THE LEVANTINE INTERMEDIATE WATER MASS FROM SARDINIA TO RHODES

by

A.R. Miller

Woods Hole Oceanographic Institution
Woods Hole, Mass., U.S.A.

In my presentation I will make reference to the following publications:

1) The Mediterranean Sea Atlas: Miller, Tchernia and Charnock. Woods Hole Oceanographic Institution Atlas Series. Vol. III.

2) The Tyrrhenian Sea Atlas (IGY): Aliverti, et al. Consiglio Nazionale delle Ricerche.

3) The Distributions of Temperature, Salinity and Sound Velocity in the Western Ionian Sea: A.R. Miller. W.H.O.I. Report No. 72-5.

When we speak about Levantine Intermediate Water in the most general terms we are talking about subsurface water that is warm and salty relative to its surroundings. If we want to be more explicit we can identify this subsurface water as warmest and saltiest. To be exactly specific I am going to try to identify all Levantine Intermediate Water passing to the west of the Strait of Sicily as products of mixing from a singular point-source entering the Strait of Sicily from the east. The value of that point-source is 14.5°C and 38.83‰.

During the International Geophysical Year (1957) Italian researchers made a very thorough investigation of the Tyrrhenian Sea for all seasons. The plan of this campaign [Ref. 2] is shown in Figure 1. Superimposed over this figure is a north-south track of ATLANTIS made in February, 1962 [Ref. 1]. Figure 2 shows the temperature profile for ATLANTIS with the subsurface LIW mass showing clearly throughout the entire section at a depth of 300 to 400 meters. Figure 3 demonstrates the salinity distribution for the same section. The high salinity core is unbroken throughout the entire length of the section with its greatest value in the south.

With the same horizontal scale but exaggerated vertical scale Figure 4 gives the temperature distribution for February from the Italian data of IGY. Again, the warm core is demonstrated similar to the ATLANTIS profile and high salinity core is shown in Figure 5. Note that the highest values are in the south. One should also note that while the general distributions are similar in geographic position, absolute values between ATLANTIS data and IGY data are not exactly the same. To determine the degree of compatibility between the two sets of data we need to examine them with the aid of the powerful but simple T-S correlation.

Figure 6 shows the distribution of observed data from the ATLANTIS section as salinity values plotted against temperature values. One should note the tight fit of points in the cold, high salinity portion of the diagram and remark as well upon the striaght-line distribution. This is the deep water regime of the Tyrrhenian Sea. Were the vertical scale given in values of potential temperature to account for adiabatic warming, the distribution would be tighter and the coldest end of the scale would straighten. The deep water values demonstrate a simple mixing between two water types. The spread of other points are from observations from the surface layers while the Levantine Intermediate Water is represented in the high salinity, warm water regime of the diagram.

The same description fits the Italian February data except the tight fit of deep water observations is not clearly demonstrated in Figure 7. Nevertheless, if we superimpose the deep water envelope (the dashed lines) from the ATLANTIS diagram over the IGY data the straightline relationship of the deep water distribution is seen to be present but with a further spread of points. The differences may be ascribed to analytical techniques for salinity determination. The Italian data, the earlier of the two sets, were determined by standard chemical titration techniques which is now recognized as a less precise but not less accurate than the analysis of salinity by conductivity methods. The latter method was used for the ATLANTIS data.

It was obvious then that the two sets of data were compatible and, also, that the deeper water values were the same. However, the Levantine Intermediate Water and surface distributions were not similar. Upon examining the LI water mass throughout the entire annual cycle there was no indication of a seasonal trend in the distribution of temperature (Figure 8) and merely a suggestion of seasonal influence in the distribution of salinity (Figure 9). Both Figures 8 and 9, besides showing the geographic position of the LI isotherms and LI isohalines for the entire period of IGY, show for comparison the February locations for ATLANTIS data. One might conclude from this that there was a massive flux of LI Water into the Tyrrhenian in the five-year interval and that water could only have come by way of the Strait of Sicily.

Upon re-examination of the T-S correlation for the ATLANTIS data we can carry the straight-line relationships further than we have already demonstrated. In Figure 10 the extension of the dashed line envelope about the deep water values extends beyond the scale of the diagram. To the left of this envelope there is a void area where no points were observed. (The colder part of the envelope has a curl due to adiabatic warming and need not be concerned in this discussion). Further to the left of this void it is possible to draw a straight line, as indicated, which is extended through the Levantine Intermediate Water intersecting the extension of the dashed-line envelope. At about 13.8°C in the fresh water side of the diagram the distribution of points permits the setting up of a triangular envelope whose upper (warmer) extension intercepts the other two extensions at the same point. Complete envelopment results in the artificial establishment of three point-sources whose connection with that of the hypothetical Levantine Intermediate Water source describes the entire Tyrrhenian Sea as various mixtures of these simple sources.

