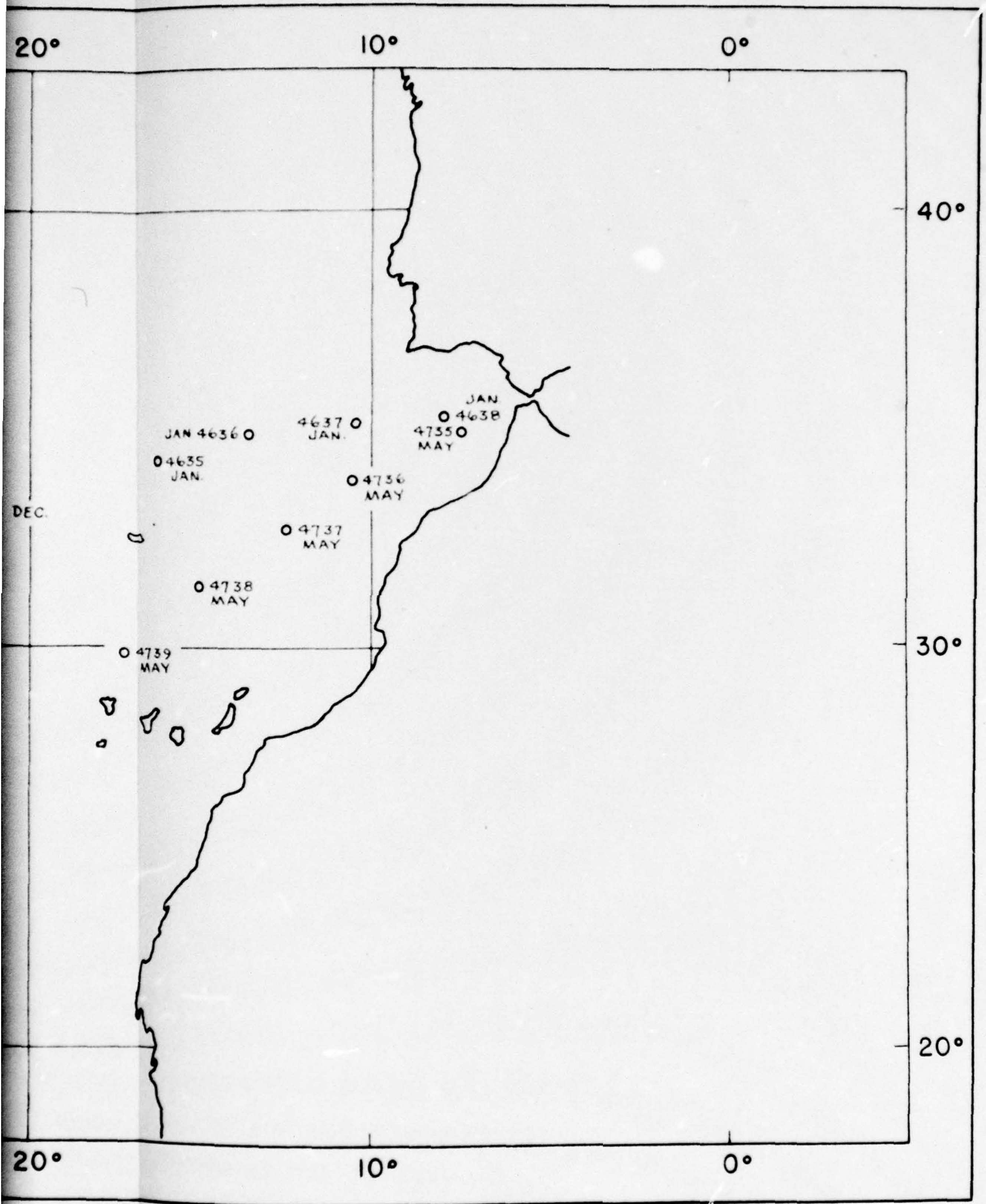
FIGURE 2.1 H



E 2.1 HYDROGRAPHIC STATIONS IN THE ATLAN



HE ATLANTIC OCEAN.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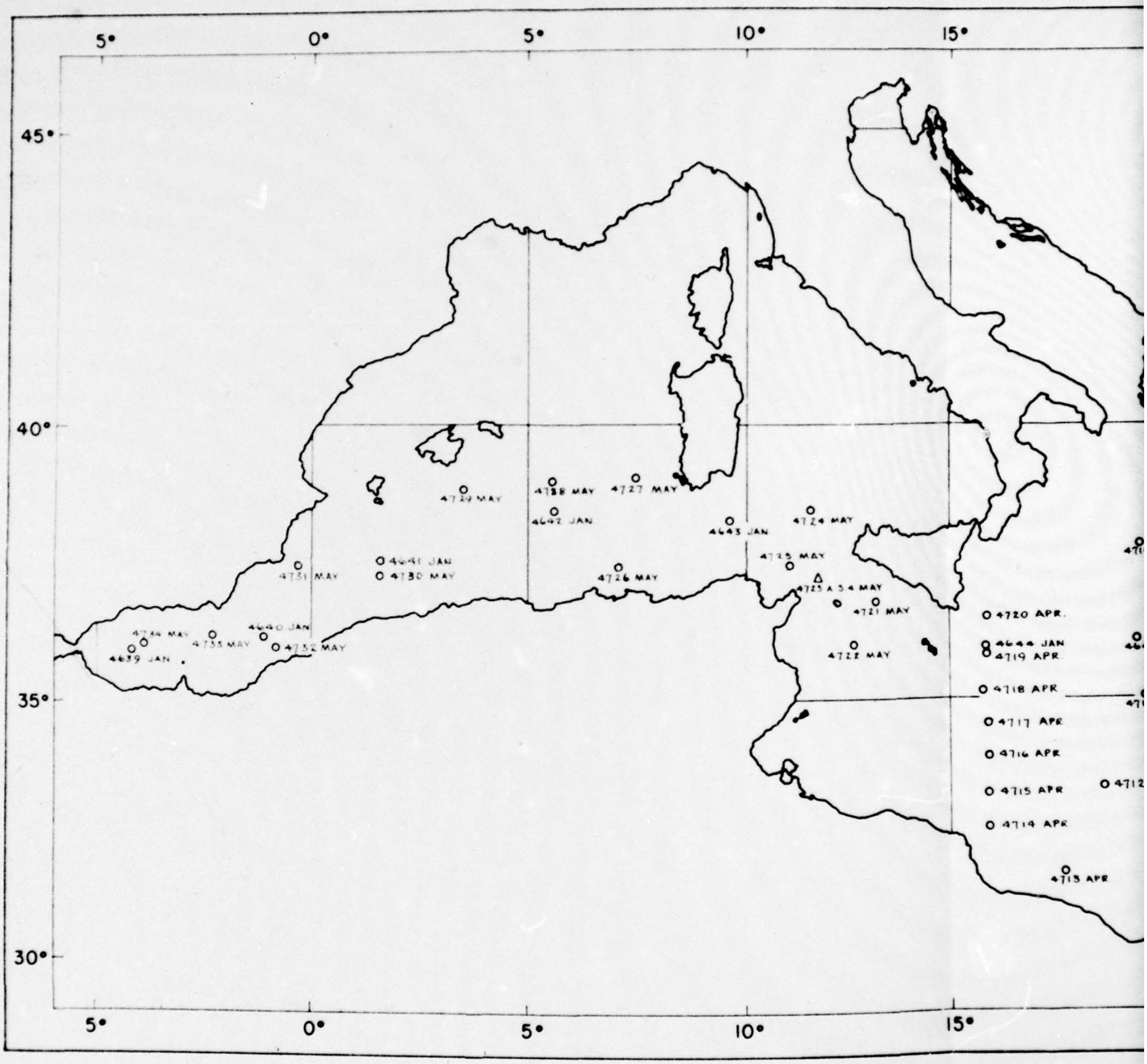
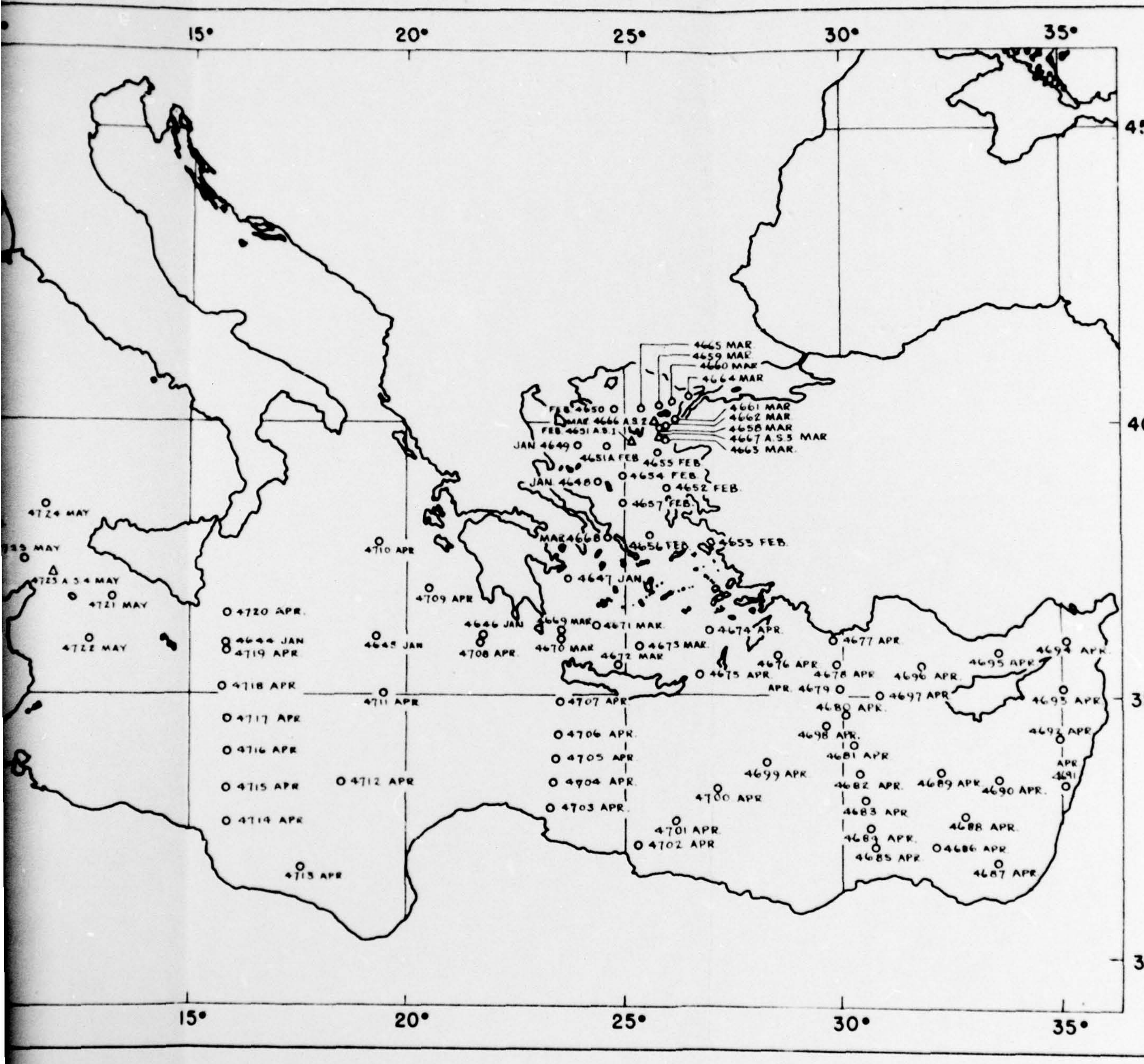


FIGURE 2.2 HYDROGRAPHIC STATIONS
AND AEGEAN SEAS.



GRAPHIC STATIONS IN THE MEDITERRANEAN
EGEAN SEAS.

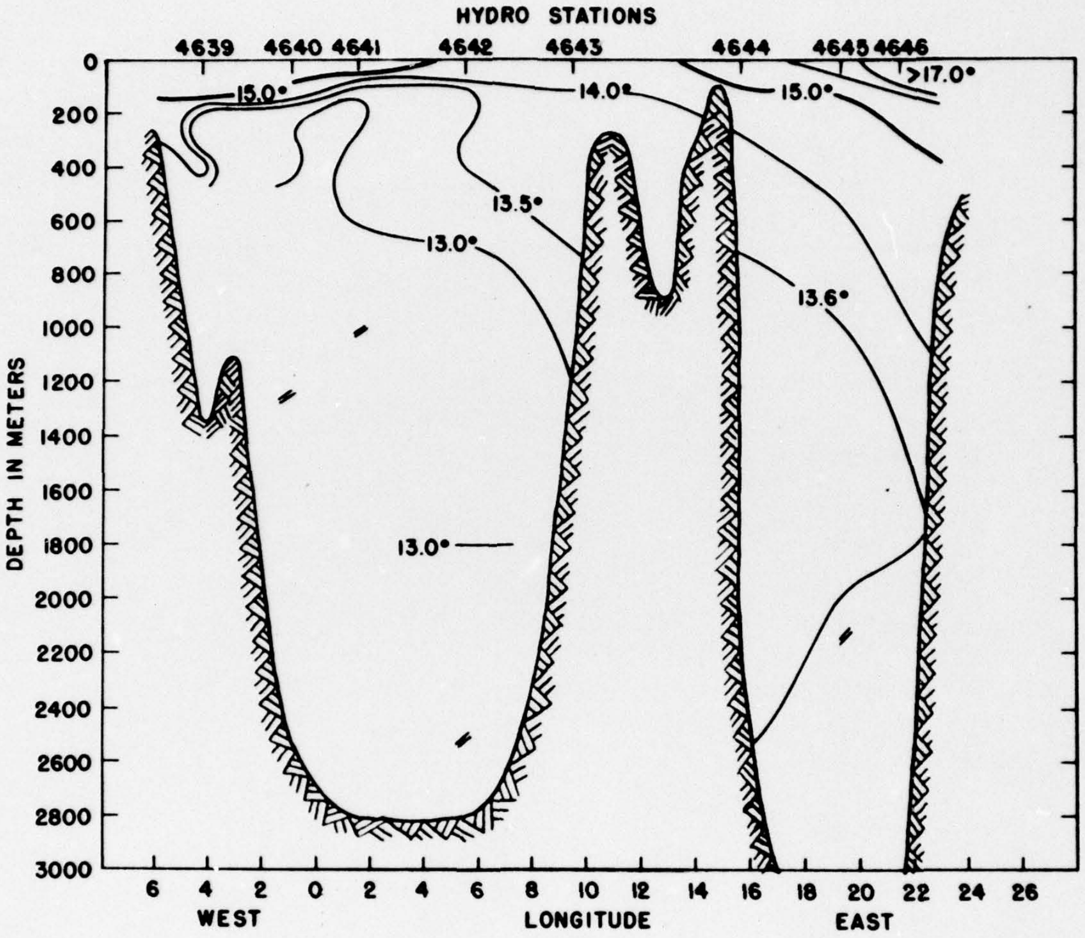


FIGURE 2.3 DISTRIBUTION OF T°C FROM GIBRALTAR TO AEGEAN SEA. JAN., 1948.

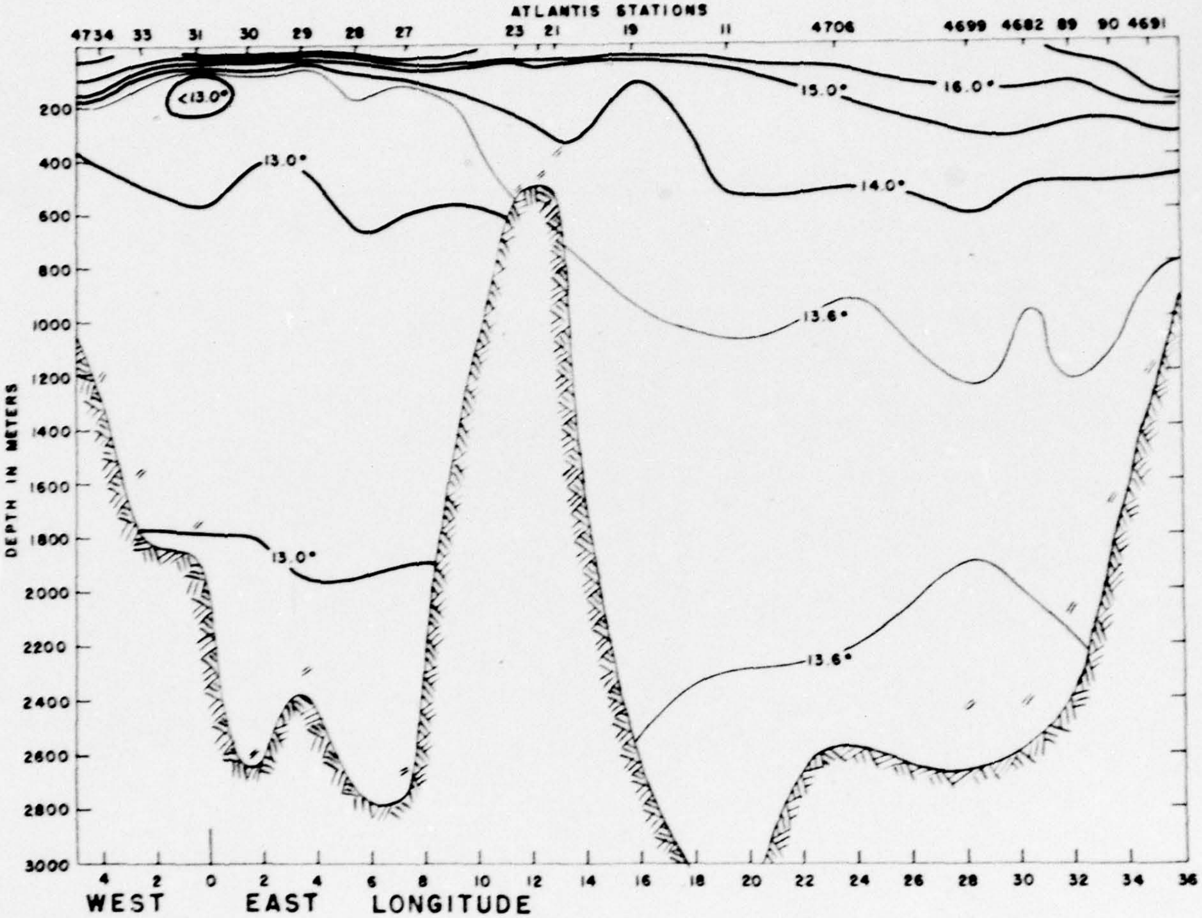


FIGURE 2.4 DISTRIBUTION OF T°C ACROSS THE MEDITERRANEAN. APRIL TO MAY, 1948.

have been analyzed.

The temperatures on the eastern side of the Aegean Sea show a marked similarity to those of the eastern Mediterranean, while those on the northern and western side are apparently modified to shallow depths by the Dardanelles outflow, which has a salinity of less than 34 °/oo and a temperature of 10°C. This points to a pronounced counterclockwise circulation in the upper layers of the Aegean. Figure 2.5 shows the temperature distribution at 200 meters in the Mediterranean Sea.

The Surface circulation in the Aegean Sea was studied by means of the STD records and is dealt with in another section.

x x x x x

The most interesting feature in the two sections across the Atlantic is the subsurface outflow from the Mediterranean. Figure 2.6 is the temperature section between Bermuda and Gibraltar on the eastward crossing in December and early January. Figures 2.7, 2.8 and 2.9 depict the temperature, salinity and sigma-t distribution from Gibraltar to the southernmost station on the westward crossing during the end of May and early June. The salinities on this leg were titrated aboard ship.

None of these sections indicates an outflow from the Straits of Gibraltar along the bottom. Instead, the bubbles, of what appears to be Mediterranean water, are found some distance off shore. This situation might arise if the subsurface outflow follows the northern side of the Straits and deflects to the south only after passing Cape St. Vincent.

Figure 2.10 shows the T-S correlation for a number of the stations across the Atlantic. The surface layer of water, to a depth of 500 to 600 meters, is central Atlantic water. Below that depth the Mediterranean influence is strongly indicated, with maximum salinities occurring at depths between 1100 and 1200 meters on the eastern stations. The depth of this point increases in a westerly direction while its salinity decreases, until the whole water column attains the characteristics of Central Atlantic water at about 40° west longitude. It is noteworthy that whereas Mediterranean water has a minimum temperature of about 13°C, the temperature at the deep salinity maximum in the Atlantic is approximately 10°C nearest the Straits, decreasing to the westward. As the salinity at this point is also considerably lower than in the Mediterranean, it can be concluded that the Mediterranean water is mixed with Atlantic water in transiting the Straits, with this process continuing at a slower rate in the Atlantic.

