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# SACLANT ASW RESEARCH CENTRE REPORT

## THE STEADY STATE OF THE STEP STRUCTURE IN THE TYRRHENIAN SEA

by

R. MOLCARD and R.I. TAIT

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NORTH ATLANTIC TREATY ORGANIZATION

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Interim Director

# The steady state of the step structure in the Tyrrhenian Sea

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**Abstract**—A deep step structure, in which mixed layers alternate with high gradient interfaces, is a characteristic feature of the Tyrrhenian Sea. Three oceanographic cruises (May 1972, May 1973 and October 1974), supported by the SACLANT ASW Research Centre, allow a precise description of this phenomenon.

Between 600 and 1500 m, under the maximum of temperature and salinity produced by the Levantine Intermediate Water, ten homogeneous layers were always found in the deepest area of the Tyrrhenian Sea.

The $\theta$–$S$ characteristic of the ten homogeneous layers are constant to within 0.01°C and 0.01‰ from one year to another. This remarkable temporal stability of the stratification observed over 3 years modifies the common hypothesis of an isolated double diffusive system which is expected to evolve in time.

## INTRODUCTION

A characteristic feature of the Tyrrhenian Sea is the presence of a persistent thermohaline step structure covering a depth range 600 to 1500 m (Molcard and Williams, 1975; Johannessen and Lee, 1974). At the Strait of Sicily the Levantine Intermediate Water flows westward, beneath the inflowing surface current, as a relatively homogeneous water mass with potential temperature, $\theta$, $\approx$ 14°C and salinity, $S$, $\approx$ 38.7‰. It sinks to its level of stability at about 400 m and spreads out above the colder and fresher ($\theta \approx 12$°C; $S \approx 38.4$‰) deep water of the western Mediterranean thus producing a maximum in the temperature and salinity profile. Over a wide area of the Tyrrhenian Sea the transition between the warm saline water and the deep water takes the form of a succession of homogeneous layers separated by relatively sharp interfaces. Similar hydrological conditions are found west of Gibraltar beneath the Mediterranean outflow (Tait and Howe, 1970; Zenk, 1970) and although there are significant differences in the stratification found in the two areas, the phenomena are clearly related.

Three oceanographic cruises, in May–June 1972, May 1973 and October 1974, have been made by the SACLANT ASW Research Centre R/V *Maria Paolina G.*, to study the step-layer zone of the Tyrrhenian Sea. A comparison of the observations from year to year has shown that the stratification as a whole remains essentially static, indicative of a lifetime greater than 3 years and therefore of steady-state conditions with respect to the transports of heat and salt.

Figure 1 shows the station positions for each year of observation. Temperature and salinity profiles were taken with Plessey 9040 STD which was calibrated in the laboratory