The fresh water source at 13.8°C is South Tyrrhenian surface water and it is not surprising that a straight-line could be drawn to the hypothetical LIW source because of its proximity to the Strait of Sicily. The cold water source at 13°C is intermediate in salinity and represents North Tyrrhenian water while the warm water source at 14.5°C is fresher than 38‰ and must represent Atlantic water from the Nroth Africa coast. With the exception of the North African source the distribution of points in the Italian data can be drawn in an identical manner with the envelope technique (Figure 11). The same point-sources are indicated but the North African water is much fresher and somewhat colder than that given in the ATLANTIS data. The change of that single point-source representing North African water appears to be a very significant factor in the upper regime of the Tyrrhenian Sea. Nevertheless, the three-way intercept outside the diagram remains constant. Its value is 14.5°C and 38.83‰. While values that high in salinity are not found in the Western Mediterranean, nor in the Strait of Sicily, its implication is that insofar as Levantine Intermediate Water, found in the west, is at various scales of dilution from some pure source that pure source may be as indicated.

I should digress here for a moment to point out that between Sardinia and North Africa at least two cores of Levantine Intermediate Water have been observed, one at either coast.

While the two cores appear to have like properties of temperature and salinity, the Sardinian core is lower in oxygen content than the African core. This might be interpreted that the Sardinian core comes from the Tyrrhenian Sea after some period of residency while the African core represents a direct route of Levantine Intermediate Water from the Strait of Sicily.

To get back to the point-source, it is worth examining the results of Phase I of the MILOC-68 Survey to determine if a point-source can be identified. This survey was to the east of Malta and included all the deep water from Sicily to the shallow-shelf of Africa. Stations were taken ten miles apart in both the north-south and east-west direction. The rectangular grid was about 120 miles on each side, so for that question of Levantine Intermediate Water entering the Strait of Sicily the grid was complete. This information is contained in Reference 3.

It is not practical to include all fifteen east-west profiles in this report. However, three will be shown. Figure 12 represents the distribution of temperature, salinity and sound velocity at 34°40'N. Levantine Intermediate Water is indicated here in the highest salinity distribution. This water is greater than 38.80‰ and as an isolated core in this section its average temperature is 14.5°C. There are only three sections which show this water abutting the Malta shelf; they are at 36°10'N, 36°20'N, and the 36°20'N is shown in Figure 14. The fact that this water has the exact value as hypothesized earlier is not coincidence. It characterizes the Levantine Intermediate Water as it appears off Malta and, as a pure undiluted source for the Western Mediterranean, it indicates that entrainment processes are already beginning once it enters the Strait of Sicily.

As an afterthought, T-S analysis shows that this water off Malta can be traced back to the east to where it breaks through to the surface in an area between Rhodes and Cyprus. In some very painstaking analysis of vapor flux A.H. Bunker in a recent report has shown that this is the area of greatest evaporation within the entire Mediterranean.