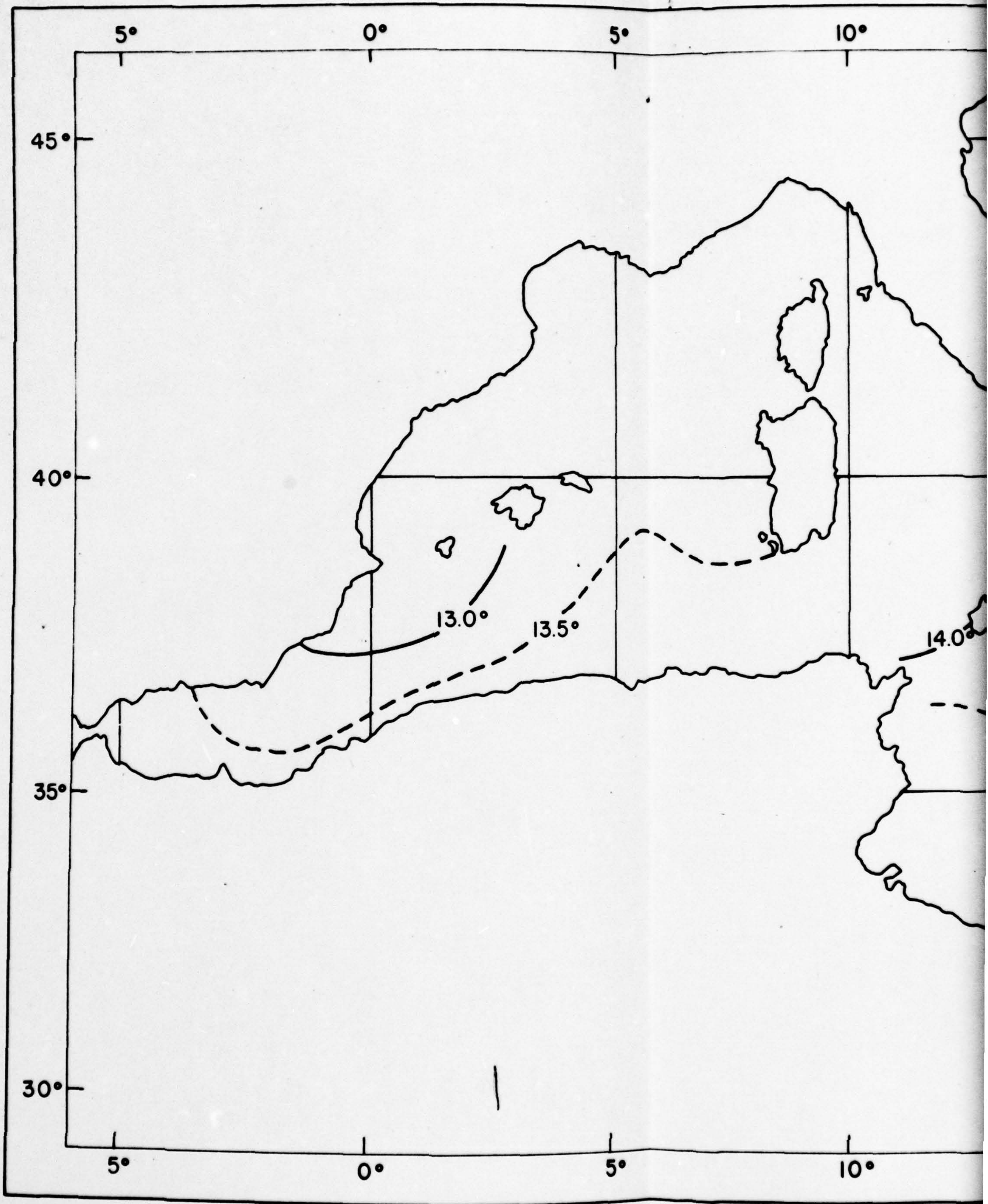
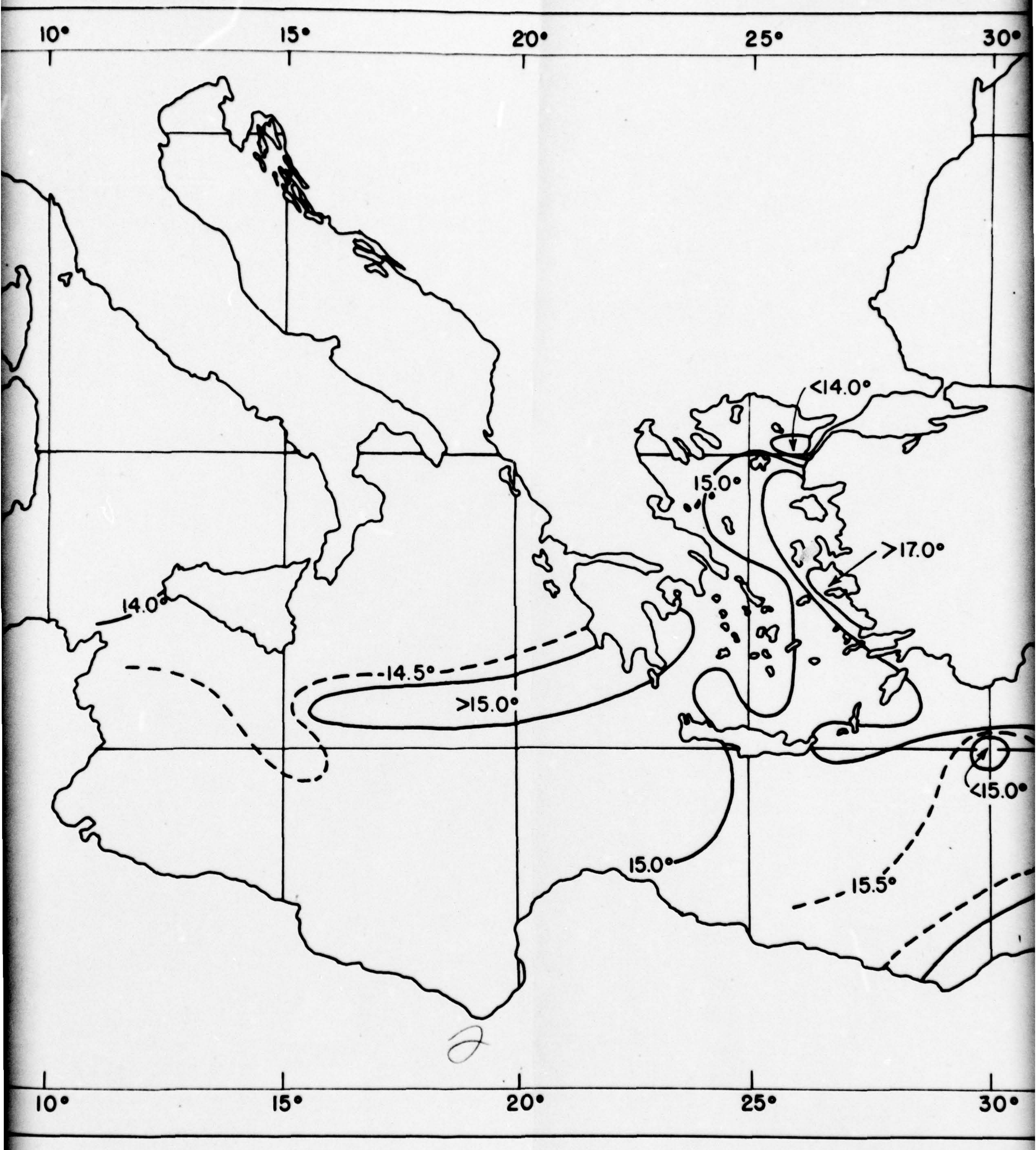
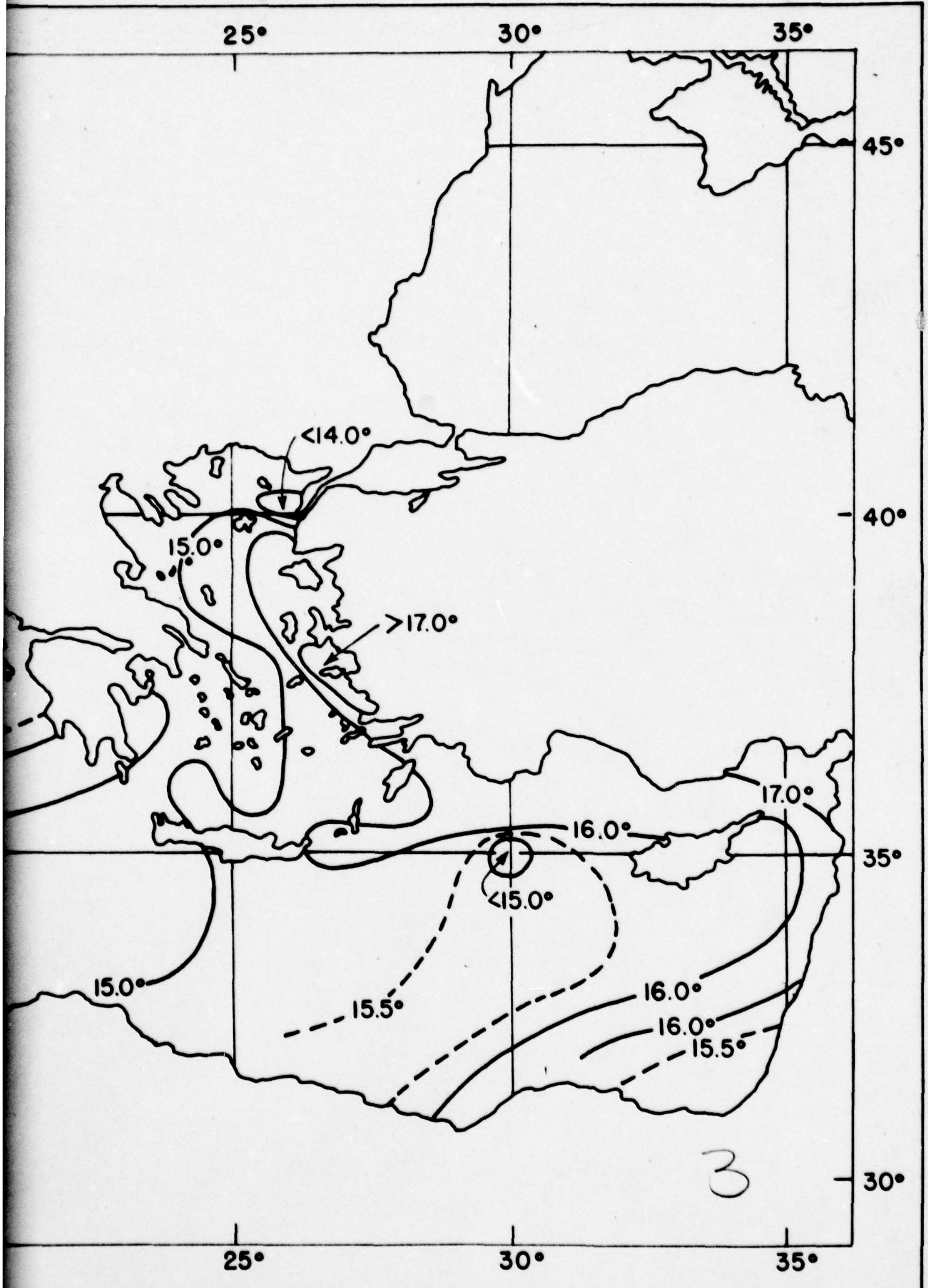


FIGURE 2.5 TEMPERATUR



PERATURE °C AT 200 METERS.



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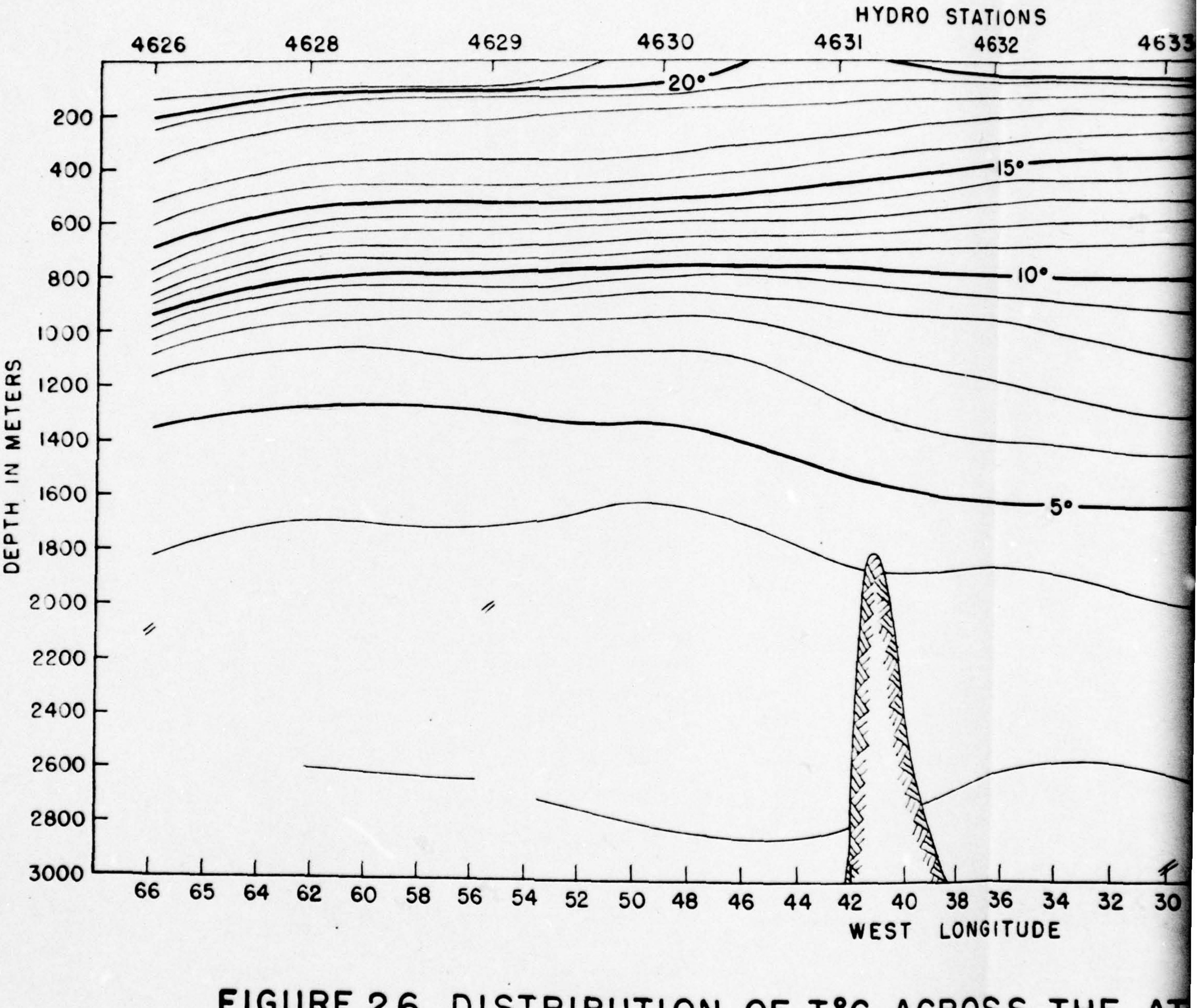
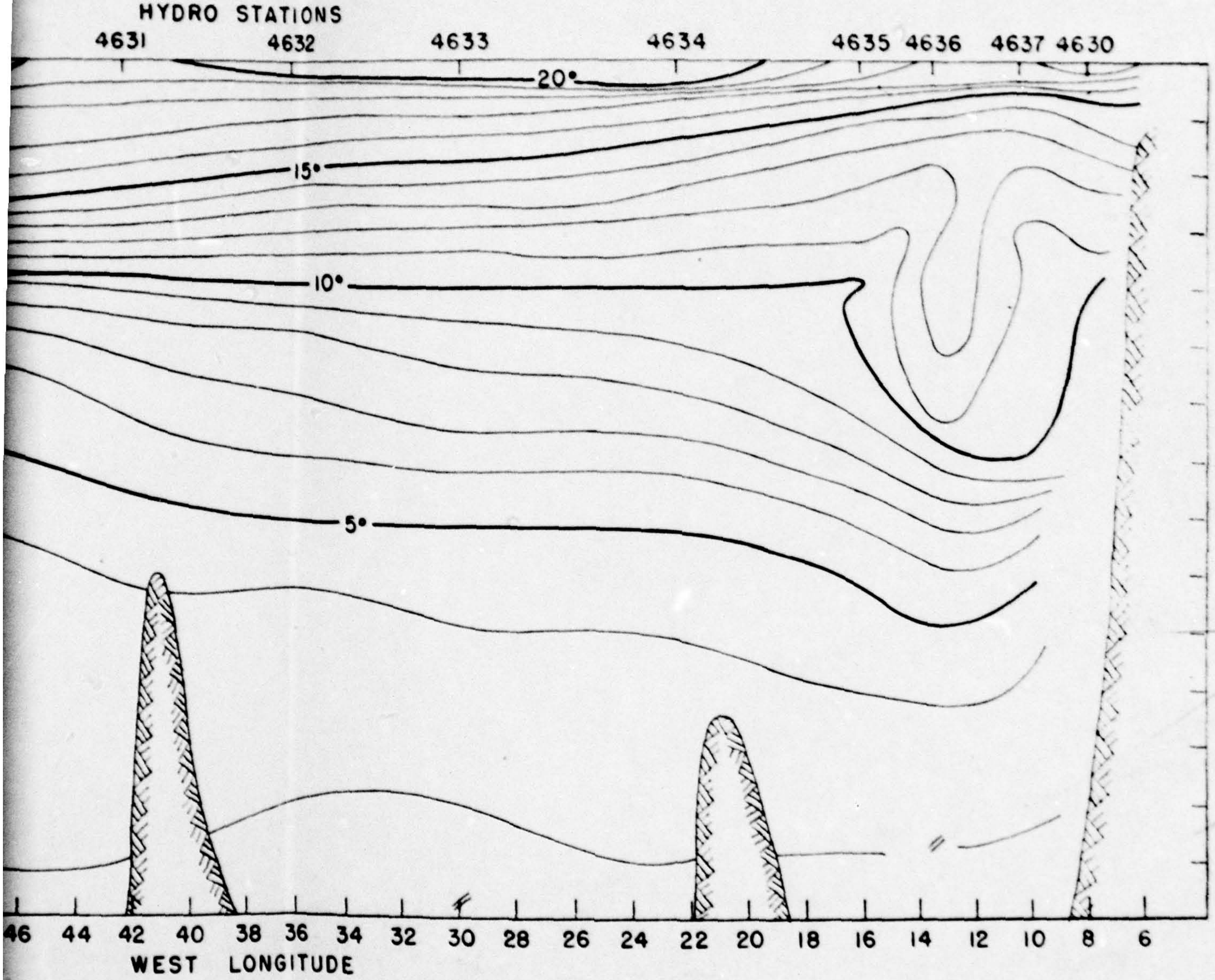


FIGURE 2.6 DISTRIBUTION OF T°C ACROSS THE AT
DEC., 1947 TO JAN., 1948.



OF T°C ACROSS THE ATLANTIC OCEAN.
JAN., 1948.

2

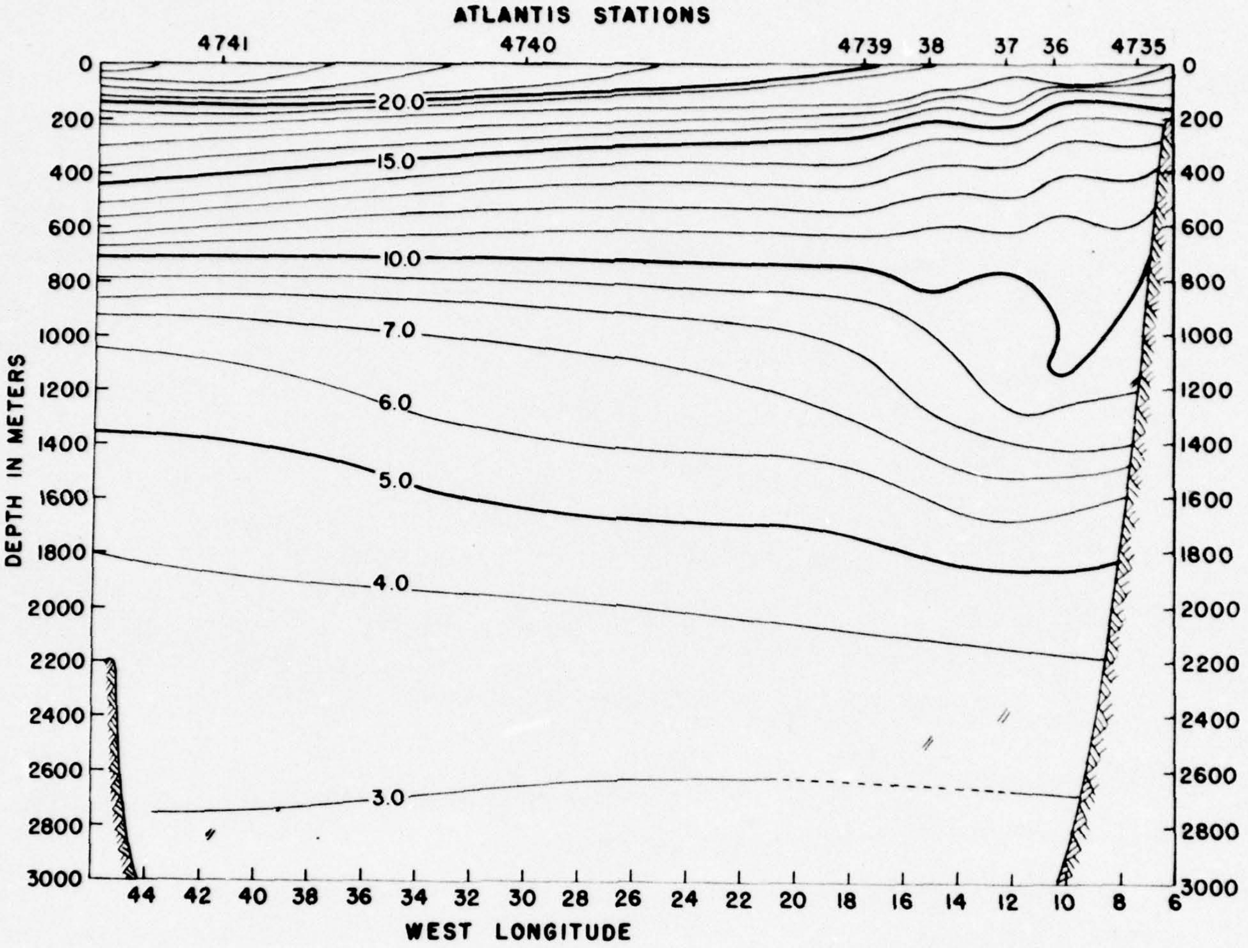


FIGURE 2.7 DISTRIBUTION OF T°C
ACROSS THE ATLANTIC OCEAN.
MAY AND JUNE, 1948.