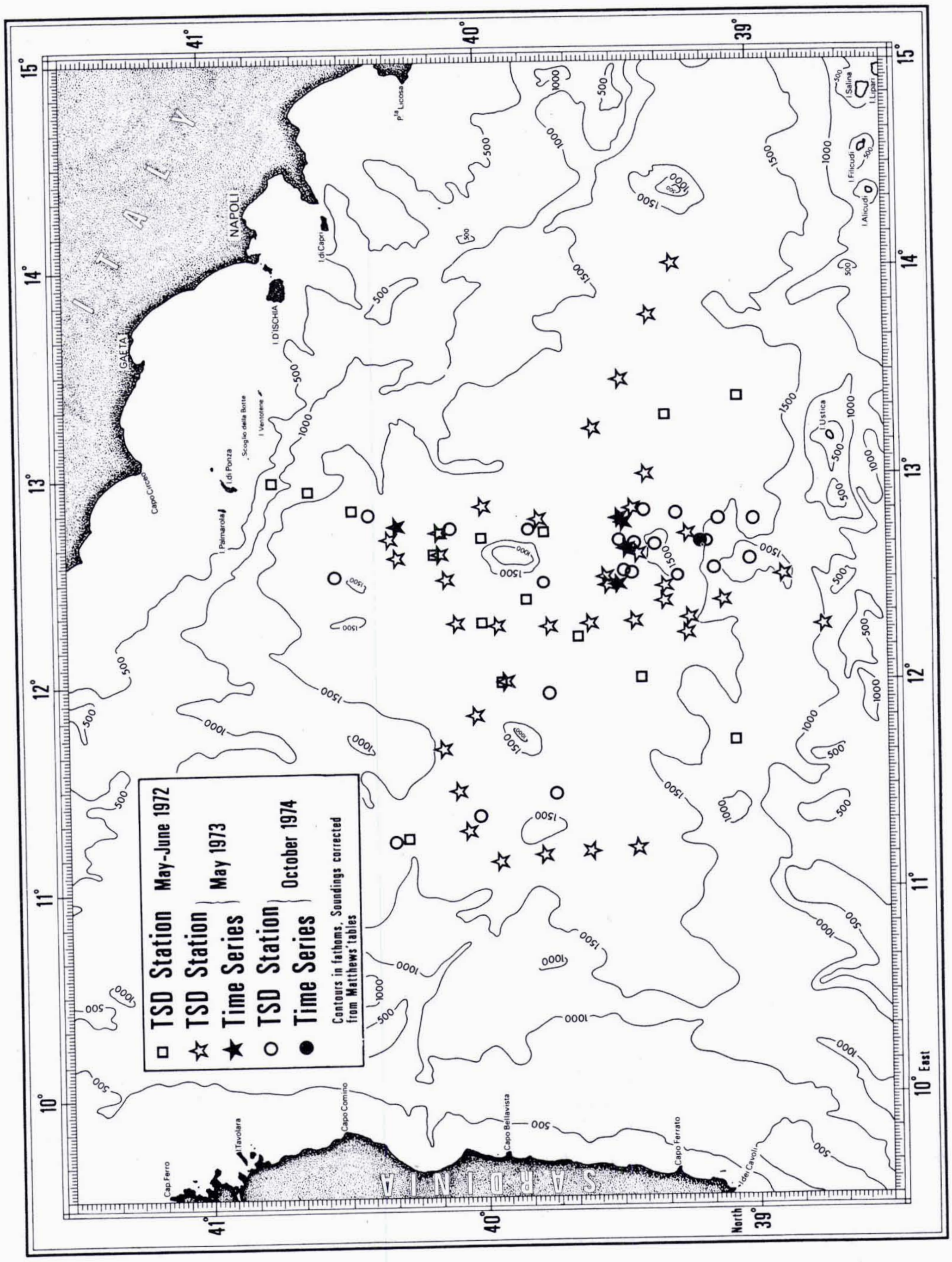


Fig. 1. Station positions for each year of observation.

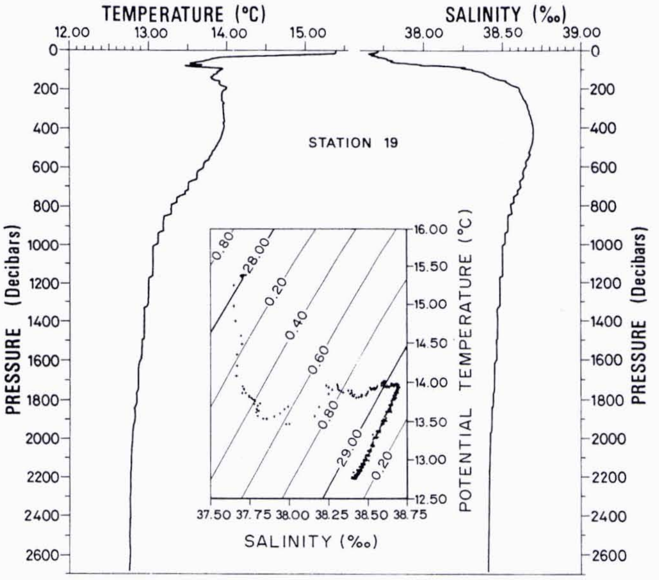


Fig. 2. Potential temperature and salinity profiles with $\theta$–$S$ diagram for Sta. 19, 1973 (39°27′N: 12°49′E).