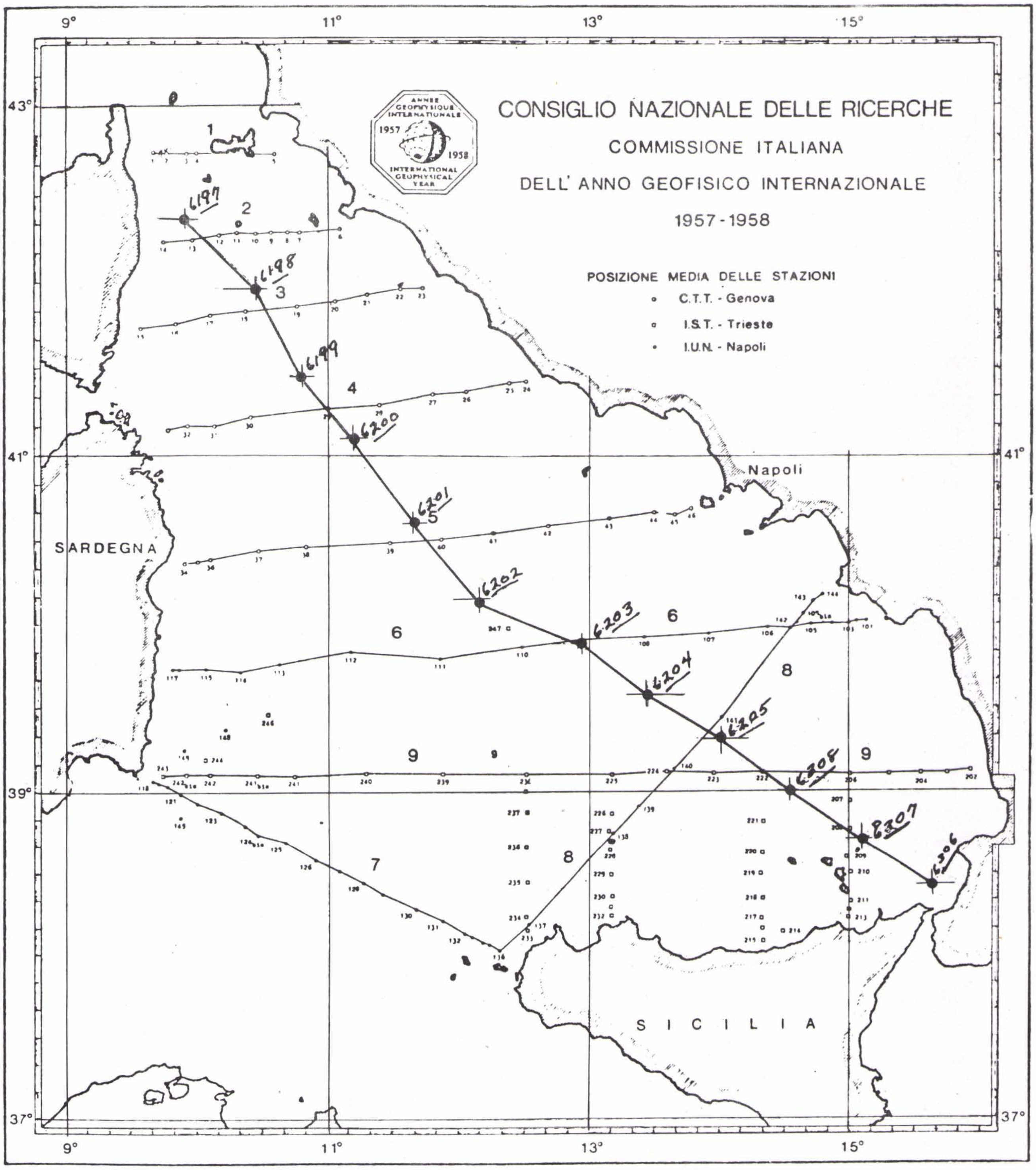

CONSIGLIO NAZIONALE DELLE RICERCHE
COMMISSIONE ITALIANA
DELL' ANNO GEOFISICO INTERNAZIONALE
1957-1958
POSIZIONE MEDIA DELLE STAZIONI
C.T.T. - Genova
I.S.T. - Trieste
I.U.N. - Napoli
SARDEGNA
Napoli
S I C I L I A
9°
11°
13°
15°
43°
41°
39°
37°
6197
6198
6199
6200
6201
6202
6203
6204
6205
6208
6307
6306

FIG. 1

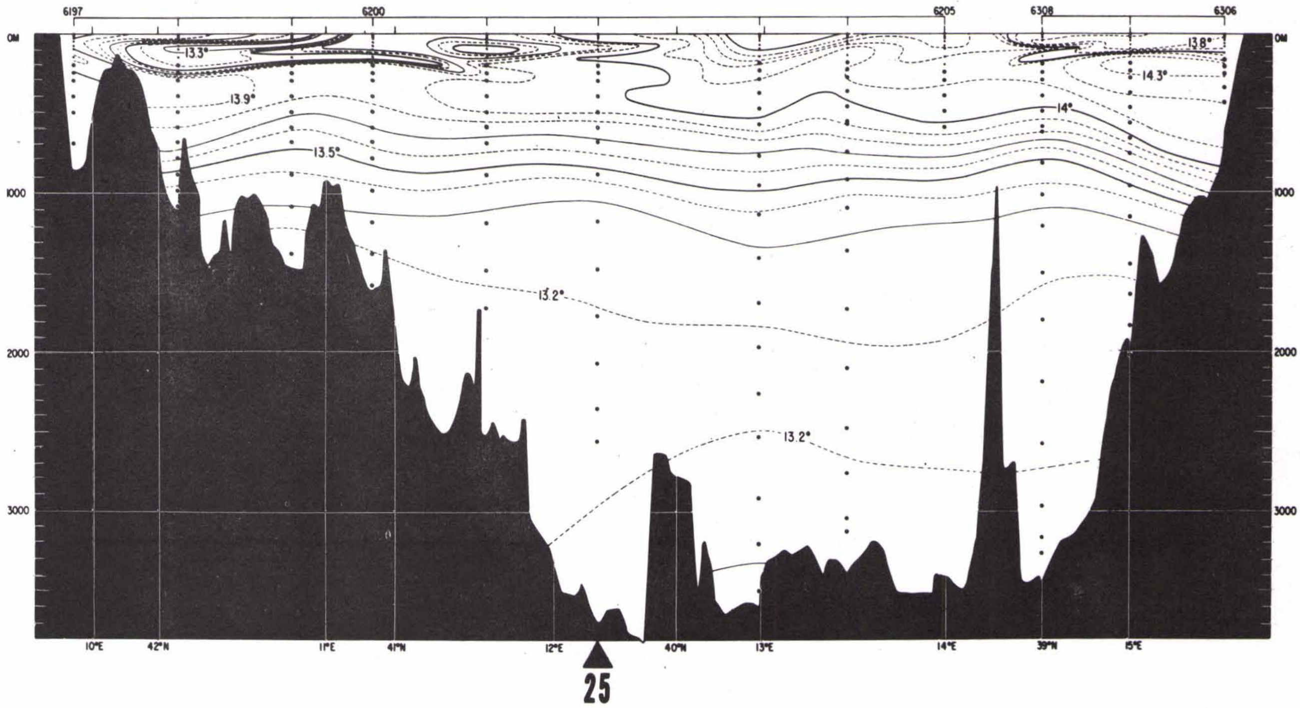

6197
6200
6205
6308
6306
13.3°
13.9°
13.5°
13.2°
13.2°
13.8°
14.3°
14°
10°E
42°N
11°E
41°N
12°E
40°N
13°E
14°E
39°N
15°E
25