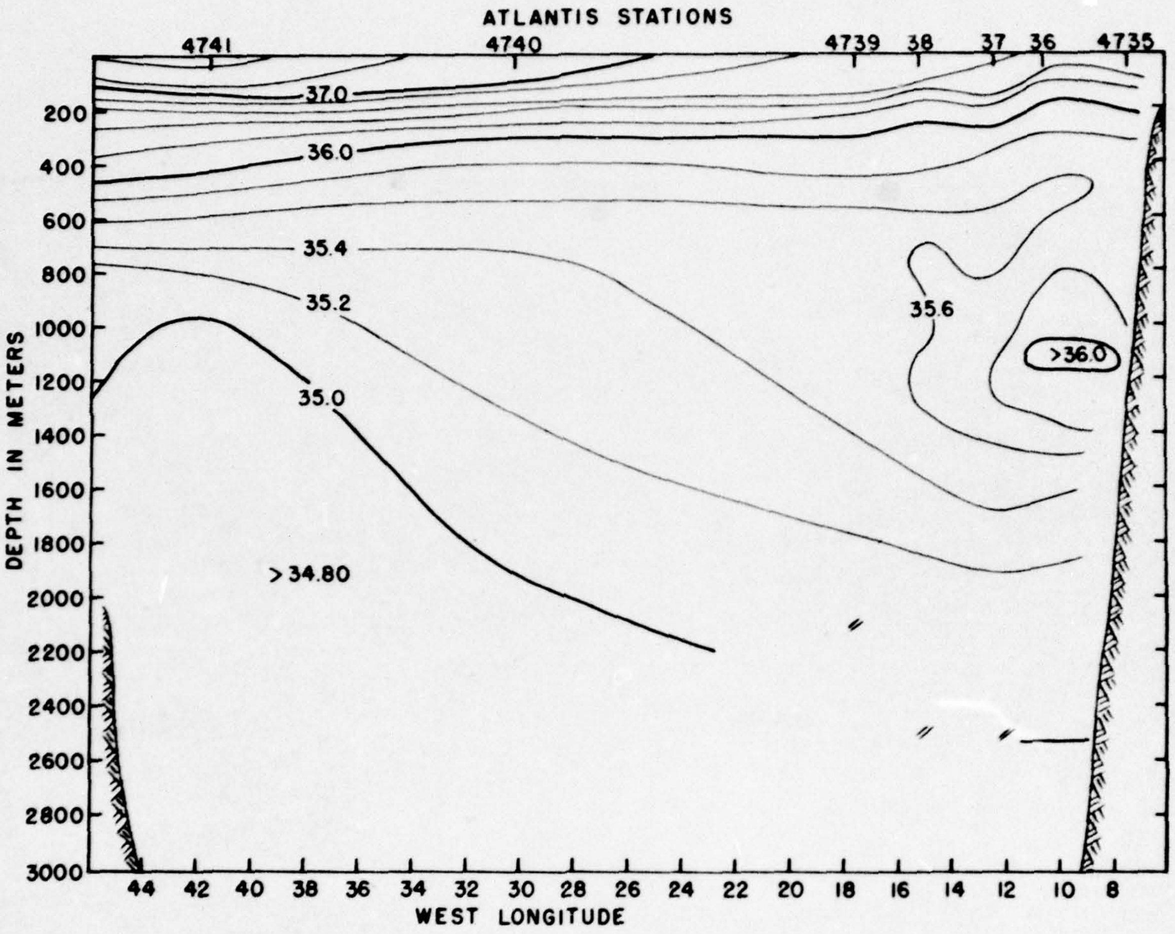


FIGURE 2.8 DISTRIBUTION OF S‰ ACROSS THE ATLANTIC OCEAN. MAY AND JUNE, 1948.

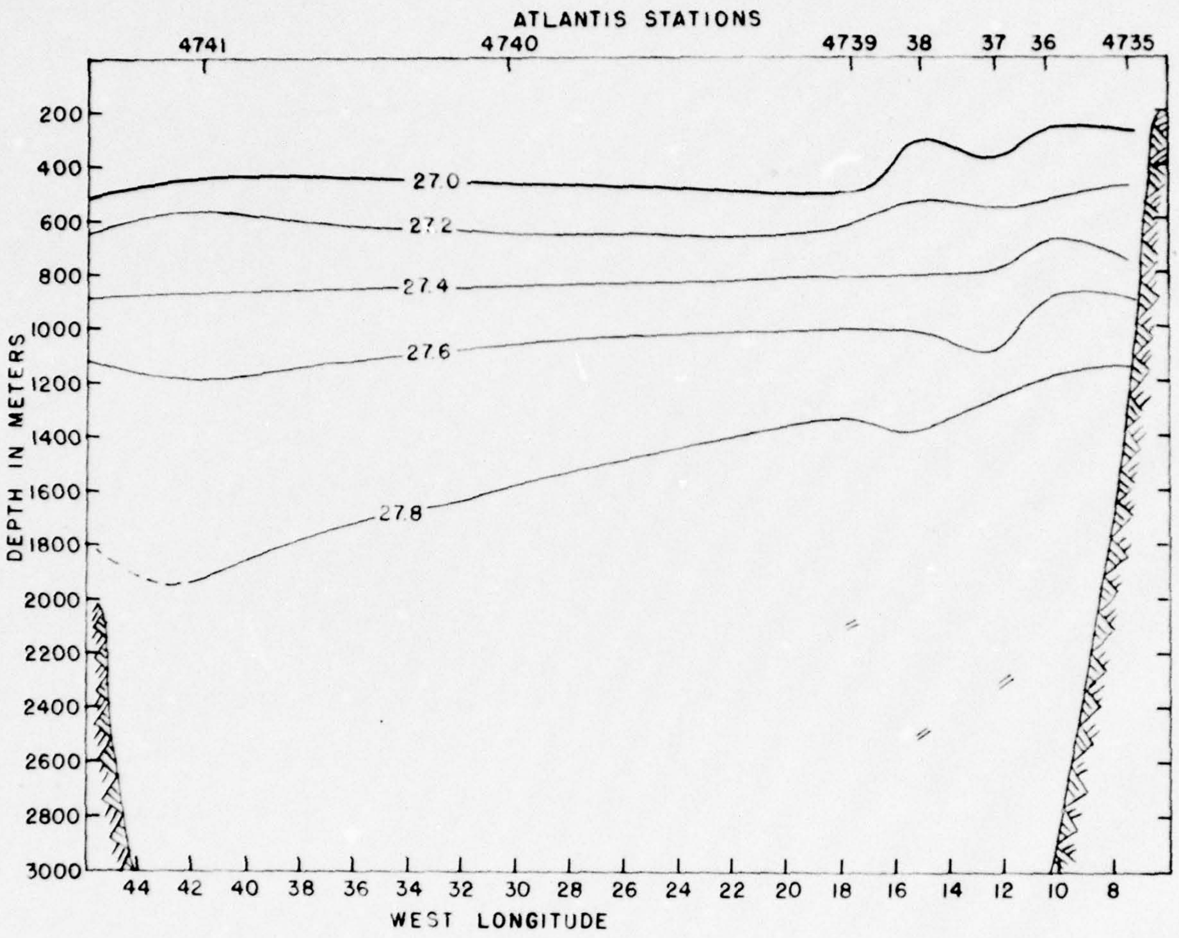
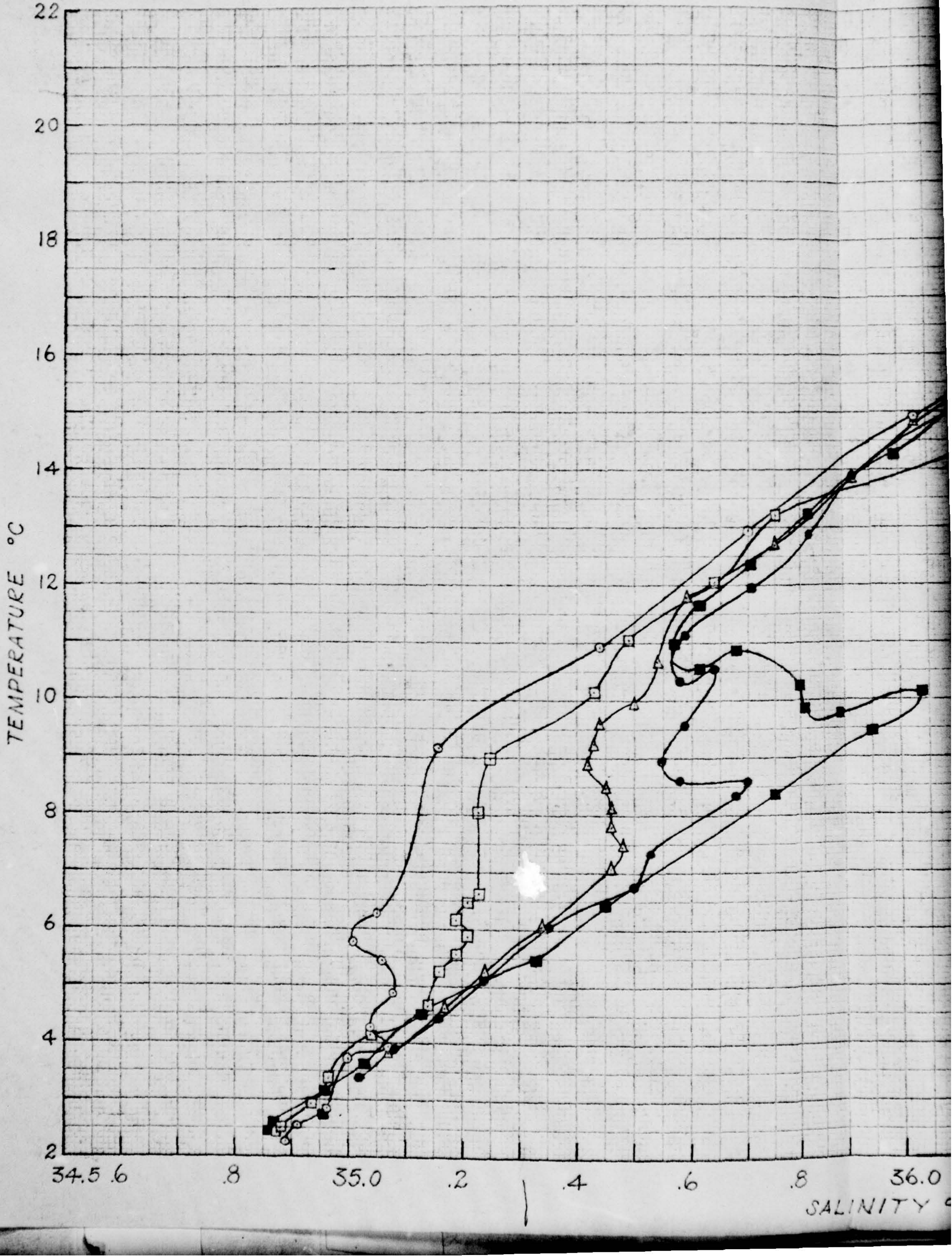


FIGURE 2.9 DISTRIBUTION OF σ_t ACROSS THE ATLANTIC OCEAN. MAY AND JUNE, 1948.


22
20
18
16
14
12
10
8
6
4
2
TEMPERATURE °C
34.5
.6
.8
35.0
.2
.4
.6
.8
36.0
SALINITY

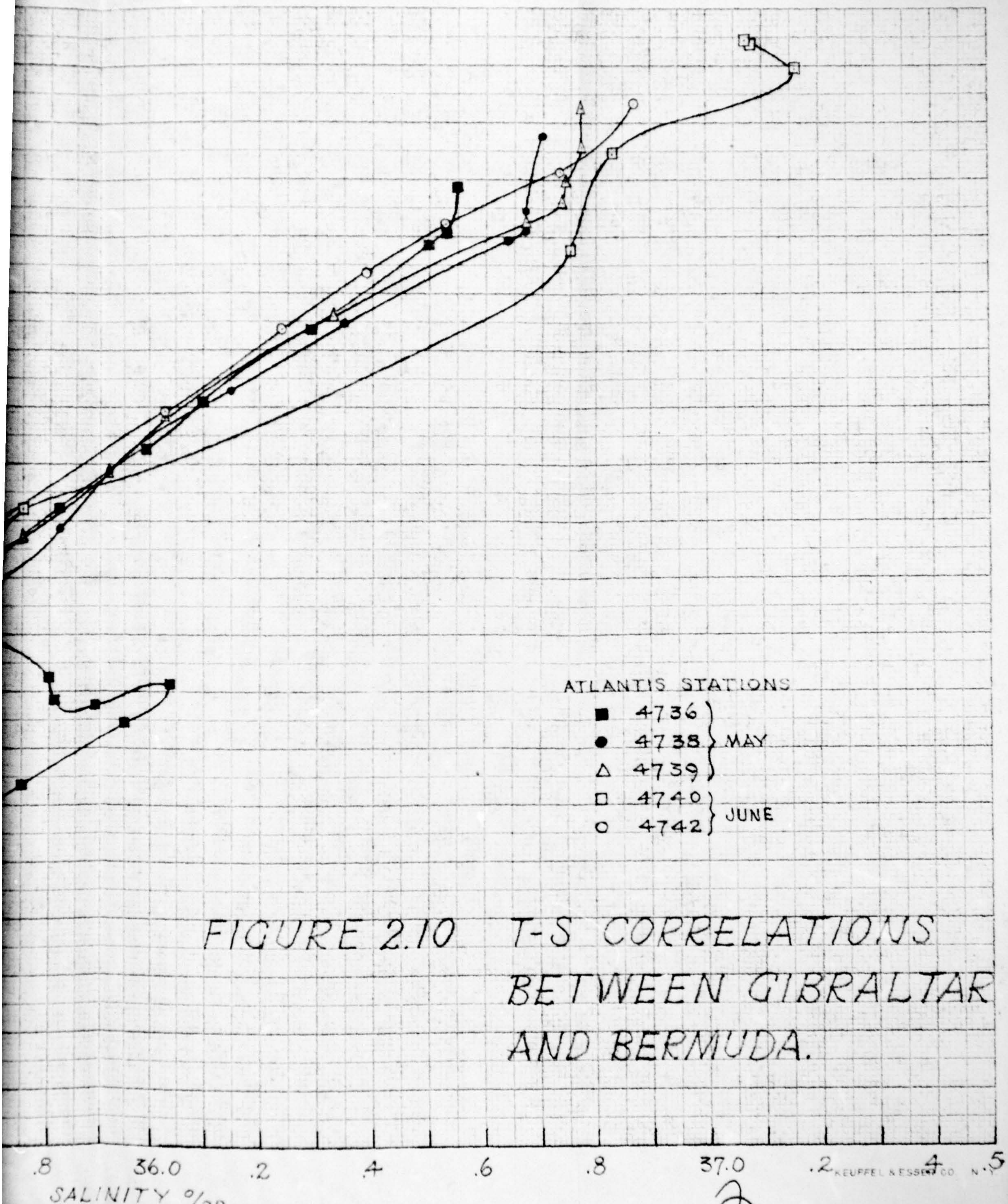


FIGURE 2.10 T-S CORRELATIONS BETWEEN GIBRALTAR AND BERMUDA.

3. Surface Circulation in the Aegean Sea

by

L. V. Worthington

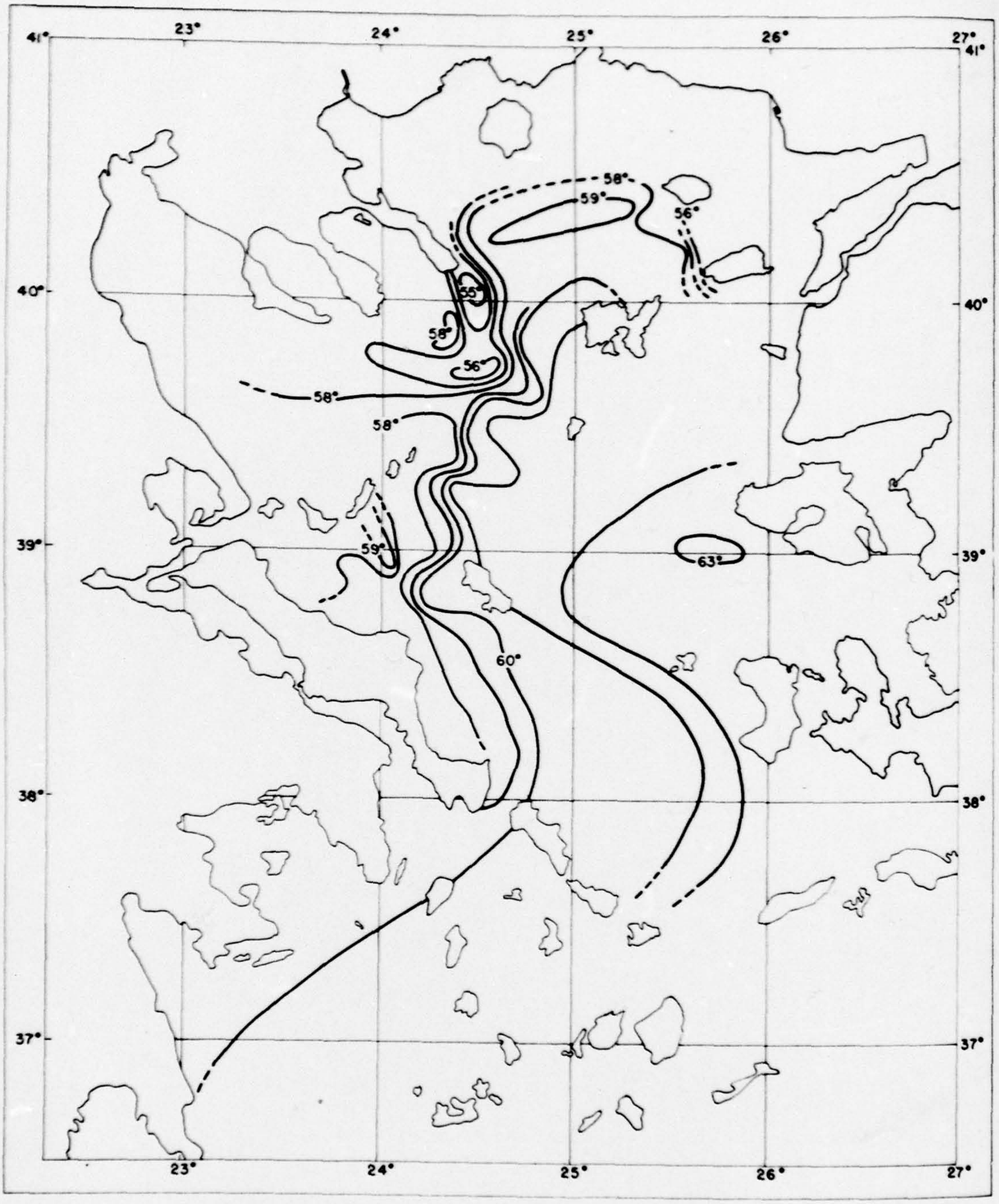
The salinity-temperature-depth recorder was run continuously throughout the cruise. The most interesting results were obtained in the Aegean Sea where the largest horizontal salinity gradients of the whole cruise were found.

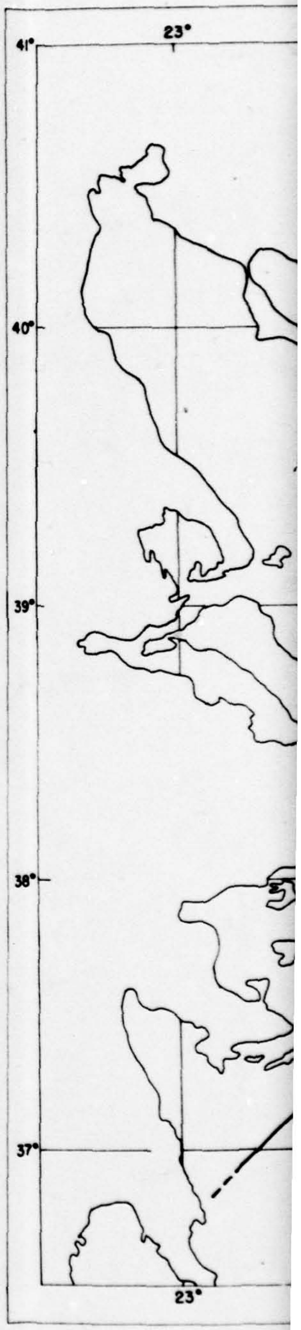
As the cell was permanently mounted forward on the port side of the ATLANTIS, 8 feet below the load water line, the depth recording was not utilized. Temperatures and salinities were compared with those obtained from a 1 meter depth at hydrographic stations. Under isothermal conditions the temperatures agreed within 0.1°F, while the salinities were 1 °/oo low. All salinity values referred to hereafter have been corrected accordingly.

The first Aegean cruise (Figure 3.1) provides the key to the circulation of the Aegean Sea. Mediterranean water with a temperature of 62-63°F and a salinity of more than 39 °/oo is found on the Eastern side. At the Dardanelles it is joined by cold, fresher water from the Black Sea. This water flows northwesterly at first, then westerly along the northern shore of the Aegean, and is finally projected to the south by the promontory of Athos. This southerly flow seems to be in eddies rather than in a steady flow. On the western side of the Aegean the remnants of Black Sea water mingle with Mediterranean water, gradually losing their identity as they move toward the south.