FIG. 2

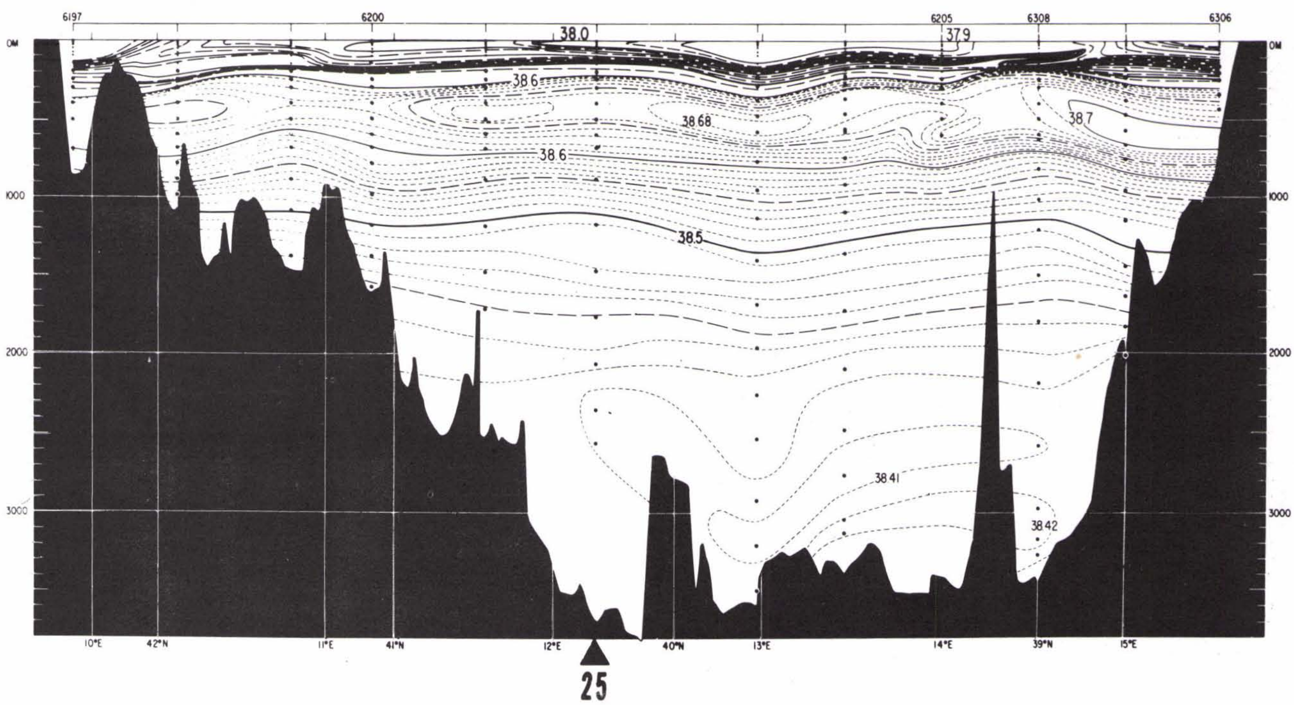

6197
6200
6205
6308
6306
38.0
37.9
38.6
38.68
38.7
38.6
38.5
38.41
38.42
10°E
42°N
11°E
41°N
12°E
40°N
13°E
14°E
39°N
15°E
25