In the second Aegean cruise (figure 3.2) the outflow from the Black Sea can be seen in more detail. The surface water emerging from the Dardanelles has a salinity of less than 34 °/oo and a temperature of less than 52°F. In spite of strong northeasterly winds prevailing at the time almost none of this water is carried to the south of the Dardanelles, but moves in a northwesterly direction as in the previous cruise.

The southern Aegean (Figure 3.3) was covered in late March and early April when much diurnal heating was taking place and it seemed wise to eliminate temperature peaks attributable to this cause. The very slightly fresher and colder water (less than 39 °/oo at the western end) could be an inflow from the Ionian sea, but the difference is too slight to draw a definite conclusion.





TEMPERATURE °F AT 8' 27 JAN. TO 17 FEB., 1948.

FIGURE 3.1

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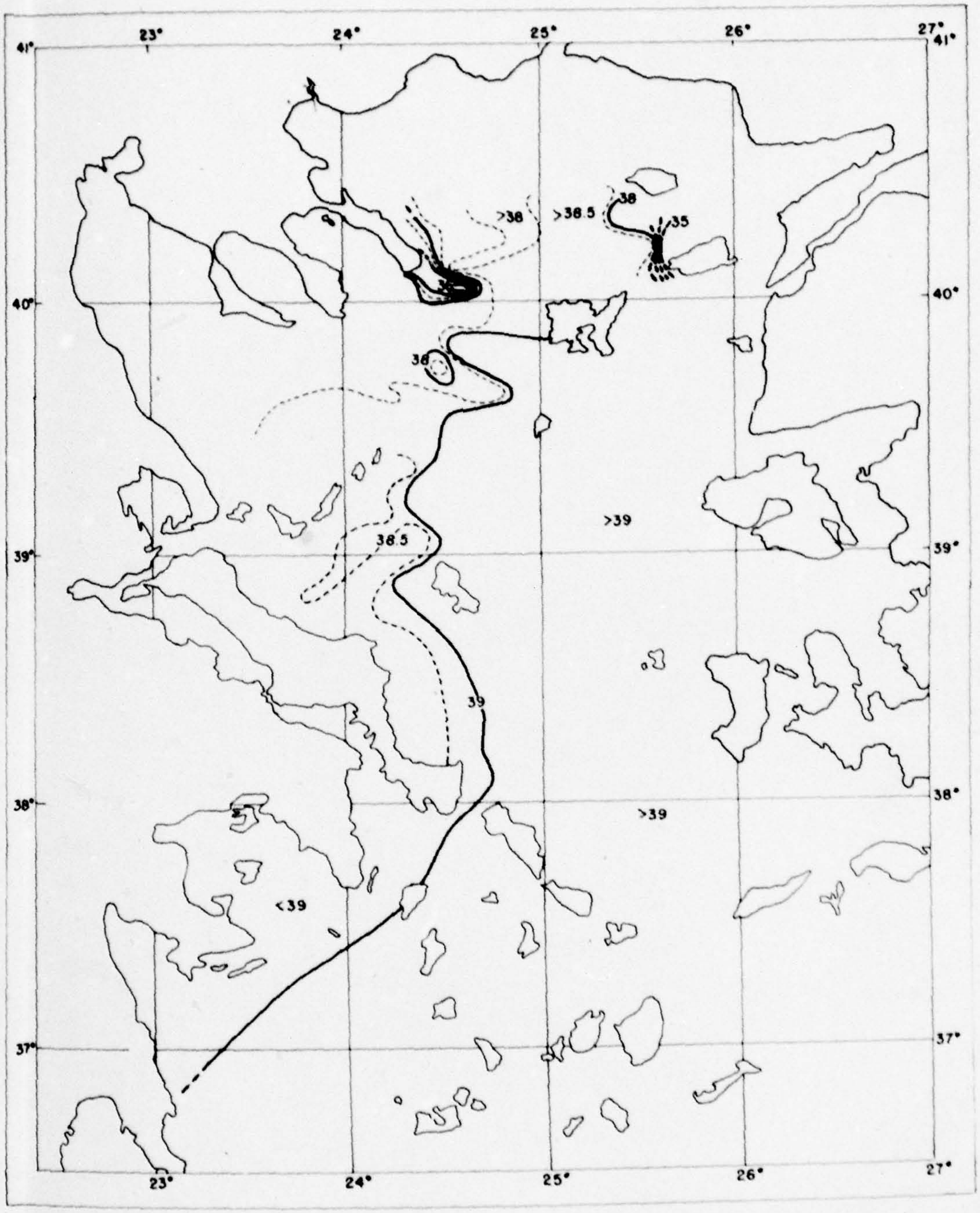


SALINITY ‰ AT 8' 27 JAN. TO 17 FEB. 1948

FIGURE 3.1

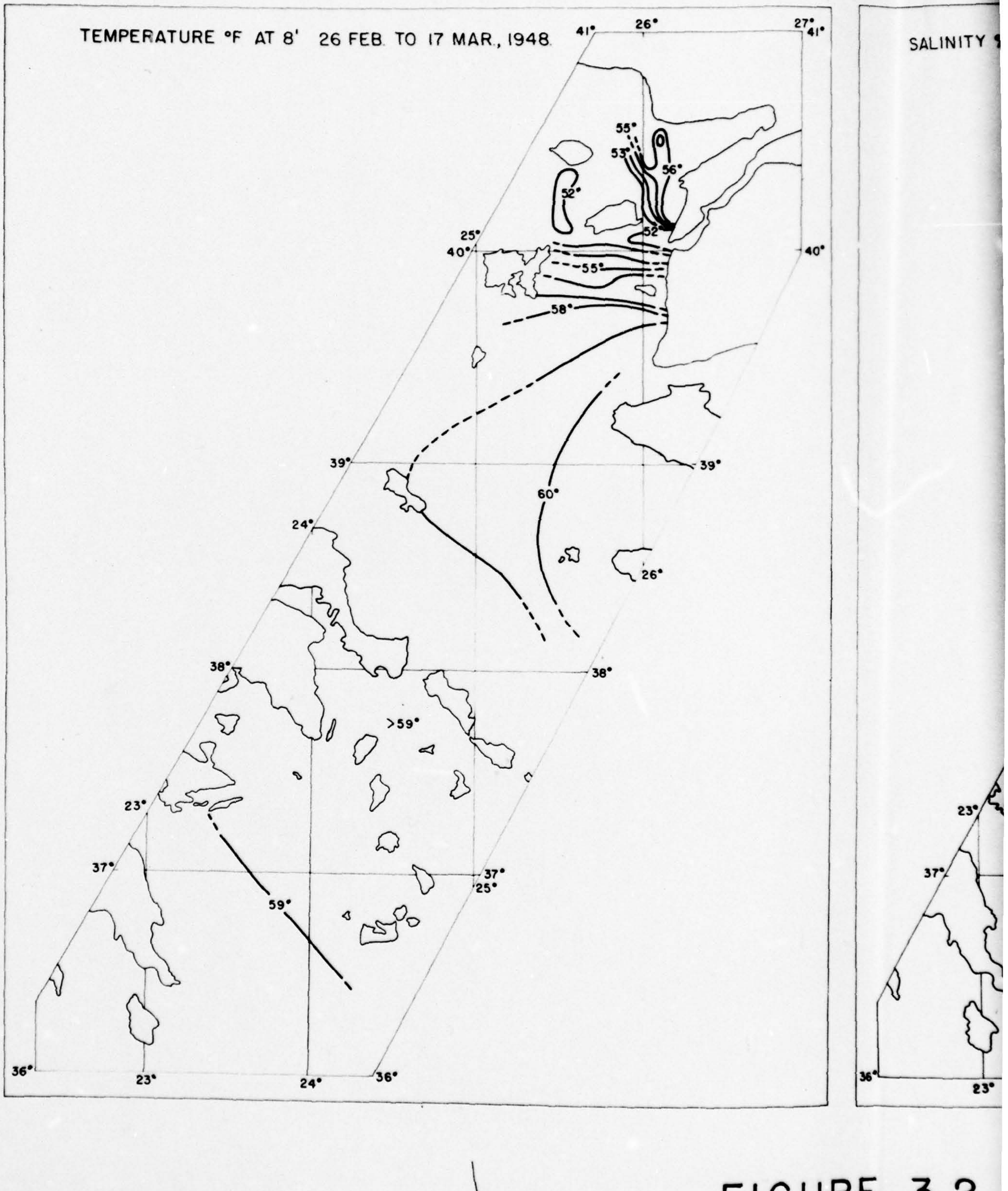
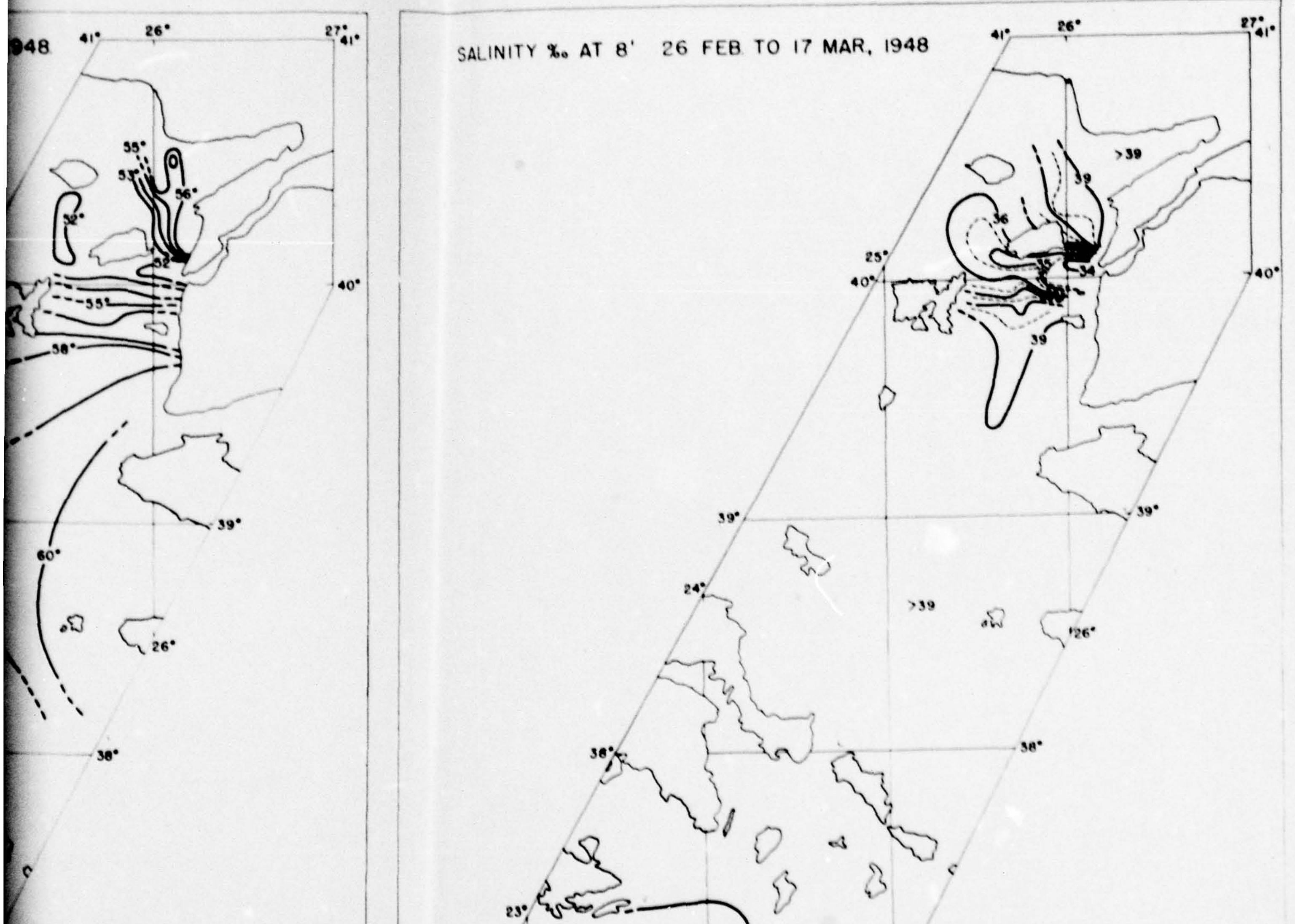

TEMPERATURE °F AT 8' 26 FEB. TO 17 MAR., 1948
41°
26°
27°
41°
55°
53°
56°
52°
52°
25°
40°
40°
55°
58°
39°
39°
60°
24°
26°
38°
38°
>59°
23°
37°
37°
25°
59°
36°
23°
24°
36°
SALINITY
23°
37°
36°
23°

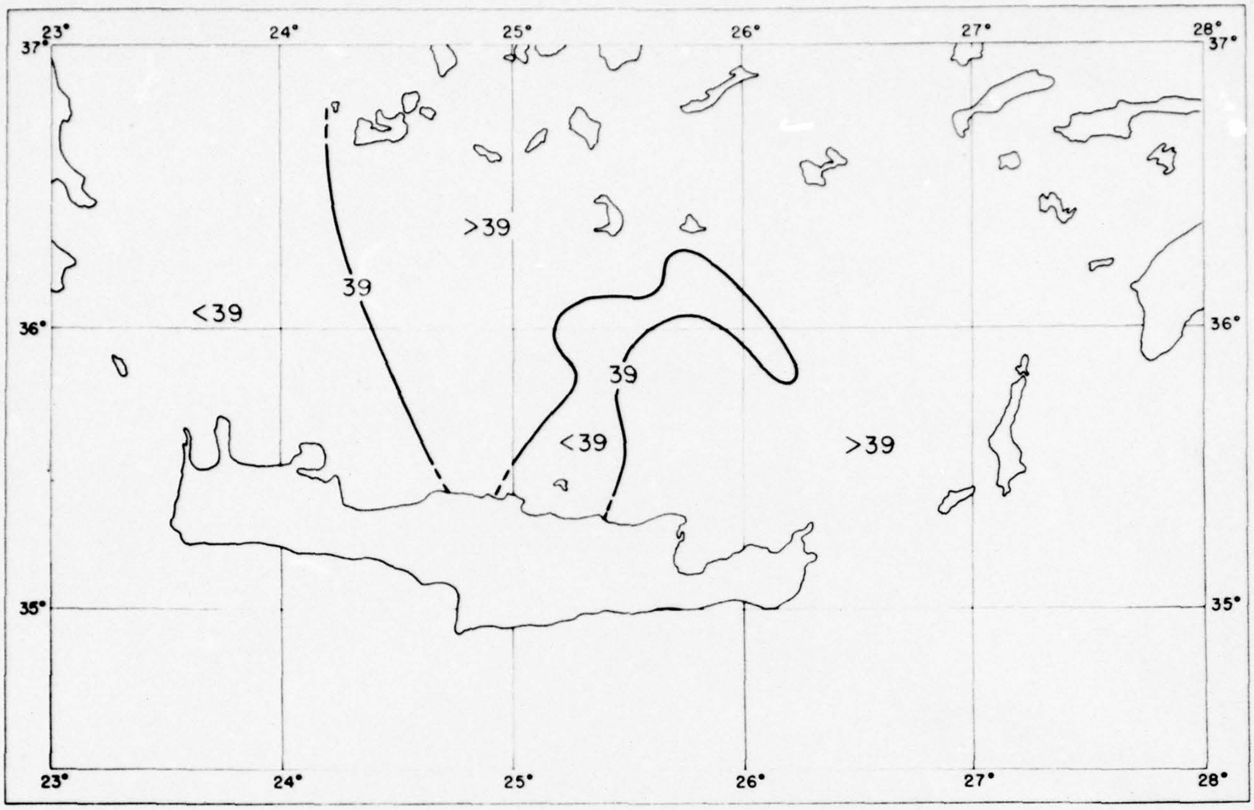
FIGURE 3.2



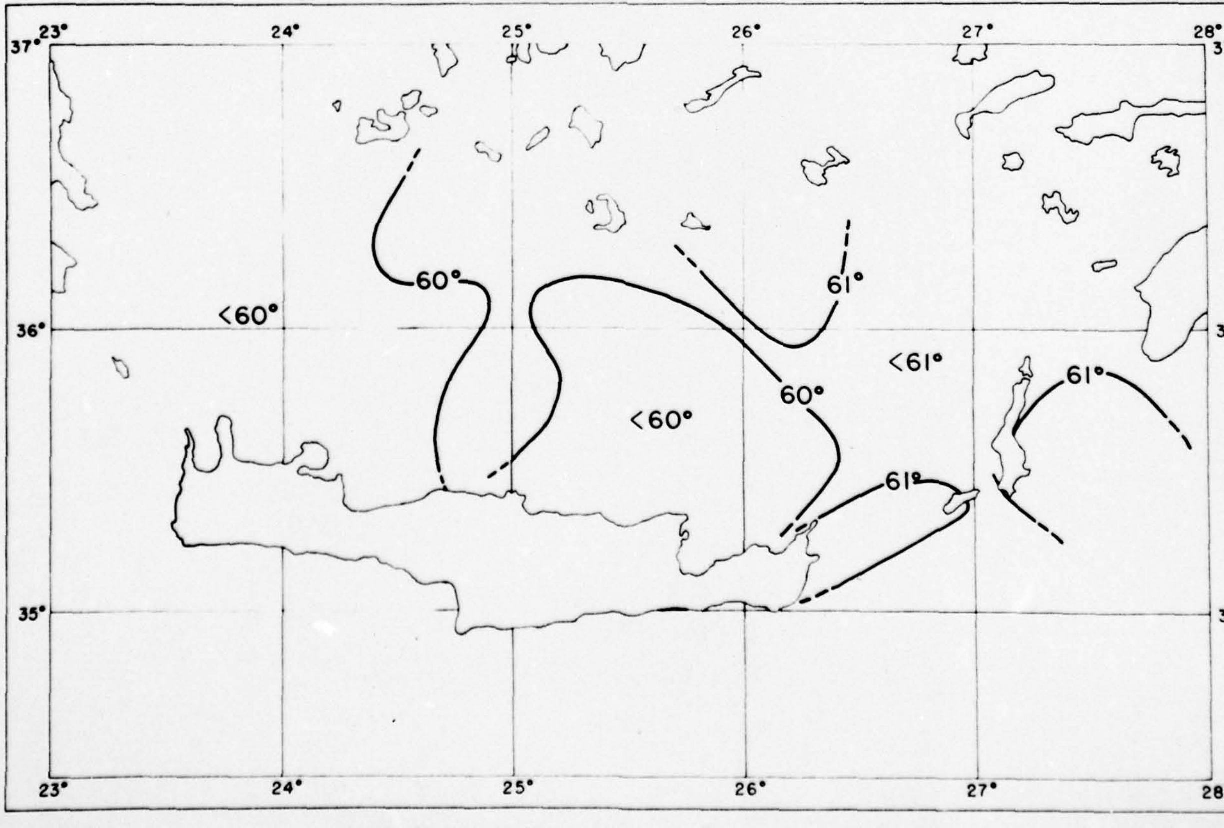
SALINITY ‰ AT 8' 26 FEB. TO 17 MAR, 1948

FIGURE 3.2

2



SALINITY ‰ AT 8' 23 MAR. TO 4 APR., 1948



TEMPERATURE °F AT 8' 23 MAR. TO 4 APR., 1948.

FIGURE 3.3

4. Distribution of Dissolved Oxygen and Plant Pigments

by

D. F. Bumpus

Analyses for dissolved oxygen according to the **Winkler** method were undertaken at nearly all of the hydrographic stations occupied during the cruise.

In the Mediterranean Sea the surface layer to 100 meters is nearly saturated with oxygen at values of 5.0 to 5.5 ml/L. Below it the values decrease to a minimum of less than 4.0 ml/L in the eastern basin and less than 4.3 ml/L in the western basin coinciding with the temperature minimum. Beyond this depth there is a slight increase of not over 0.3 ml/L. The decline to the minimum is gradual in the eastern Mediterranean but rather sharp in the western Mediterranean, where concentrations of 4.3 ml/L are reached at 300 meters. These features are depicted in Figure 4.1, an east-west profile of oxygen distribution in the Mediterranean in spring. No attempt has been made as yet to determine the percentage saturation of the oxygen in the sea water at its incident temperature and salinity.

In the Aegean Sea, where surface oxygen values vary from 5.1 to 5.5 ml/L, the concentration decreases to 5.0 ml/L at depths between 400 and 700 meters. A further slight decrease takes place below this point, with the lowest value observed being 4.65 ml/L at 1200 meters. Superimposed upon this scheme is the more highly oxygenated water coming out of the Dardanelles. The stations in the flow of this watr exhibit concentrations of slightly over 6.0 ml/L in the surface layer, below which the values decrease to those characteristic of the region. This Dardanelles influence, which is traceable to a depth of about 400 meters at some distance from the outflow, confirms the premises of the movement of that water deduced from the temperature and salinity distribution.

During the winter crossing of the Atlantic Ocean surface values for oxygen were slightly less than 5.0 ml/L, rising to slightly greater than 5.0 ml/L at the approaches to the Straits of Gibraltar. During the May-June crossing the surface values were greater than 5.5 ml/L near the Straits diminishing to less than 5.2 ml/L in a westerly direction. Below the surface the concentrations decrease to an oxygen minimum layer of less than 4.0 ml/L, centered on 800 meters, after which they again increase, attaining values greater than 5.5 ml/L below 1600 meters. The concentration in the minimum layer decreases in a westerly direction from less than 3.7 ml/L near the eastern side of the ocean to less than 3.0 ml/L just east of the Gulf Stream. Figure 4.2 shows the oxygen distribution for the winter section running from north of the Gulf Stream to southeast of Bermuda and then west to Gibraltar.