FIG. 3

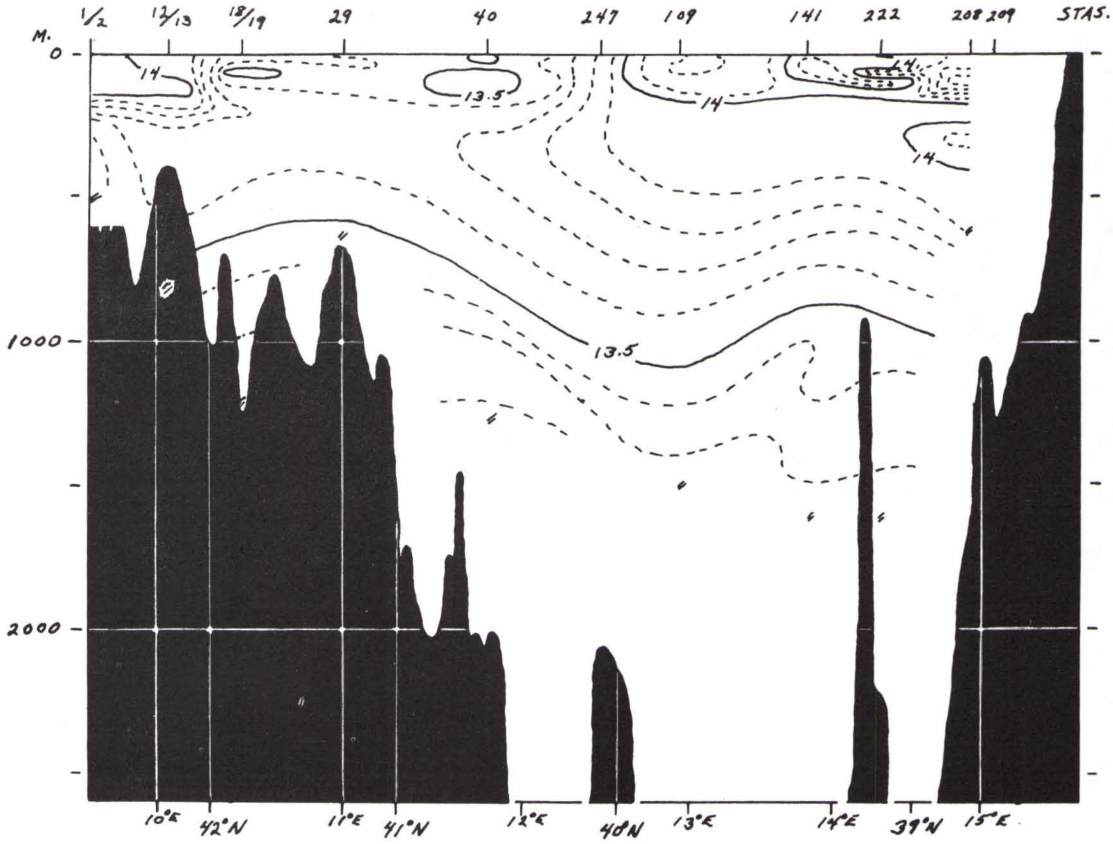

1/2 12/13 18/19 29 40 247 109 141 222 208 209 STAS.
M.
0
1000
2000
14
13.5
14
14
13.5
10°E 42°N 11°E 41°N 12°E 40°N 13°E 14°E 39°N 15°E

FIG. 4

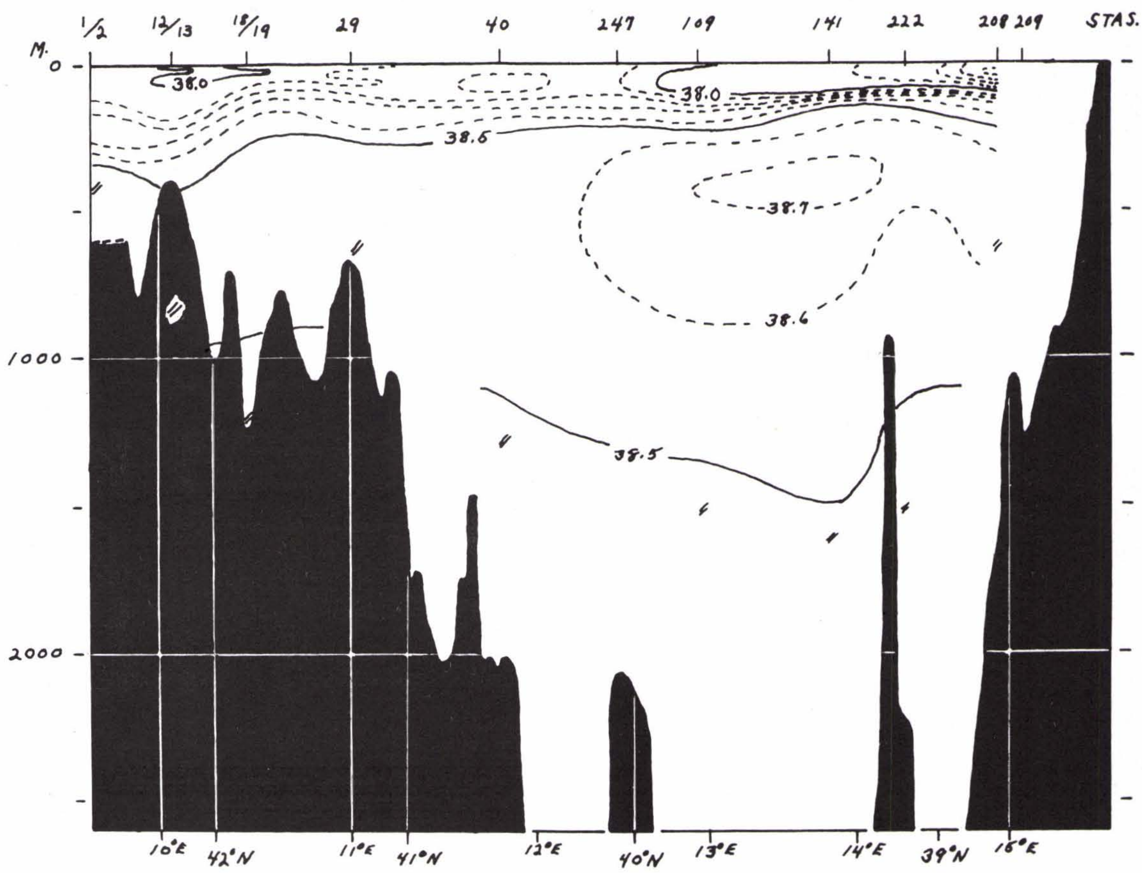

1/2 12/13 18/19 29 40 247 109 141 222 208 209 STAS.
M.
0
1000
2000
38.0
38.0
38.6
38.7
38.6
38.5
10°E 42°N 11°E 41°N 12°E 40°N 13°E 14°E 39°N 15°E