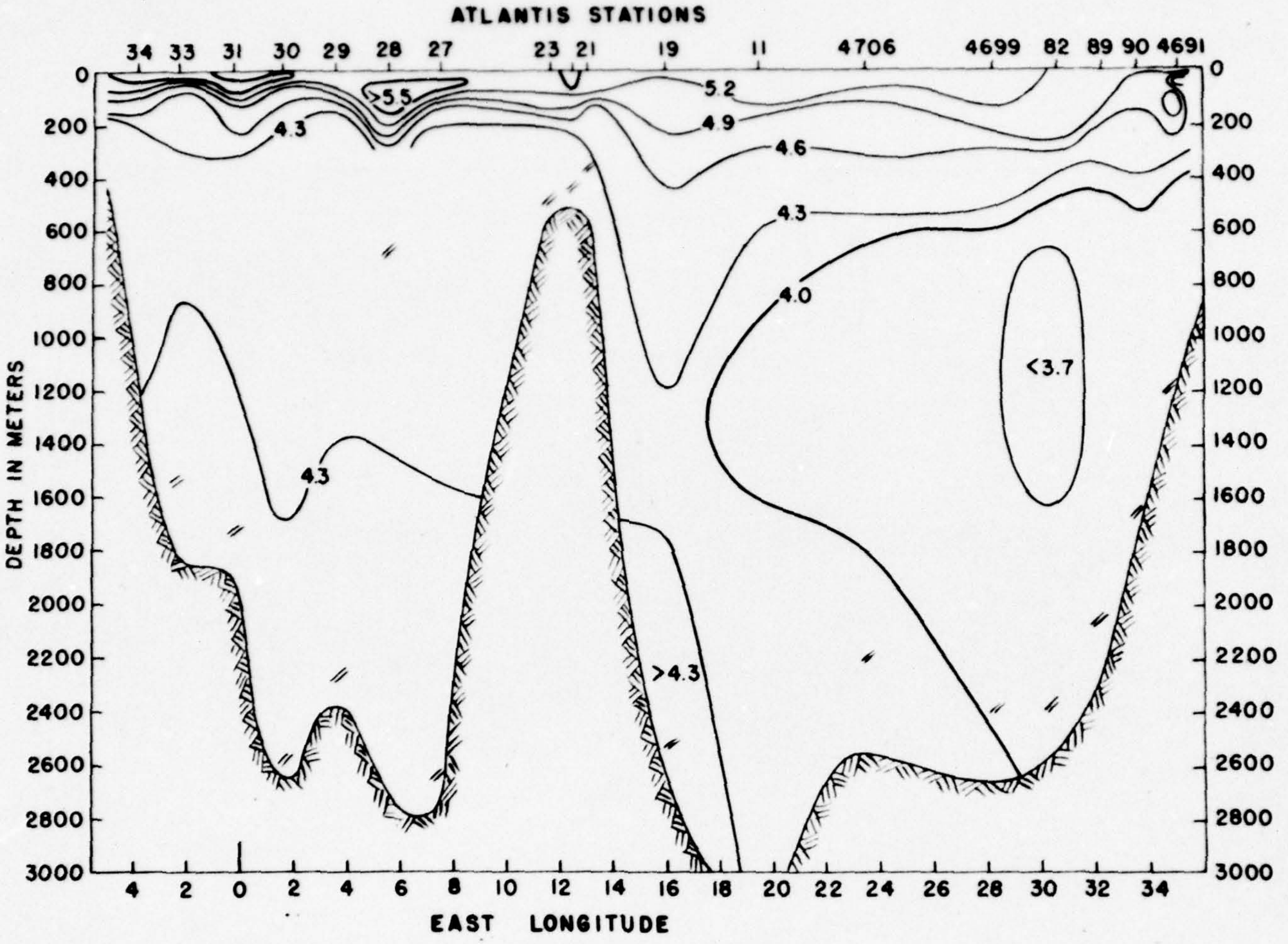


FIGURE 4.1 DISTRIBUTION OF OXYGEN (ml/L) ACROSS THE MEDITERRANEAN. APRIL AND MAY, 1948.

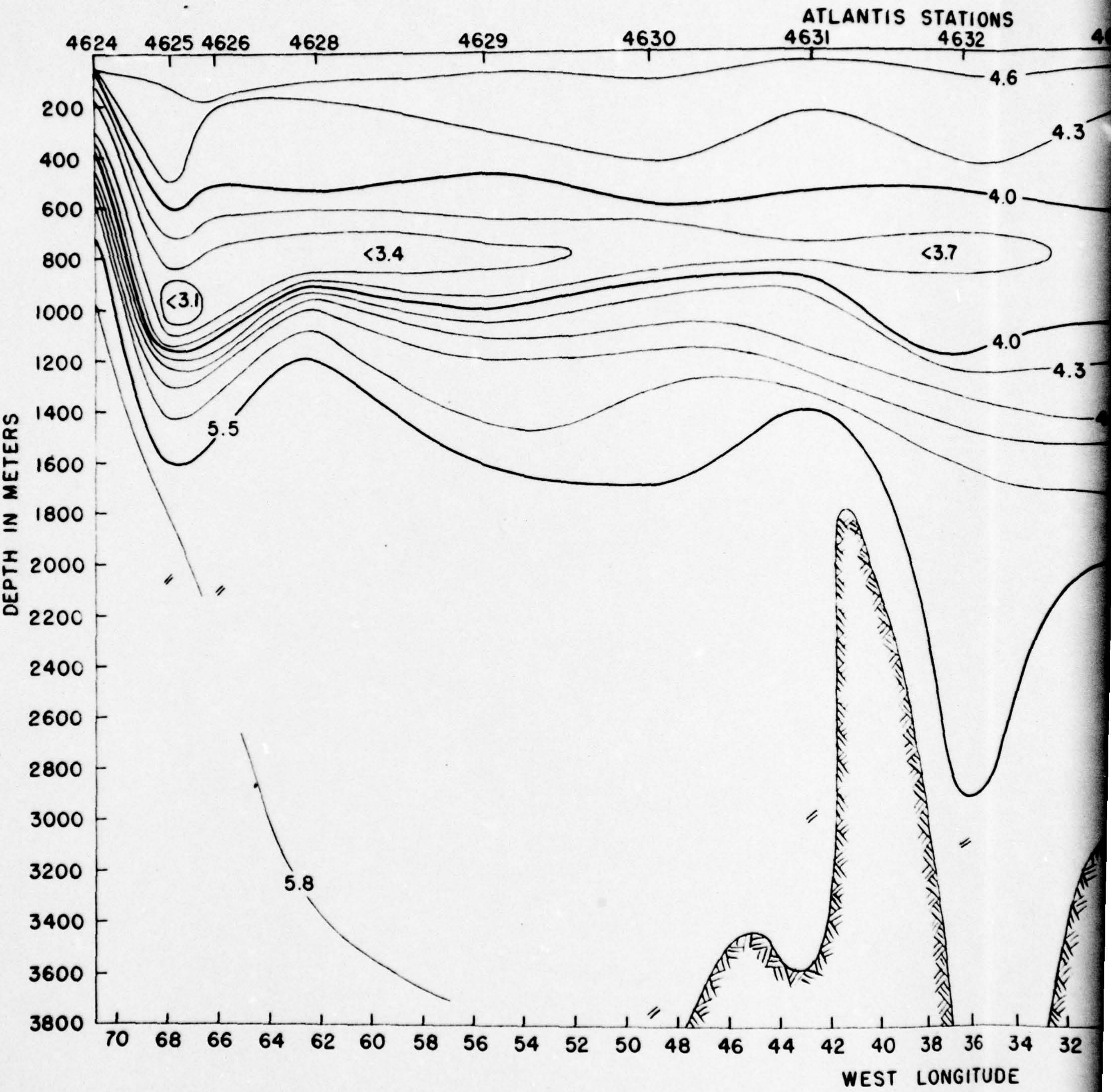
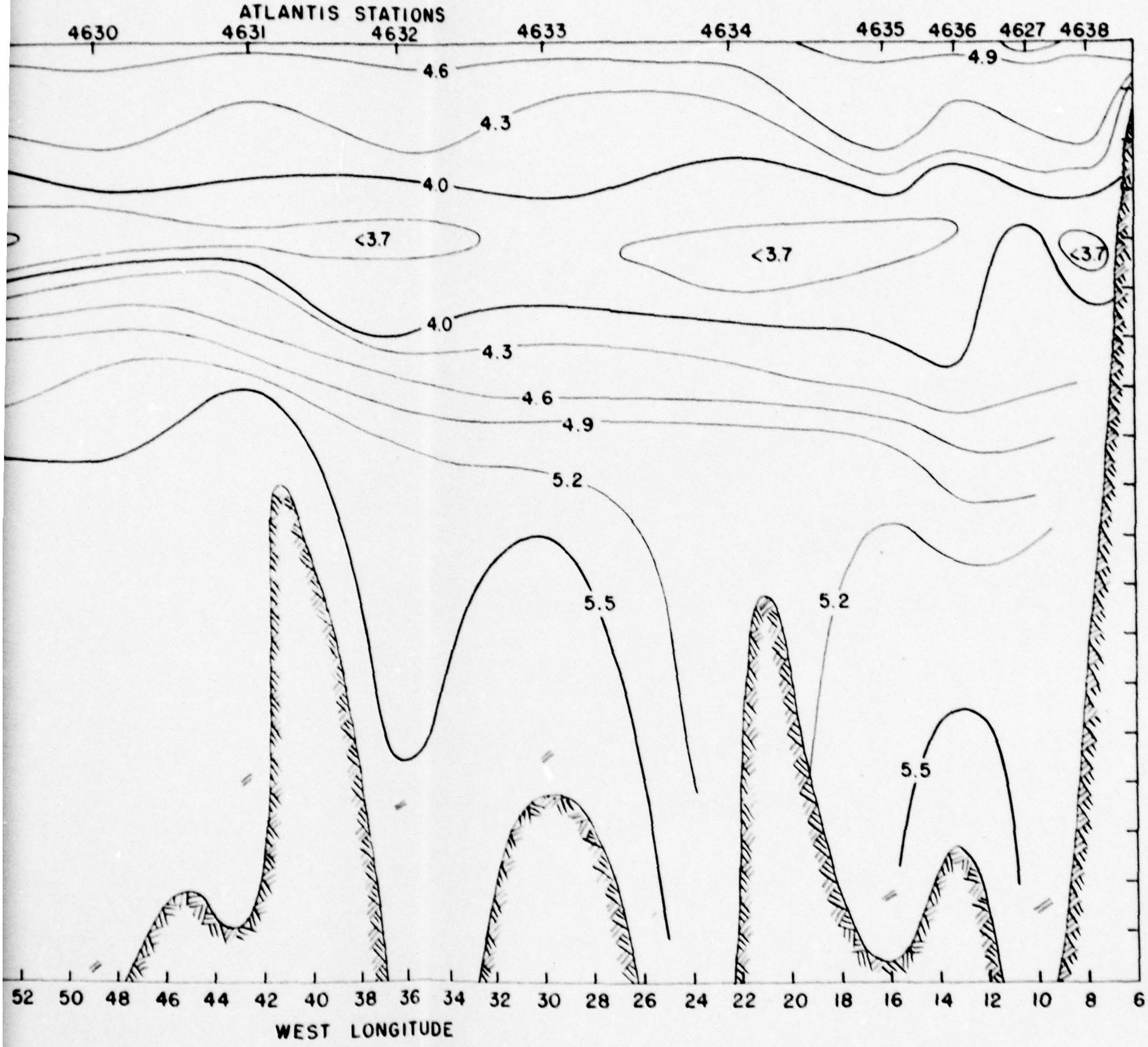


FIGURE 4.2 DISTRIBUTION OF OXYGEN (*ml*/L) AC
11 DECEMBER 1947 TO 5 JAN



BUTION OF OXYGEN (mℓ/L) ACROSS THE ATLANTIC OCEAN
11 DECEMBER 1947 TO 5 JANUARY 1948

2

x x x x

Analyses for plant pigments were made to depths of 200 meters at a majority of the hydrographic stations using the method of Harvey with one modification; in place of the colorimeter an electric eye photoelectric colorimeter with lavender filters (Corning 5113, 2mm thick) was used. A calibration curve was drawn based on a comparison between various concentrations of the potassium chromate-nickel sulphate standard against distilled water (Figure 4.3). Then 1, 2, 3 and 4 liters of the same sea **water** were filtered all yielding the same concentration per liter when analyzed. Since the weak solutions of plant pigments in acetone are a faint yellow in color, the lavender filter proved to be the most satisfactory one. Red filters (Corning 2408, 4mm thick) were much less sensitive to various concentrations of the standard.

The concentrations of plant pigments throughout the course of the cruise were exceedingly low. Figure 4.4 shows the average concentrations in Harvey Units per Liter for the upper 200 meters in the Mediterranean and Aegean Seas. There was either no vertical structure or only a slight negative gradient in this layer. The lowest values, as low as 0.3 HU/L, occurred in the central eastern Mediterranean during April, with maximum values for that month approaching 1.0 HU/L. In January concentrations between 1 and 2 HU/L occurred. The Aegean exhibited values averaging 1.0 HU/L from January to April with generally higher concentrations on the western side. The western Mediterranean, especially the Alboran Sea, produced the highest concentrations, averaging 2.4 HU/L in January while during May the values were only one-third that figure. There appears to be no correlation between the concentration of PO4-P and plant pigments.

The Atlantic also yielded low concentrations. The average for 11 stations during the winter crossing was 1.9 HU/L ranging from 1.0 to 3.1. The values for five stations of the late spring crossing were much lower, averaging 0.5 HU/L over a range from 0.3 to 0.7 HU/L.

FIGURE 4.3 CALIBRATION CURVE FOR PLANT PIGMENT ANALYSIS.

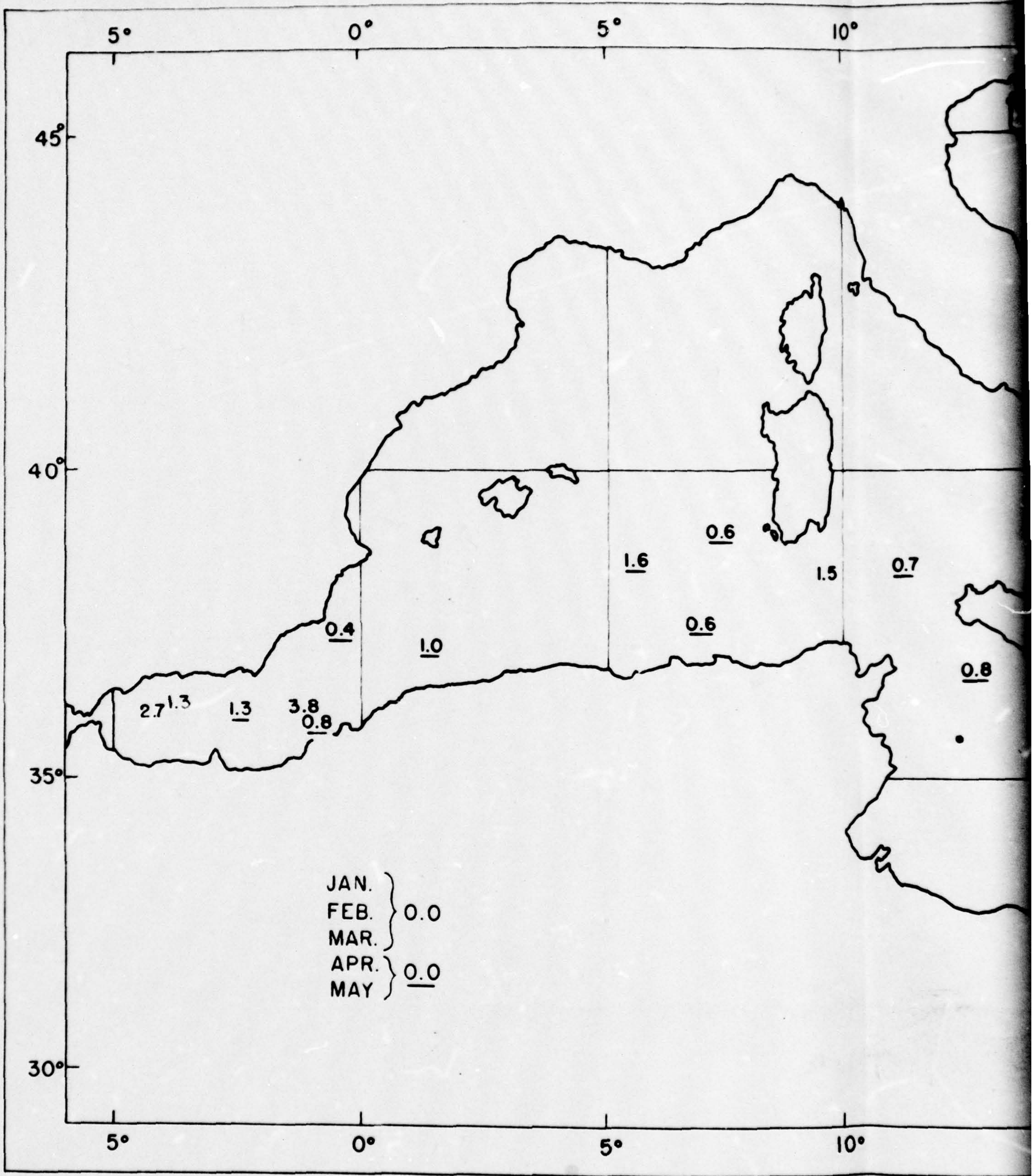
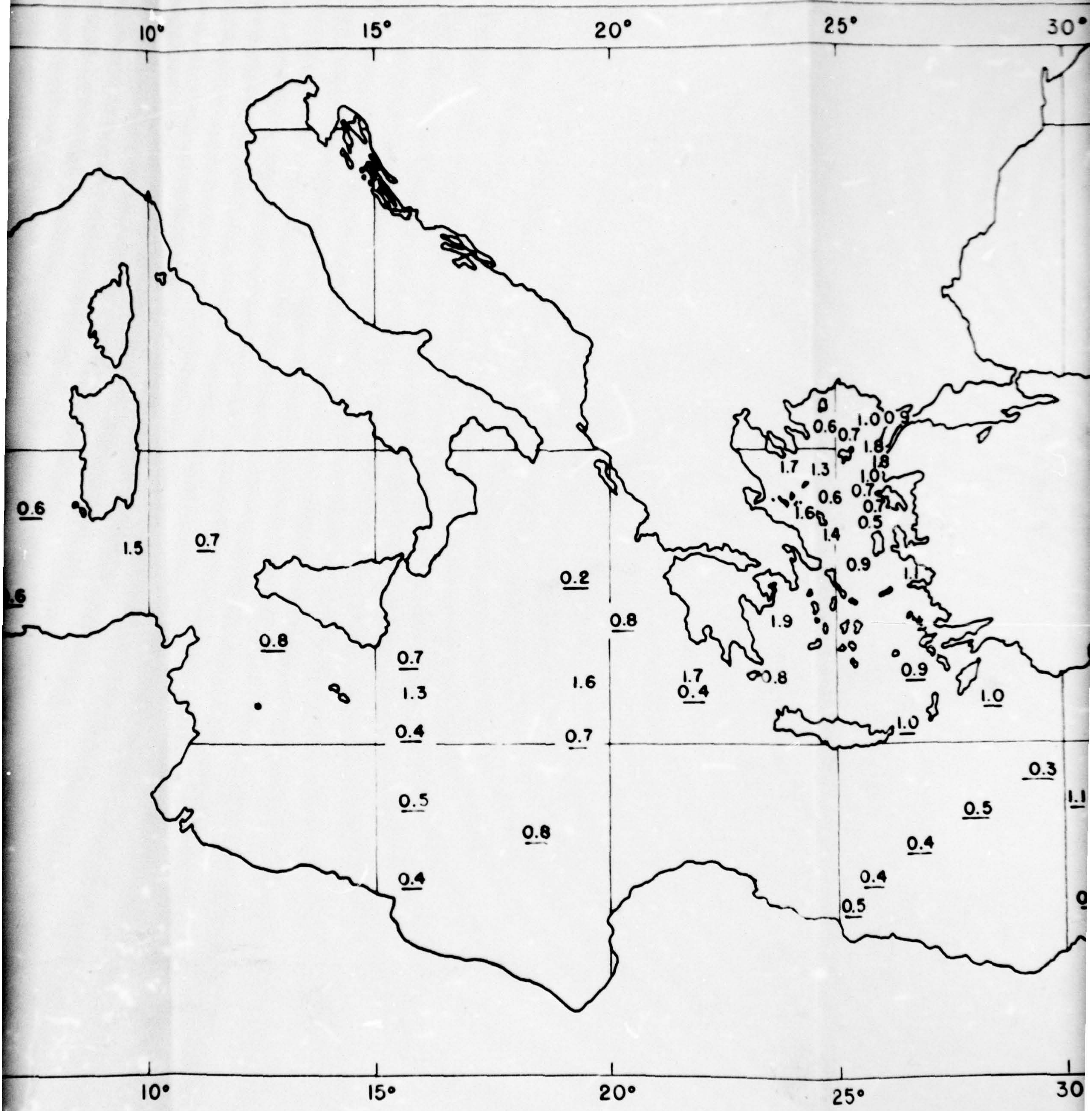
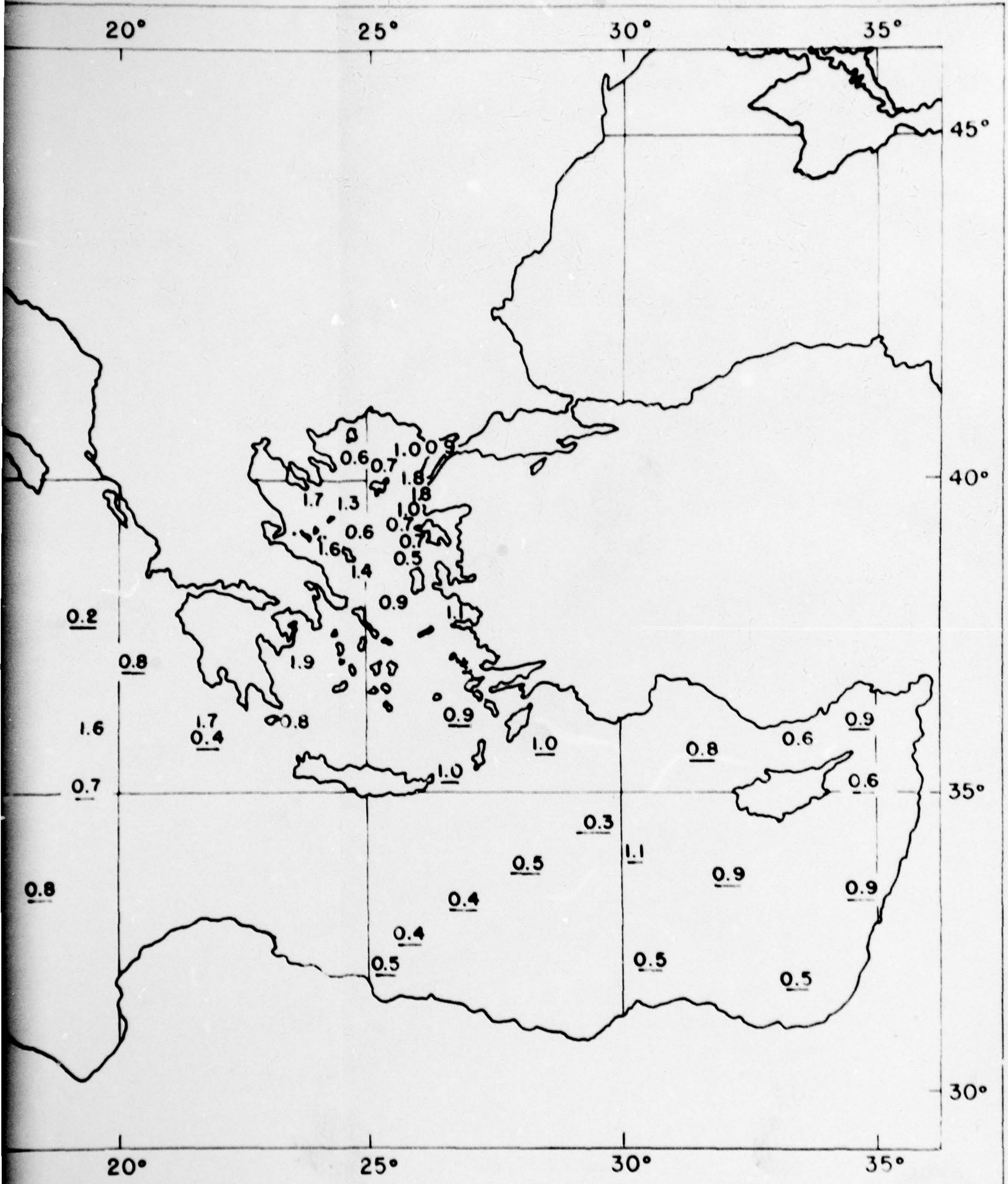