FIG. 5

FIG. 6

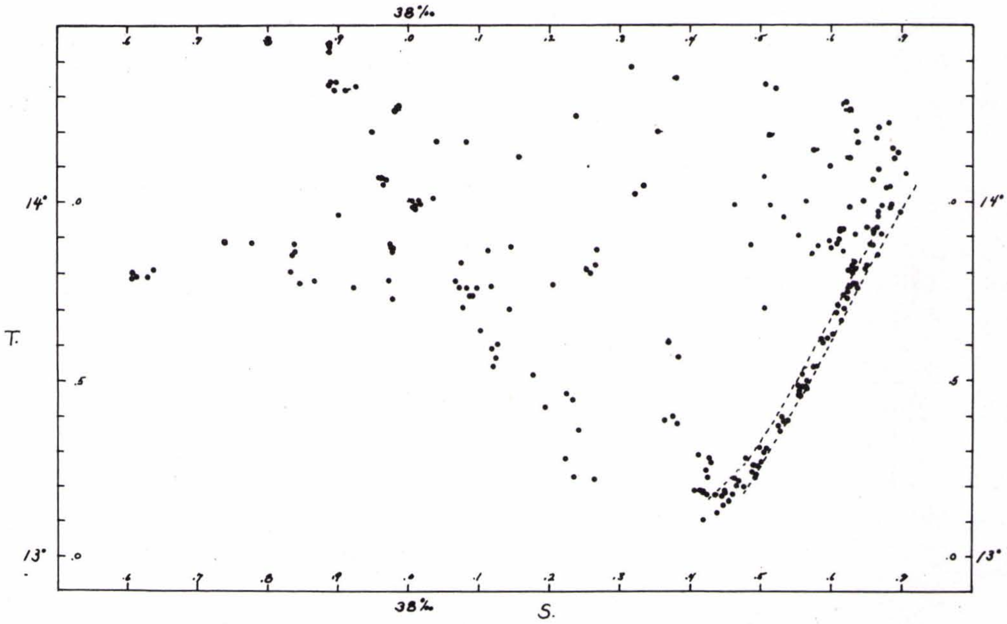


FIG. 7

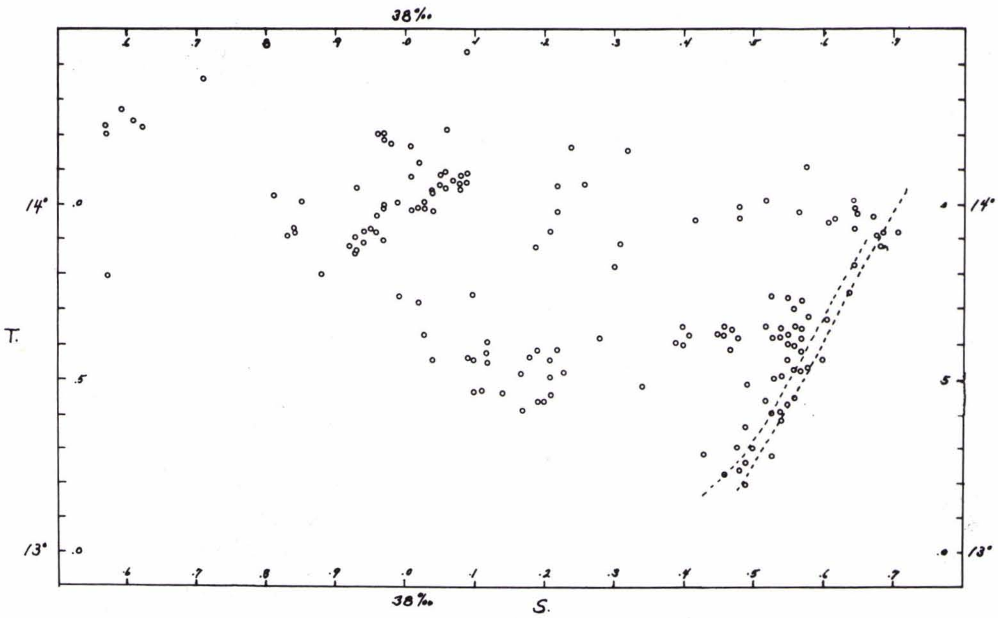


FIG. 8

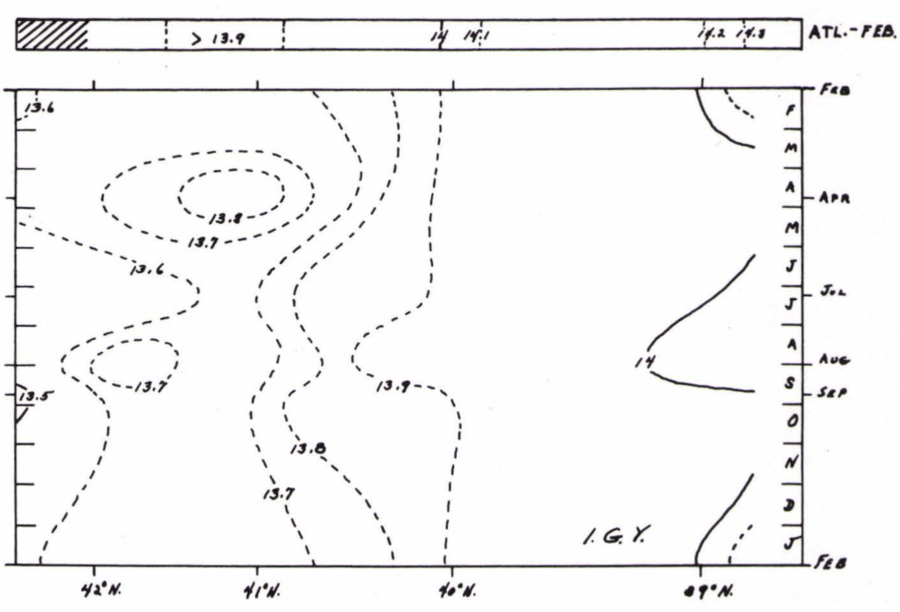
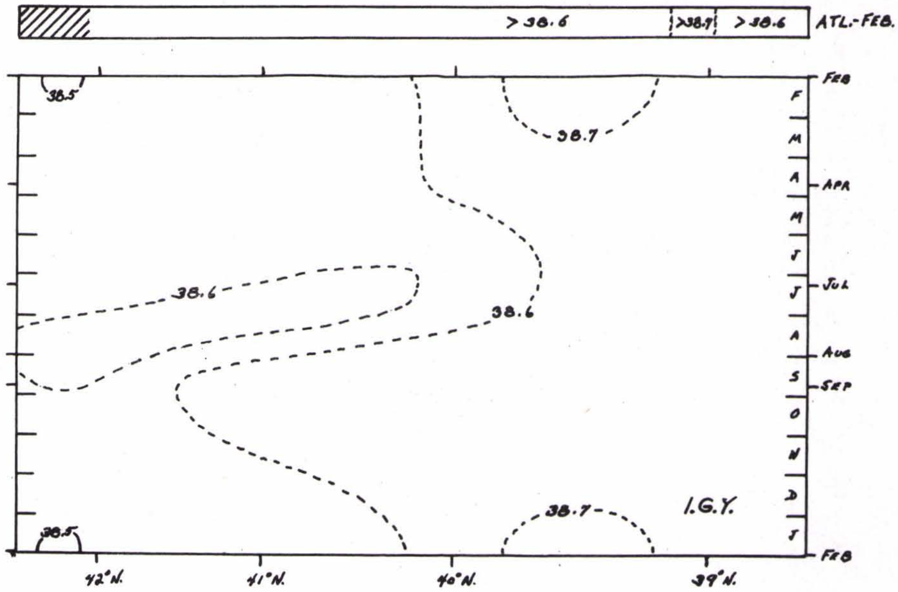