FIGURE 4.4 PLANT PIGMENT



PLANT PIGMENT AVERAGES FOR UPPER 200 M. IN HU/L

2



ES FOR UPPER 200 M. IN HU/L

3

2

5. Distribution of Nutrient Chemicals and Silicates

by

R. B. Abel

Throughout the cruise a study was made of the following chemical constituents of ocean water: Phosphate-P, Nitrate-N, Silicate-Si, and Nitrite-N. All analyses were accomplished by means of an electric eye photoelectric colorimeter, an instrument well suited for work at sea. The outstanding feature observed was that the concentrations of these ingredients in the Mediterranean and Aegean Seas in no case approached those in the Atlantic Ocean, the Aegean being even more devoid of these constituents than the Mediterranean.

x x x x x x

Phosphate-P values obtained across the Atlantic yielded the characteristic phosphate curve shown in Figure 5.1, together with typical curves from the Mediterranean and Aegean Seas. The N/P ratio of 18:1 held fairly constant during this period. As the Straits of Gibraltar were neared, phosphate concentrations, like those of all the ingredients, took a very sharp drop, rising slightly upon a still closer approach to the Straits. This development appears to be in agreement with the temperature and salinity distribution in this area. This situation was reversed upon leaving the Straits five months later.

That section of the Mediterranean between 5° and 10° East Longitude, covered during the month of January, showed a type of concentration curve which was later found to be typical of the entire Mediterranean area. As is shown in the above figure the phosphate concentrations at deeper levels were on the order of .3 - .4 muGA/L in contrast with values of about .6 mu GA/L mentioned in the literature. In this connection it was found that Mediterranean values determined on this cruise were generally about 30% lower than previously described.

Results in the northern and central Aegean area were not at all uniform. Concentrations were very low, seldom reaching values of more than .2 muGA/L and at times becoming too small to be measurable. Observations became more fruitful in the southern Aegean where curves acquired a certain amount of rationality. Phosphate concentrations increased very little with depth, the main feature being constant surface concentrations of about .05 muGA/L. Subsurface concentrations increased slightly from west to east showing a large gain as the Mediterranean proper was reached.

In the eastern Mediterranean the curves for all the chemical constituents became quite regular. In fact, the phosphate curves for this area were, with but few exceptions, nearly identical.

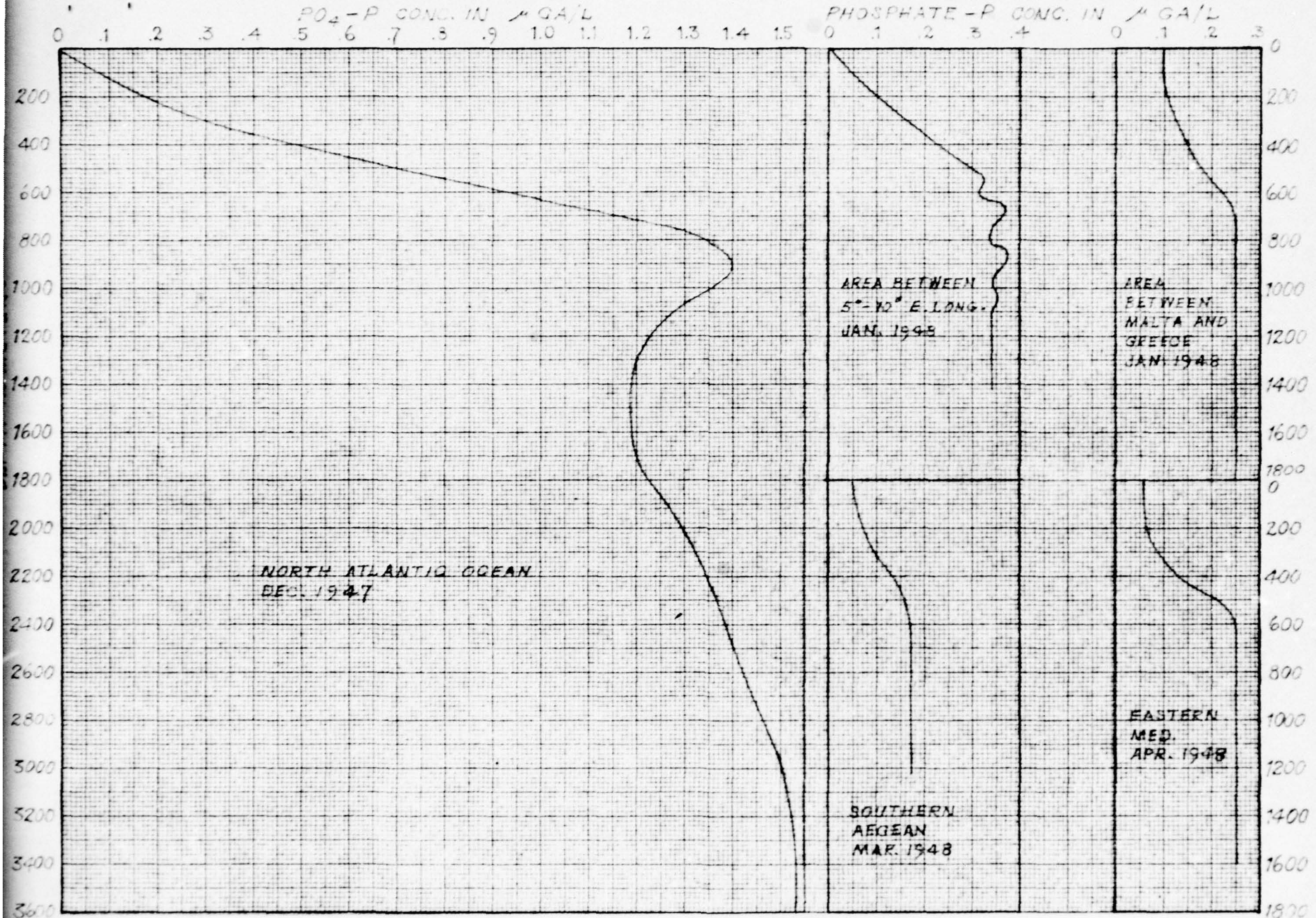


FIGURE 5.1 CHARACTERISTIC PHOSPHATE-P CURVES.

However, there were some variations in the surface concentrations, the values generally increasing eastward. The maximum concentration, 14 muGA/L was attained near the mouth of the Gulf of Alexandretta, northeast of Cyprus. This is of interest since the highest surface concentration in the Aegean was also found in a nearly landlocked basin, the Gulf of Xeros, north of the Dardanelles. Other particularly high surface values were found off the southwest coast of Greece south of the Gulf of Corinth, and just southwest of Crete. At the latter station the concentrations decreased with depth, attaining values normal for the area at 100 meters.

The surface phosphate concentrations, on the whole, showed excellent agreement with the results of plant pigment analyses. The N:P ratio fluctuated greatly in the eastern Mediterranean but appeared to be generally lower than in the Aegean Sea.

In the Straits of Sicily and the southern Tyrrhenian Sea high surface concentrations (up to .10 muGA/L) were found. Surface values in the central part of the western Mediterranean, on the other hand, held constant at .02 - .04 muGA/L. In the Alboran Sea, 150 miles east of Gibraltar, both surface and subsurface values increased again, possibly due to the influence of Atlantic water, with the curves as a whole becoming less regular.

The phosphate-P analysis proved simple, accurate and consistent. It was found that an appreciable error was introduced by using other than freshly made up $SnCl_2$. It is also interesting to note the decrease in the size of the reagent blanks. This is believed to be a result of using the water produced by the laboratory still which performed excellently throughout the voyage. The calibration curve held very well, the only changes being occasioned by changing the cell and repairing the photometer.

x x x x x

Probably due to the inexperience of the operator, nitrate curves across the Atlantic during the month of December were, at times, irregular. Their outstanding characteristic, as can be seen from Figure 5.2, was their close resemblance to the phosphate curves. Nitrate concentrations took their greatest drop, approximately 40%, about 450 miles west of the Straits of Gibraltar just as did the other constituents. On the return trip across the Atlantic, values took approximately the same jump, there again being close correlation between phosphates and nitrates.

There were many sections of the Aegean Sea where no nitrate could be detected at the surface, and even subsurface values seldom reached 3 muGA/L. That area in the vicinity of the Dardanelles was especially barren, concentrations not exceeding 1 muGA/L. Curves became slightly more regular in the southern Aegean, although at depths of 300-400 meters, curious jumps in

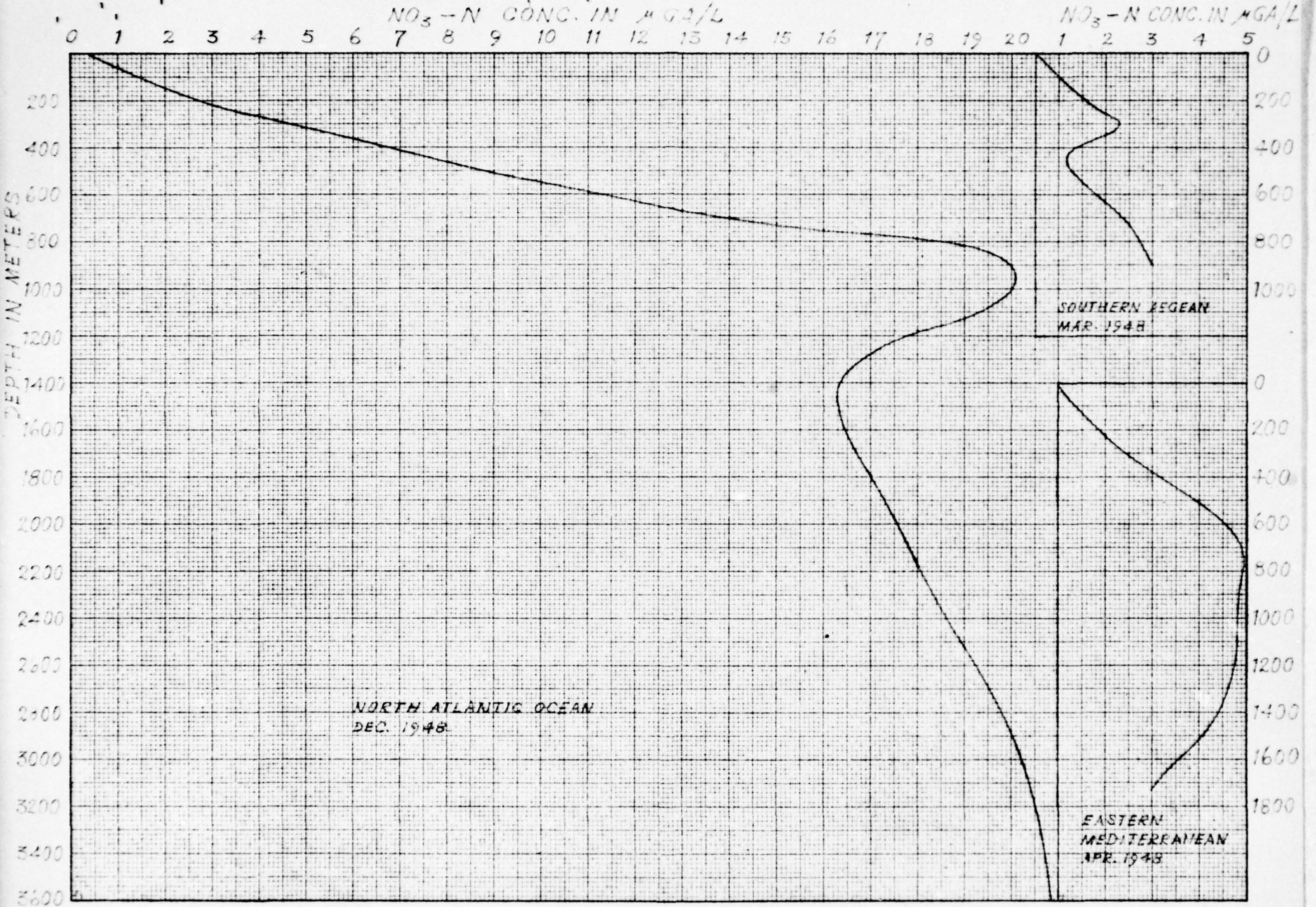


FIGURE 5.2 CHARACTERISTIC NITRATE - N CURVES

the concentrations occurred. Below these depths the curves returned to normalcy.

Figure 5.2 also shows the increasing regularity of the nitrate curve as the eastern Mediterranean was reached. The decrease in concentration near the bottom may be due to lower nitrate water developed elsewhere. This development was characteristic of nearly all nitrate curves east of Crete. In general, nitrate curves showed a fair approach to coherency except in that area between the 18th and 25th degree of east longitude, where concentrations were apt to take sudden jumps at certain depths. The surface concentrations decreased westward to the Straits of Sicily where they were approximately doubled.

First results in the western Mediterranean were, at best, uncertain. However, it can be stated quite conclusively that values attained were about 40% lower than those previously given in the literature. In May the section between Sicily and Gibraltar contained some of the most interesting gradients encountered anywhere in the cruise. The surface concentration held constant until within about 250 miles of Gibraltar, then rose sharply. Even more remarkable was the change in vertical gradients. At the entrance to the Alboran Sea, concentrations tended to rise as much as 8 muGA/L in 400 meters, characteristic of Atlantic waters. However, during this time, the curves retained unusual regularity.

The nitrate analysis was the only one presenting serious problems. The strychnidine reagent seemed quite undependable at times, working for a few days, then suddenly becoming poisoned to such an extent that not only would it frequently fail to produce the color, but would remain pale even after the red complex was added to portions of it. The duration of stability ranged from four days to a week. While running calibration curves on standards it seemed at times as if one or more side reactions commenced upon the addition of the reagent resulting in a system of two complete curves. Some possible sources of error, such as contamination and effect of ship's motion, were ruled out by experiments. Remaining possibilities include decomposition of the dry strychnidine due to excessive laboratory temperatures, the original impurity of the substance and the liberation of too much HCl due to excessive shaking of the reactants.

x x x x x

Very little work was done on nitrites because of the uselessness of the information without accompanying data on ammonia concentrations. The outstanding feature of nearly all the nitrite curves was their abrupt and inexplicable change of gradient at certain depths. The analysis itself proved simple, accurate and consistent.

x x x x x

Analyses of silicates revealed a type of curve differing from those of the nutrients in that there was no definite maximum. Results of observations made across the Atlantic in December revealed a curve punctuated in two places by sharp changes in gradients as shown in Figure 5.3. As was the case in the concentrations of the nutrients, the silicates suffered a drop of 30-55% upon approaching the Straits of Gibraltar.

The curves in the northern and central Aegean Sea were rather irregular. The high surface concentrations, between 2 and 3 muGA/L, were greater than any previous determinations had shown. The concentrations in this area stayed fairly constant from the surface to a depth of about 200 meters where they began increasing slowly to the bottom. Surface concentrations were still higher in the southern Aegean. It was noticeable that the gradients down to 250 meters became more negative from west to east but remained normal below those depths.

As the eastern Mediterranean was reached, surface concentrations decreased toward the south, but never becoming as low as western Mediterranean and Atlantic values. Those surface concentrations found north of Crete and westward as far as Cyprus were the highest of the cruise, reaching 4 and 5 muGA/L. In and about the Straits of Sicily, the surface concentrations were found to decrease, in contrast to the rise in surface concentrations of the nutrients.

The curves in the western Mediterranean were rather indefinite (Figure 5.3), becoming most irregular in the vicinity of the Balearic Sea and the Straits of Gibraltar. This was especially true at 100 meters where extreme changes of gradients occurred, no doubt due to the influence of Atlantic water.

For analytical purposes the silico-molybdate reaction proved quite reliable. The standards and calibrations seemed good for an indefinite length of time, the same curve being used throughout the cruise.

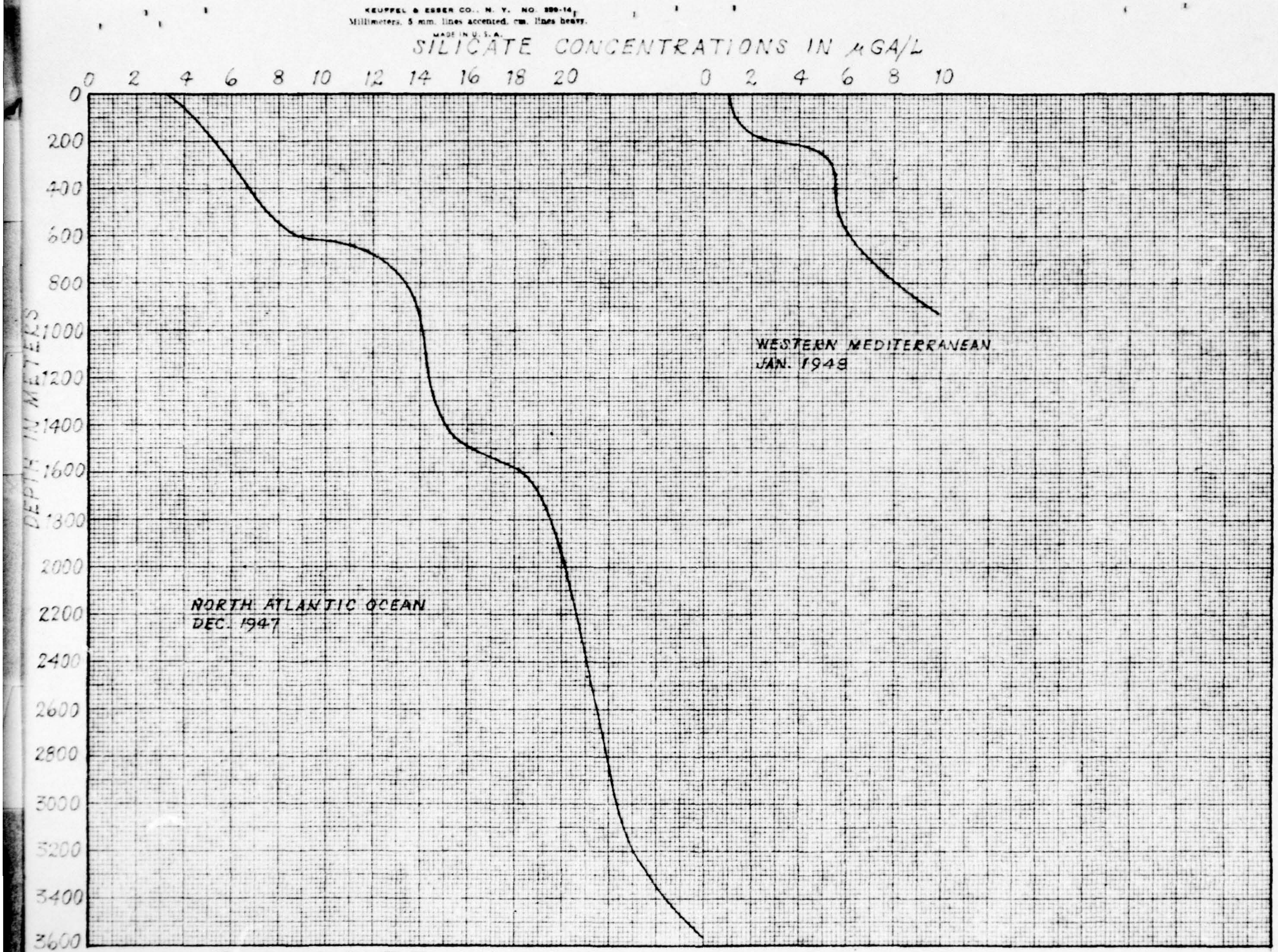


FIGURE 5.3 CHARACTERISTIC SILICATE-SI CURVES

6. Experiments on Photosynthetic Rate and Oxygen Consumption

by

D. F. Bumpus

It was hoped at the outset of this cruise that some data could be obtained upon the photosynthetic rate, oxygen consumption by known quantities of zooplankton and the grazing rate by known quantities of zooplankton in impoverished waters. A quantity of data has been collected on the first two items. Knowledge concerning the third remains completely unimproved. Fifty-five sets of experiments were run, 15 in the Atlantic, 27 in the Mediterranean and 13 in the Aegean, using the following methods.

A. Photosynthetic Rate:- Samples of natural surface sea water were carefully siphoned into oxygen bottles, one was covered with a black, light-proof bag, the other left uncovered. Both were placed in an exposed tank of running sea water on deck for 24 hours. At the end of that period both were analyzed for dissolved oxygen by the Winkler method. The concentration of oxygen in the light bottle minus that in the black bottle equals the photosynthetic rate.

B. Oxygen consumption by known quantities of zooplankton:- Four silk plankton nets were rigged in a novel manner: A #10 net, ½ meter in diameter, was fitted with a canvas collar about ½ meter long ahead of the net, the forward opening of the collar being 30 centimeters in diameter. A #2 net, 30 centimeters in diameter, was securely lashed into the opening so that when this tandem rig, Figure 6.1, was streamed at the surface for thirty minutes the water flowed through the #2 net, with the mason jar at the cod end retaining the larger members of the plankton population. The smaller members continued on through the #2 net and those large enough were retained by the #10 net. A similar rig was streamed at the same time using a 30 centimeter #10 net ahead of a ½ meter #19 net. Thus four samples of the plankton population were captured at each station:

the population retained by a #2 net;
that which passes a #2 but is retained by a #10 net;
that which is retained by a #10 net;
that which passes a #10 but is retained by a #19 net.

(It was hoped that the bulk of the population retained by the #19 net would be phytoplankton, but such was not the case. As the oxygen consumption experiments show, the bulk if not all the population was zooplankton and on several occasions the aliquots from the #19 net used more oxygen than similar aliquots from coarser nets.) Aliquots of 5, 10 or 15 cc were drawn up in a wide mouth pipette from the thoroughly stirred plankton samples

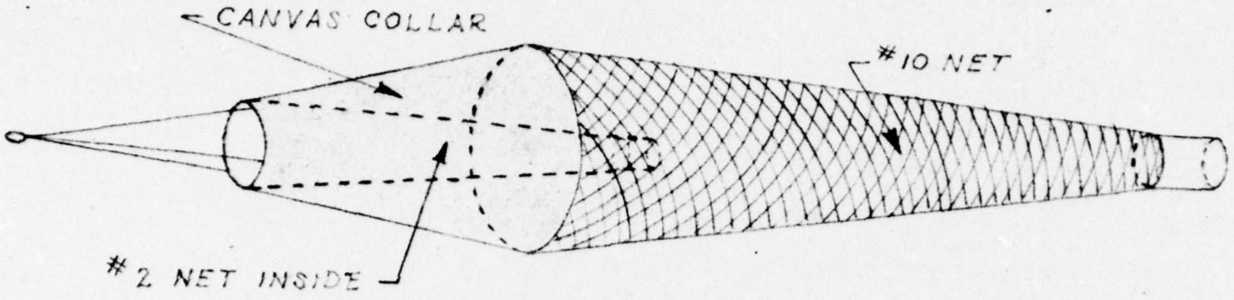


FIGURE 6.1 TANDEM TOW NET RIG

and placed in light and dark bottles containing surface sea water. These were allowed to repose in the salt water bath on deck for 24 hours and then analyzed for oxygen content. The concentration in the dark photosynthetic rate bottle minus that in the dark plankton bottle and the concentration in the light photosynthetic rate bottle minus that in the light plankton bottle represented two values for oxygen consumption.

C. Grazing experiments:- Aliquots from the #19 net were added to several quart bottles nearly full of surface sea water. One was kept for control; to the others, aliquots of zooplankton from the coarse net tows were added. These bottles were then placed in black bags and allowed to remain in the deck tank for 24 hours, after which the zooplankton were filtered out through a #10 silk and analysed for plant pigments by the Harvey method. Only a few such experiments were run since most inconclusive results were obtained. This was due to the small quantities of phytoplankton captured by the nets and to the increase in plant pigments which invariably took place in the course of the experiment.

The results of the photosynthetic rate experiments indicate that little to no photosynthesis goes on in the impoverished waters of the Mediterranean, Aegean and central Atlantic during the periods covered by this cruise. All but one experiment yielded a photosynthetic rate of plus 0.30 to minus 0.22 ml O_2 per L per day, the exception yielding 1.17 ml O_2/L/day. This occurred at Station 4640, in January, where the plant pigments were present in the largest quantity observed during the cruise, i.e., 3.8 HU/L average for the upper 200 meters with a high concentration of 5.0 HU/L at 100 meters. These results are inconclusive, however, for the maximum oxygen concentration occurs at the surface in these waters, diminishing sharply below the photic zone. Furthermore there was no correlation between the concentration of plant pigments at the stations and the photosynthetic rate of those waters.

The results of the oxygen consumption experiments must await the analysis of the rate of carbon consumption per gram of zooplankton, determined by weighing the plankton samples. It is interesting to note that the relative volumes of plankton in the four townets varied from station to station. For instance, at one station the bulk of the population might not pass the #2 net while at another the largest quantity would be retained by the #19 net. These variations were, as they should be, directly reflected in the oxygen consumption.

In addition to the surface tows for experimental purposes, two plankton samplers were sent down to about 500 meters (1000 meters of wire at 55° to 70° wire angle), one with a #2 net and the other with a #10 net, making an oblique tow down and up. These quantitative plankton samples may be useful for population studies. Sixteen night-time plankton samples in the Atlantic and 1 in the western Mediterranean were collected at the surface with a 3/4 meter stramin net for scattering layer studies. Thus a total of 360 plankton tows (number of nets streamed) were made, distributed as follows: 108 in the Atlantic, 190 in the Mediterranean and 62 in the Aegean Sea.

7. Current Measurements

by

D. F. Bumpus and N. Corwin

Four anchor stations for current measurements were made on the cruise, three in the Aegean Sea near the Dardanelles and one in the Straits of Sicily. A new type Ekman current meter, lowered in sequence to selected depths between surface and bottom, was the main source of data. A von Arx current meter was also used at each station, usually at one depth only, in order to obtain a continuous record of current fluctuations. However, since it is not sensitive to velocities of less than 0.8 knots, it was useful only at Anchor Station #2. This latter record has not yet been studied. All the results of these four stations warrant more detailed analyses than have been carried out so far.

The first anchor station in the Aegean, in 58 fathoms of water between the islands of Limnos and Evstratios, was abandoned after 9½ hours when high winds caused the ship to drag and finally lose her anchor. Currents at all depths were weak, averaging 12.2 cm/sec toward 111° at 15 meters, 21.2 cm/sec toward 099° at 50 meters and 14.0 cm/sec toward 099° at 90 meters. However, since a chip drifted toward 270° at 14 cm/sec there is some question as to whether the ship was ever firmly anchored at this station.

The second station, made one month later in 38 fathoms of water between the islands of Imroz and Limnos, was occupied for 32 hours. This produced an excellent set of data in the axis of the Dardanelles outflow. Velocities varied between 38 and 88 cm/sec near the surface, and between 7 and 36 cm/sec near the bottom. The average direction, which showed no significant vertical variations, was 332°. Only a limited number of observations deviated as much as 60° from the average. A definite periodicity in surface velocities was apparent as well as a correlation between current velocity and depths of the isotherms as recorded by the bathythermograph.

A third anchor station in the Aegean Sea was made in 47 fathoms of water between the islands of Limnos and Bozcaada. The current from the surface to a depth of 10 to 25 meters had an average velocity of about 14 cm/sec toward 252°, while below this layer the average velocity was about 16 cm/sec toward 130°. The station was abandoned after 9 hours because of rising winds and the general weakness of the currents.

The anchor station in the Straits of Sicily in 290 fathoms of water was occupied for 13 hours. Velocities ranged from 8 to 41 cm/sec with the highest values below 200 meters. In the upper 150 meters the general drift was toward the eastern Mediterranean, below that toward the western Mediterranean, with the latter current somewhat more constant in direction.

8. Wave Measurements

by

F. J. Mather

The purpose of the wave work on this cruise was to obtain offshore wave measurements and the meteorological data necessary for their analysis. In this way it is hoped to check existing theories of wave propagation and decay of waves and swell. The methods employed were cinephotographs of a damped pole and direct visual estimates from the vessel.

The use of the photographic method was severely limited by the time requirements of other phases of the cruise program and hence by the necessity of working simultaneously with hydrographic stations. These were generally made irrespective of their desirability from the point of view of wave observation and were frequently postponed if the weather was severe. In the Aegean most of them were made at night for reasons of safety. The hydrographic work also made it impossible to maintain good light conditions and the proper distance from the pole by maneuvering the vessel. In addition, there was always danger of the pole rig fouling the hydrographic wire, especially when the vessel was hove to under sail.

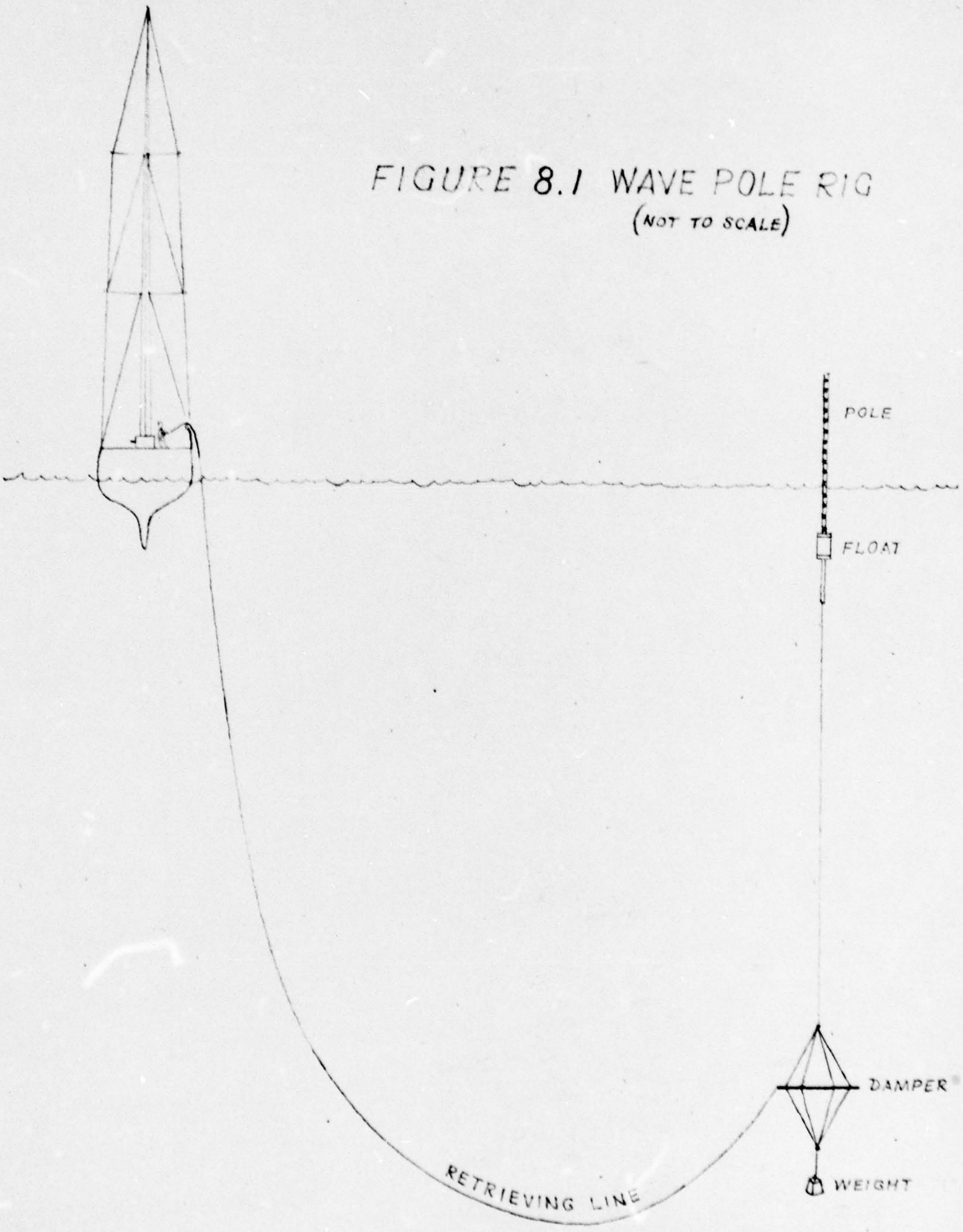
x x x x x

The arrangement of the damped pole is shown in Figure 8.1. The pole extended 20 feet above the float and was painted black and white in alternate bands one foot wide. The extension of the pole below the float was attached to the damper by a line whose length was varied to suit the wave period expected. In the Mediterranean 150 feet were used while in the Atlantic at least 250 feet were required. Below the damper, a 4 foot diameter steel ring with canvas stretched across it, a weight was suspended, sufficient to submerge the float and about one-half of the pole. At least 600 feet of rope or wire led from one side of the damper to the ship for retrieving the rig.

The rig first used was made up of a Dan buoy and required 120 pounds of weight below the damper. The second rig was much lighter and easier to handle consisting of a canvas covered cork float and a weight of only 20 pounds. The operation of both rigs was similar. The retrieving line was left slack as the vessel drifted away from the gear. When the pole had reached equilibrium and was clear of the slick of the vessel, cinephotographs of it were taken, each run lasting from 1½ to 2½ minutes.

The light rig seemed to be as good as the heavy one in

FIGURE 8.1 WAVE POLE RIG
(NOT TO SCALE)



moderate weather, but took longer to sink to equilibrium and had less resistance to tipping by wind or wave crests. The vertical stability of the poles seemed satisfactory except in very long swells. In winds of over 20 knots the vessel drifted so fast that the pole was often out of photographic range before it had reached equilibrium and a run could be completed. In really heavy weather photography is impractical because of flying spray and violent motion of the vessel.

Visual estimates were made when the ship was underway and when hove to under conditions unsuitable for photographic methods. Heights of 6 feet or more could be estimated by the height of eye when the wave crest lined up with the horizon while the ship was in the trough. Heights above the load waterline were marked off on the mizzenmast. Heights less than 6 feet were estimated by inspection. Period was measured by timing successive crests as they passed a patch of foam or a floating object. Wave length was estimated visually using the vessel's length as a yardstick.

Wind speed was measured with a hand anemometer and the direction noted. Additional meteorological information for the wave studies carried out in the Mediterranean was secured in the form of daily synoptic charts issued at Malta and at Gibraltar. Additional data on the state of the sea, wind force and direction are available in the bathythermograph log, the ship's log and the hydrographic log. These should be useful in filling in history before and after wave observations.

x x x x x

Visual wave observations were made daily and thirty-four sets of photographic measurements were taken, 14 in the Atlantic, 16 in the Mediterranean and 4 in the Aegean.

The most interesting feature of the crossing from Bermuda to Gibraltar was swell. Winds were moderate to light and wind sea was not often significant. Swell patterns were complicated and appeared clearer when viewed from the mast instead of the deck. Seven power binoculars were of assistance in studying these formations. The highest swell was observed 5 January 1948 at 35°37'N., 07°31'W. Visual estimates indicated a height of 14 feet or more and periods of 12 to 14 seconds.

The return passage from Gibraltar in the trade wind belt gave the opportunity to study waves which had probably reached the maximum for the wind velocity. The duration and fetch were probably not limiting factors. For a 16 knot wind, heights averaging 6 to 7 feet with a maximum of 10 feet, and periods of 7 to 9 seconds were observed.

In the Mediterranean swell was much more prevalent in the western basin than in the eastern one. The maximum heights were 6 to 7 feet with periods up to 9 seconds. Some heavy weather was encountered, permitting the study of fairly high wind seas. On March 13 a gale off Cape Malea with velocities averaging 40 knots and reaching over 50 knots produced waves averaging 9 to 10 feet with a maximum of 15 feet. The periods were from 7 to 10 seconds. The fetch from the Gulf of Athens was about 90 miles.

Few wave stations were made in the Aegean as most of the hydrographic stations were occupied at night, preventing photography. There were also few occasions when the fetch was not interrupted by islands. The sea was characteristically short and steep. Periods seldom exceeded 6 seconds while heights reached well over 10 feet.

These comments are all based on visual estimates, as there has been no opportunity to develop and analyse the photographic records.

9. Transparency Measurements

by

D. F. Bumpus

On every daylight occasion when the ship stopped the transparency of the surface waters was measured by means of a white Secchi disc, 20 cm. in diameter. A few measurements were also made with a white 40 cm. disc and with a bright red, 20 cm. disc. A total of 126 observations were obtained, 28 in the Atlantic, 51 in the Mediterranean and 47 in the Aegean.

Secchi disc readings (D) were converted to extinction coefficients (k) by means of the equation $k = 1.7/D$. The most opaque waters of the Mediterranean area were found in the Alboran Sea (k = 0.10 to 0.17 or D = 17 to 10 M) and in the northern Aegean off the entrance to the Dardanelles (k = 0.12 to 0.28, D = 14 to 6 M). The remainder of the Aegean is considerably clearer, with extinction coefficients varying between 0.05 and 0.14, the higher values being generally close inshore. The clearest waters appear in the central parts of the eastern Mediterranean with extinction coefficients of 0.05. In general the Mediterranean is about as transparent as the Sargasso Sea, with values averaging about 0.06 and 0.07.

Comparison of the 20 and 40 cm. discs in fairly clear waters (k = 0.07) indicates that the 40 cm. disc can be seen only 1.2 times as far as the smaller disc.

Comparison of the white and red discs of the same size indicates that the red disc can be seen 0.45 times as far as the white one in the relatively clear Mediterranean waters (k = 0.09 to 0.05).

Seven series of transparency measurements were made with the Clarke Marine Photometer, 3 in the Atlantic, 2 in the Aegean and 2 in the eastern Mediterranean (Figure 9.1). Two others were attempted but cloudy sky and/or rough sea rendered them useless.

Of the three stations in the Atlantic only one (Station 4631) was deep, exhibiting the clearest ocean water ever reported; from 30 to 127 meters the extinction coefficient was 0.018, the upper 30 meters being quite normal for that region (k = 0.052).

The Aegean station in Doro Channel (Station 4668) was the most opaque one of the cruise with an extinction coefficient for the upper 30 meters of 0.077 and from 30 to 90 meters of 0.068. The eastern Mediterranean stations were quite uniform. The extinction coefficient in the upper 30 meters was about 0.06 and below that about 0.05.