FIG. 9



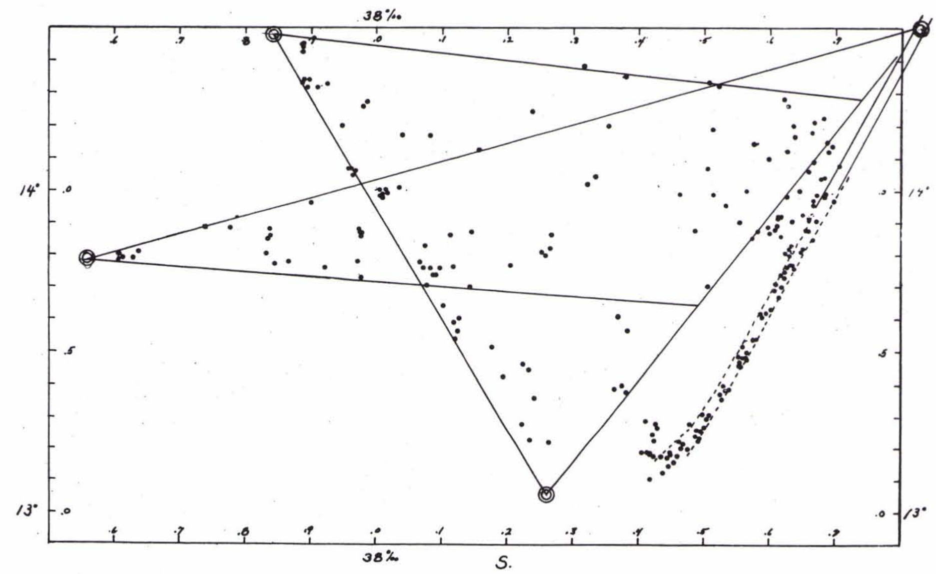


FIG. 10

FIG. 11

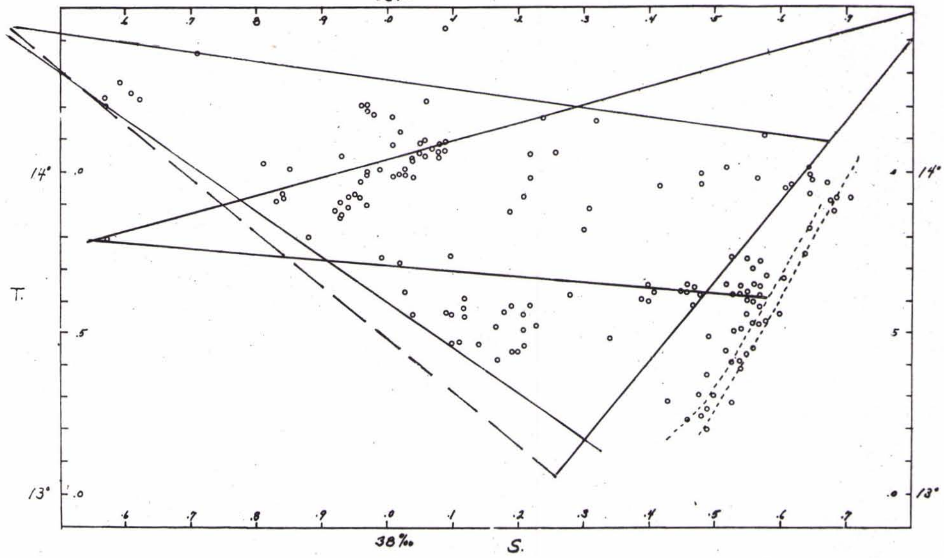


FIG. 12

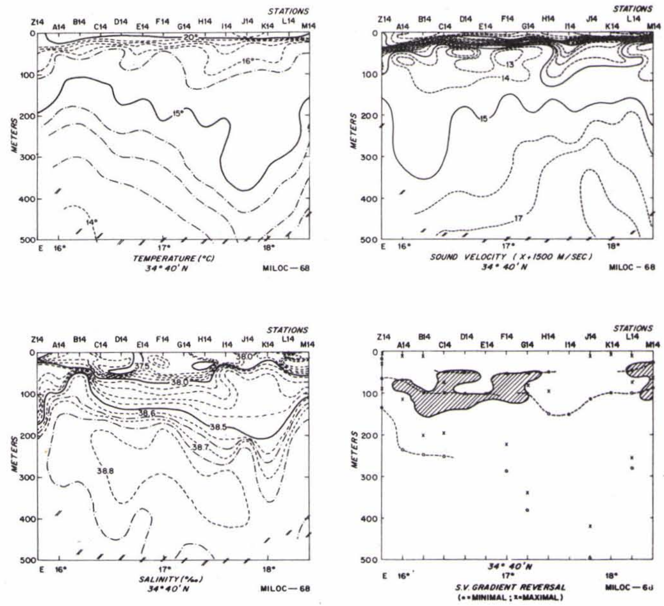


FIG. 13

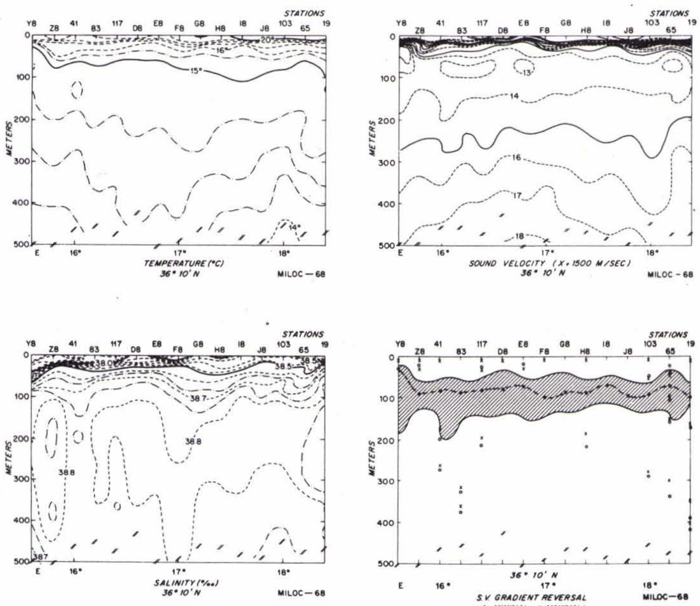


FIG. 14