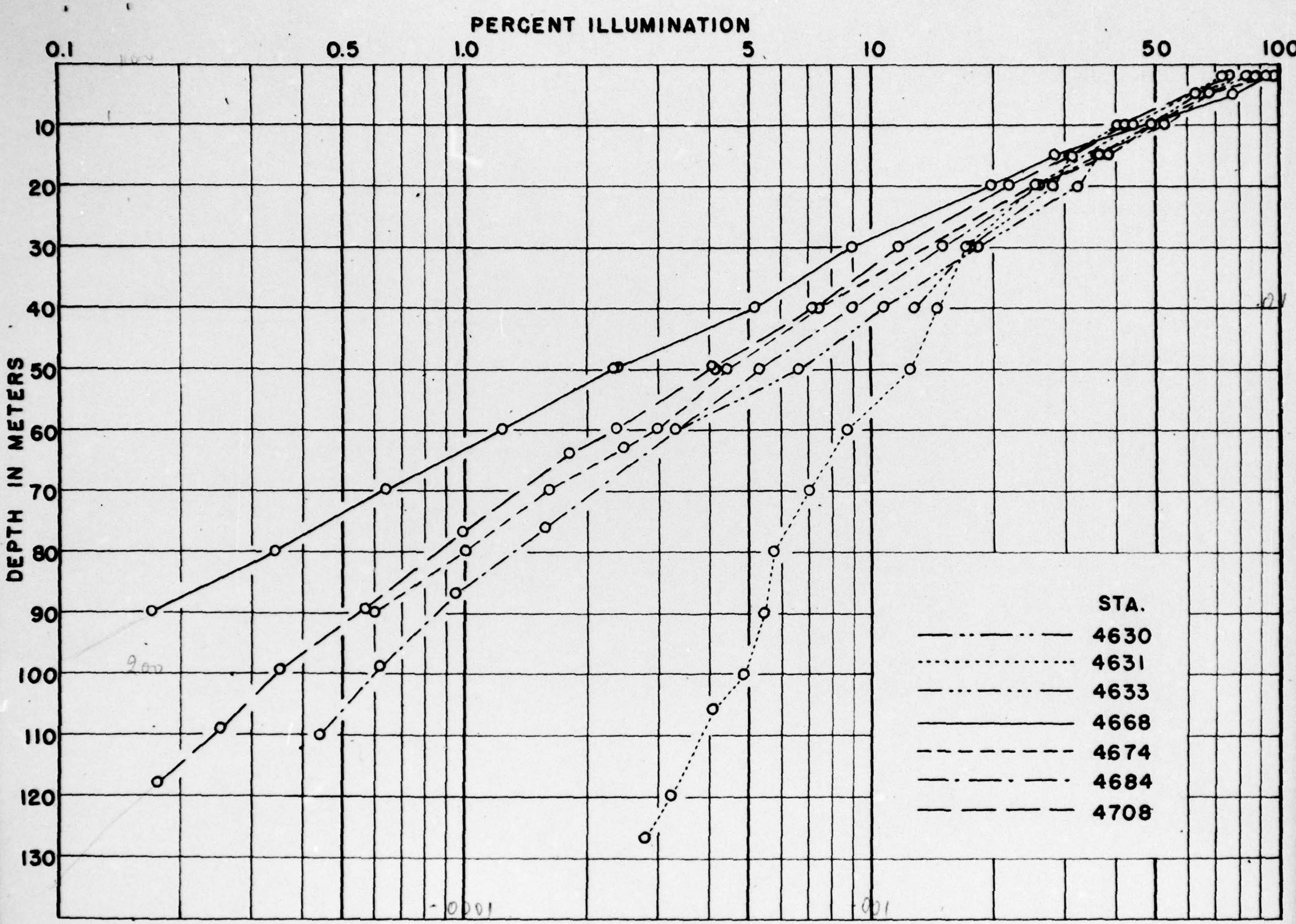


FIGURE 9.1 PERCENT SURFACE ILLUMINATION AT DEPTH.

10. Underwater Photography and Bottom Samples

by

D. M. Owen

In the course of this cruise 73 successful bottom photographs were made, 10 in the Atlantic, 39 in the Mediterranean and 24 in the Aegean Sea. A report on the geological and biological significance of these photographs cannot be given, of course, until every negative is enlarged and studied by specialists in those fields.

The underwater camera used for this work was loaned to us by Dr. Maurice Ewing. Figure 10.1 shows the complete rig as used on a majority of the lowerings. While a number of failures occurred due to various causes, the general performance of the camera was excellent. As the cruise progressed and more experience was acquired in the use of the instrument and in determining possible sources of trouble, results improved markedly, particularly at depths greater than 1000 fathoms.

The first two camera lowerings out of Woods Hole, on 7 December, were made in 21 and 53 fathoms respectively with the B.T. winch. The resulting bottom pictures were unclear, possibly due to either muddy water near the bottom, or camera trouble not ascertained as yet. Lowering number 3, however, made in 1000 fathoms on the Continental Shelf, was fortunate in catching a Sea Spider, three Brittle Starfish, and numerous little tracks and holes in the bottom. This is perhaps the outstanding bottom photograph of the cruise. This, and all subsequent lowerings were made with the hydrographic winch. Two attempts to photograph the crest of the mid-Atlantic Ridge met with failure. This was partially compensated for by one of the subsequent lowerings, east of the Ridge, when a photograph at the record breaking depth of 2287 fathoms was obtained. The capabilities of the camera rig were clearly demonstrated in this instance as success was achieved despite unfavorable wind and sea conditions resulting in a wire angle of 50°. On the return trip across the Atlantic an even greater depth of 3026 fathoms was attained. This picture (Figure 10.2) shows a number of circular objects, as yet unidentified, which resemble sea urchins to some extent.

Of the 73 successful bottom photographs taken, perhaps 15 are outstanding with regard to subject matter, clearness, or both. The most likely looking negatives were enlarged to 8 X 8 inches, during spare moments in port, to observe results more closely. Of particular note is an exceptionally clear picture of a shrimp swimming several inches off bottom, taken at 354 fathoms. Several photos in the Aegean Sea revealed "colonies" of two inch holes, arranged in well formed circular patterns. The last shot of such holes, taken in the Mediterranean in shallow

FIGURE 10.1

UNDERWATER CAMERA

(AT MOMENT OF FIRING)

DIAGRAM LESS WIRING AND WEIGHTS

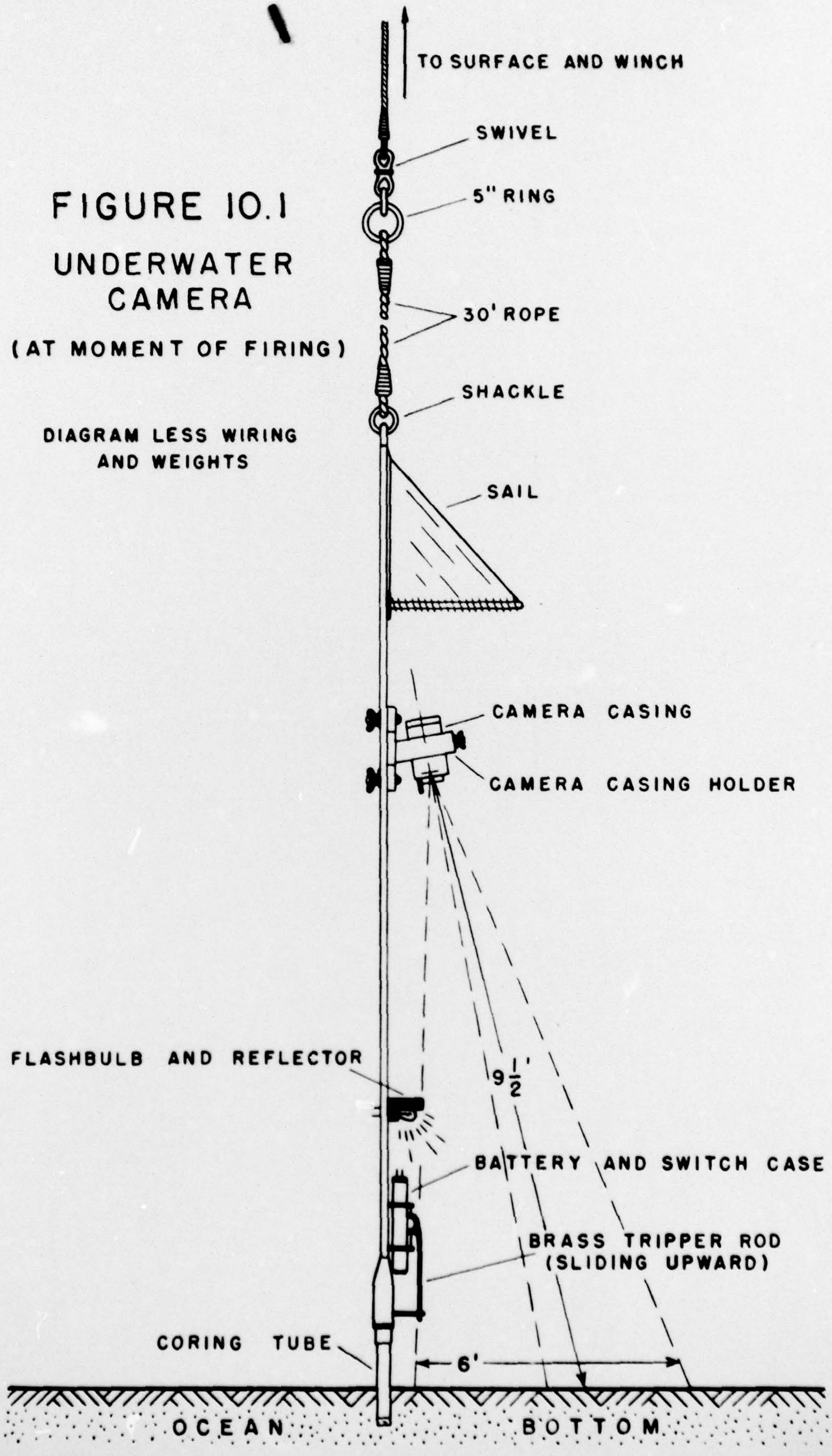


FIGURE 10.2 SEA BOTTOM AT 3026 FMS.
LAT. 30°37'N. LONG. 59°07' W.

water, caught a fiddler crab like affair halfway down one of these holes. A clear picture at 1893 fathoms shows numerous worm tracks. One picture of a sponge bank, and several of coral banks, in the Straits of Sicily, are in the collection.

x x x x x

In the period from 10 December 1947, through 13 June, 1948, 127 bottom samples were obtained. Their geographical distribution and the type of sampler used, at depths ranging from 11 to 3000 fathoms, are shown in the following table.

	Camera	Scoopfish	BTscoop	Phleger	Orange Peel	Plankton Net
ATLANTIC	11	½	1	½	0	0
AEGEAN	25	19	5	6	4	0
MEDITERRANEAN	37	15	0	1	1	1

In the course of two Atlantic Ocean crossings, the mid-Atlantic Ridge area yielded 5 one-foot cores to the undersea camera, two from one section of the Ridge itself and the remainder straddling the mountain range to a maximum depth of 3000 fathoms. The former consisted of vanilla gritty and coffee grey mud, while the latter, taken some six months later, were largely soft brown mud alone.

Ampere Bank, near Gibraltar, received some degree of attention. The scoopfish, BT scoop, and Phleger core sampler could extract only a few grains of sand and shell from the apparently hard bottom at 25 fathoms. Approaching Gibraltar one day later, the camera obtained a very soft brown mud core at 2287 fathoms.

Alboran Sea, east of the Strait of Gibraltar, gave cores which were dark brown at the top and grey near the bottom. The Straits of Sicily were widely sampled with the camera and scoopfish. At depths of 35 to 85 fathoms the scoopfish obtained coral, while it found shell and gravel at 89 fathoms, sand and grey and brown mud at 95 fathoms. Use of the underwater camera resulted in cores of sand and shell at 92 fathoms, grey sand at 208 fathoms, gritty light brown and grey mud at 310 fathoms. The eastern Mediterranean bottom was predominantly light brown and grey mud, seeming to contrast with a darker brown mud in the west.

In the Aegean Sea area it is difficult at this time to compare bottom sediment types of individual areas. One foot cores of grey or light brown mud were found in nearly every sector of the Aegean. The deepest coral, however, lay in a bank fifteen miles west of Skiros Island, at 77 fathoms. The bottom in the vicinity of the Dardanelles entrance consisted almost entirely of grey sand, shell, and coral at an average depth of 45 fathoms. Operations off the island of Lesvos yielded brown or grey mud outside the 100 fathom curve, sand and shells inshore of it.

Although many cores contained mud of two colors in distinct layers, only one, from the eastern Mediterranean, was composed of three colored mud. From top to bottom (one foot), light brown, green, and grey mud made up this unusual combination. Several specimens of Scaphopods were found in this sample, taken from 1900 fathoms.

11. Meteorological Observations

by

E. K. Krance

Meteorological observations, consisting of wet and dry bulb temperatures, sea surface temperature, weather, and wind direction and force, were taken every two hours while the ship was under way and at least once on every hydrographic station. One of the main objectives of these observations was to compute the evaporation rate for each set of data.

Temperatures were measured to the nearest tenth of a degree Fahrenheit, weather was tabulated according to the I.M.M.O. code, and wind was given in Beaufort units except on stations when an anemometer was used. The aqueous vapor pressure over sea water and for the air were computed, using average values for salinity and barometric pressure. From these values and the wind force the rate of evaporation was then determined.

The data were averaged for different regions and periods of the cruise as shown in the tables below. For this purpose the wind directions were combined into eight principal parts of the compass, with N, E, S and W including 3 points each, and NE, SE, SW and NW including 5 points each. The table shows the percentage of the total observed time that the wind blew from each direction. $e_s - e_b$ is the aqueous vapor pressure difference in millibars and E is the rate of evaporation.

Western Mediterranean from Gibraltar to Malta, 10 January to 16 January; 137 hours observed.

Wind Direction	%	Average Force	Range of Force	$e_s - e_b$	E
N	none				
NE	"				
E	"				
SE	"				
S	4	4	2-5	1.40	1.36
SW	31	4	2-5	2.50	2.00
W	4	4	3-4	1.85	1.48
NW	61	4	2-5	3.56	2.85
Calm	none				

Average evaporation rate: 2.47 dg/cm^2/day

Eastern Mediterranean from Malta to Piraeus, 17 January to 21 January; 87 hours observed.

Wind Direction	%	Average Force	Range of Force	$e_s - e_b$	E
N	none				
NE	"				
E	"				
SE	41	4	2-6	2.69	2.15
S	7	4	4	2.72	2.80
SW	39	4	3-5	4.96	3.97
W	13	4	3-5	7.24	5.79
NW	none				
Calm	"				

Average evaporation rate: 3.34 dg/cm^2/day

Piraeus to northern Aegean and return, 27 January to 17 February; 407 hours observed.

N	16	5	4-6	9.06	9.97
NE	29	5	1-6	7.37	8.11
E	4	3	1-3	6.52	3.26
SE	10	2	1-5	6.48	1.94
S	13	3	1-5	3.69	1.84
SW	18	3	2-5	5.51	2.76
W	1	2	2	1.27	0.38
NW	6	3	1-5	7.00	3.50
Calm	none				

Average evaporation rate: 5.22 dg/cm^2/day

Piraeus to northeastern Aegean and return, 26 February to 17 March; 412 hours observed.

N	21	4	2-7	7.15	5.72
NE	51	5	2-7	7.64	8.40
E	2	3	2-3	2.10	1.05
SE	2	3	2-3	6.51	3.26
S	1	1	1	4.01	0.40
SW	3	3	1-3	7.30	3.65
W	5	3	1-5	5.32	2.66
NW	11	3	2-3	6.53	3.27
Calm	none				

Average rate of evaporation: 5.98 dg/cm^2/day

Southern Aegean, Piraeus to Station 4675, 23 March to 3 April; 183 hours observed.

Wind Direction	%	Average Force	Range of Force	$e_s - e_b$	E
N	14	3	1-5	8.52	4.26
NE	15	3	1-4	7.57	3.78
E	5	1	1	8.54	0.85
SE	12	2	1-3	6.12	1.84
S	6	3	2-3	5.94	2.97
SW	18	2	2-4	5.36	1.61
W	16	2	1-5	6.76	3.38
NW	13	3	2-5	8.24	4.12
Calm	none				

Average rate of evaporation: 2.99 dg/cm^2/day

Eastern Mediterranean, Station 4675 to Famagusta, Cyprus via offing of Nile Delta, 3 April to 11 April; 183 hours observed.

N	8	3	2-4	4.49	2.24
NE	26	4	2-4	3.59	2.87
E	none				
SE	12	4	3-4	4.74	3.79
S	none				
SW	16	3	2-4	5.36	2.68
W	11	2	1-4	3.62	1.09
NW	27	3	3-4	4.15	2.08
Calm	none				

Average rate of evaporation: 2.49 dg/cm^2/day

Eastern Mediterranean, from Famagusta north of Cyprus, southwesterly to African coast, northwesterly to Ionian Sea thence to Malta; 15 April to 30 April; 350 hours observed.

N	13	3	1-4	3.24	1.62
NE	21	2	2-3	3.35	1.00
E	4	2	1-4	2.27	0.68
SE	13	2	1-2	4.77	1.43
S	2	3	3-4	5.43	2.72
SW	10	2	2-4	5.64	1.69
W	10	2	1-2	3.33	1.00
NW	25	3	1-5	3.35	1.68
Calm	none				

Average rate of evaporation: 1.18 dg/cm^2/day

Western Mediterranean, Malta to Gibraltar, 3 May to 19 May; 385 hours observed.

Wind Direction	%	Average Force	Range of Force	$e_s - e_b$	E
N	4	2	1-3	2.61	0.78
NE	10	2	1-3	3.20	0.96
E	11	3	1-4	2.06	1.03
SE	22	3	2-5	2.04	1.02
S	5	2	1-4	2.35	0.70
SW	9	2	1-3	3.93	1.18
W	13	2	1-4	3.07	0.92
NW	24	3	1-4	2.67	1.34
Calm	8	0	0	2.82	----

Average rate of evaporation: 1.04 dg/cm^2/day

While an average evaporation rate for the whole cruise would tend to be a meaningless value in view of the unequal distribution of time spent in the various sectors of the Mediterranean, it is interesting to compare the average values from the above tables with the figure computed by Schott. The latter gives an average annual rate for the whole Mediterranean of 3.97 dg/cm^2/day. This is considerably greater than any of the ATLANTIS values except the two series from the northern Aegean.

Figure 11.1 shows the percentage distribution of the weather conditions for the same periods as the tables for wind and evaporation.

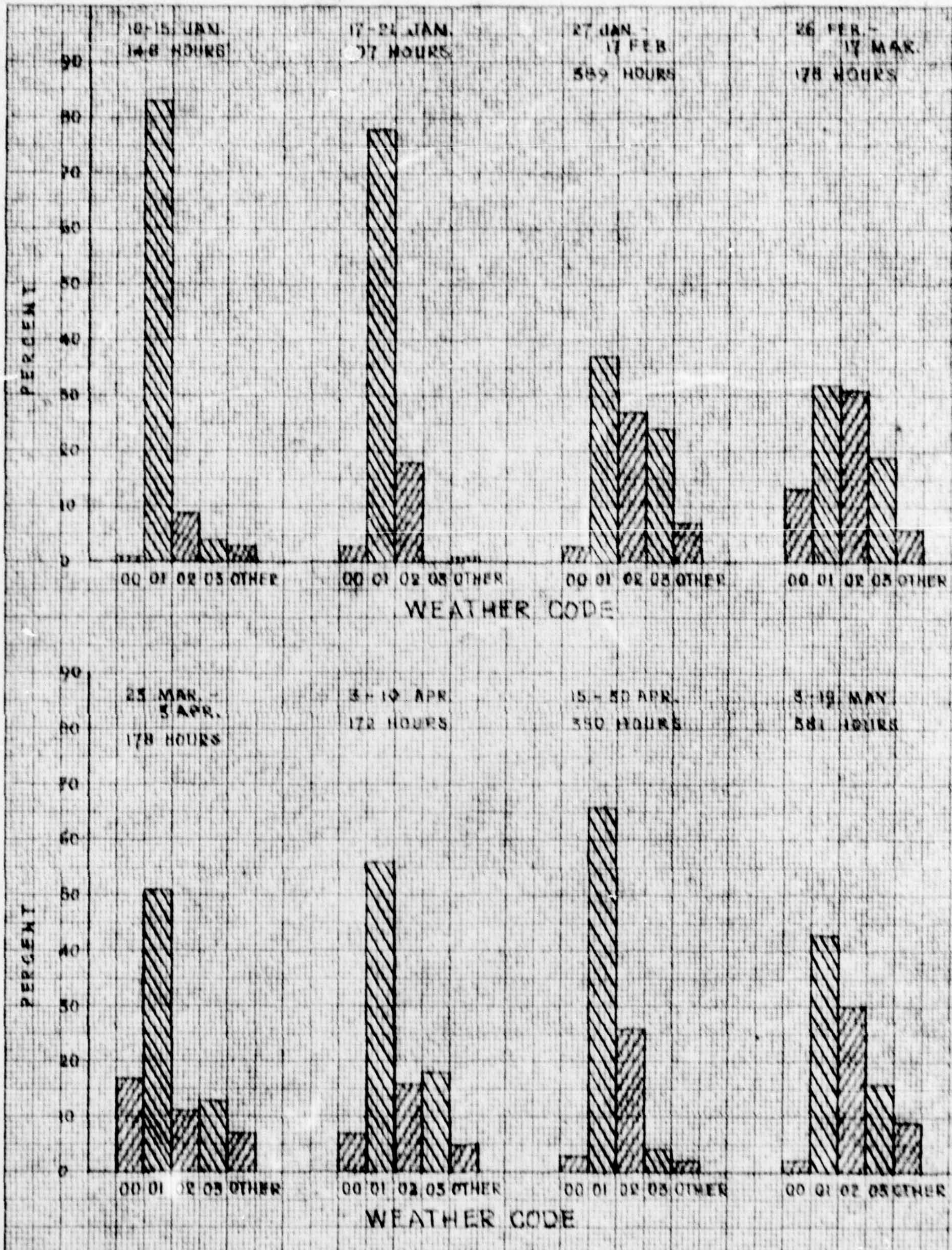


FIGURE II.I FREQUENCY OF WEATHER TYPES

12. Scattering Layer Observations and Seismic Measurements

by

R. D. Campbell

A pronounced scattering layer was in evidence on both Atlantic crossings whenever the fathometer was turned to the shoal scale. On the eastward crossing the transducer in a towed fish was inoperative and only the scattered fathometer records of the layer were obtained. On the return trip several records were obtained by means of the transducer, the signals being transmitted to an oscilloscope of which continuous strip photographs were taken. A record of one ascent of the layer was made near Bermuda.

A scattering layer was also noted in the western Mediterranean on both traversals and a number of records were made on the return trip. While the ship was operating in the eastern Mediterranean a weak scattering layer first became evident east of the Straits of Sicily. The layer increased in intensity towards the west.

x x x x x

Seismic reflection records were made at two hour intervals during the westbound crossing from Gibraltar to Bermuda. The same schedule was resumed for the leg of the trip from due east of Cape Charles to Nantucket Lightship. A total of about 225 reflection records were obtained.

The charges consisted of half-pound and one pound TNT blocks fired by a fuze with a delay mechanism. The receiver consisted of a Rochelle Salt hydrophone towed from the BT cable, with the signals being transmitted to an oscilloscope and photographed in the same manner as that used for the scattering layer records.