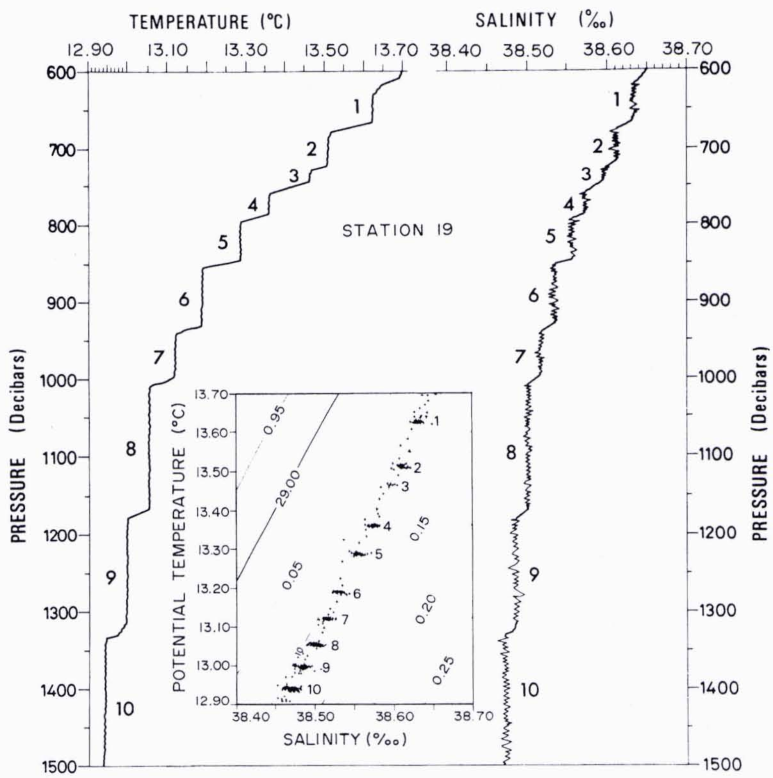


Fig. 3. Enlarged part of Fig. 2 from 600 to 1500 m.

*Table 1. θ–S histogram based on a* 0.01°C × 0.01‰ *window, with the choice of layer windows in which mean temperature and mean salinity were calculated in Table 2.*

| | 38400 | 38410 | 38420 | 38430 | 38440 | 38450 | 38460 | 38470 | 38480 | 38490 | 38500 | 38510 | 38520 | 38530 | 38540 | 38550 | 38560 | 38570 | 38580 | 38590 | 38600 | 38610 | 38620 | 38630 | 38640 | 38650 | 38660 | 38670 | 38680 | 38690 | 38700 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.900 | 0 | 0 | 0 | 0 | 1 | 7 | 25 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.910 | 0 | 0 | 0 | 0 | 2 | 6 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.920 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.930 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 16 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.940 | 0 | 0 | 0 | 0 | 0 | 1 | 15 | 32 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.950 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.960 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.970 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.980 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 12.990 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 42 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.010 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.020 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.030 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.040 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.050 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 24 | 46 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.060 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.070 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.080 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.090 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.110 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.120 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.130 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.140 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.150 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.160 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.170 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.180 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 17 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.190 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.210 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.220 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.230 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.240 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.250 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.260 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.270 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.280 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 16 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.290 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.300 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.310 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.320 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.330 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.340 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.350 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.360 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.370 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.380 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.390 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.400 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.410 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.420 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.430 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.440 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.460 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.470 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.480 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.490 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.510 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.520 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.530 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.550 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.560 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.570 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.580 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.590 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.610 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 0 | | 0 | 0 | 0 | |
| 13.620 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.630 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | |
| 13.640 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |
| 13.650 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.660 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |
| 13.670 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | |
| 13.680 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13.690 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | |
| 13.700 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

*Table 2. Mean potential temperatures $\bar{\theta}_i$ and salinities $\bar{S}_i$ with their standard deviations $\hat{\sigma}$ for each layer i*

$N_i$ is the number of data points within each layer and $\triangle\theta$ and $\triangle S$ are the differences in temperature and salinity between consecutive layers

Position 39°27′N 12°49′E

MAY 1973 (4 MAY 73) Intensity 7.1

| θ-S interval | $\bar{\theta}_i$ °C | $\hat{\sigma}\times10^3$ °C | $\Delta\theta\times10^3$ °C | $\bar{S}_i$ ‰ | $\hat{\sigma}\times10^3$ ‰ | $\Delta S\times10^3$ ‰ | $\sigma_\theta$ | $N_i$ | i |
|---|---|---|---|---|---|---|---|---|---|
| 12.930 38.460<br>12.950 38.480 | 12.941 | 3,2 | | 38.472 | 4,4 | | 29.112 | 74 | 10 |
| | | | 54 | | | 14 | | | |
| 12.980 38.475<br>13.000 38.495 | 12.995 | 2,8 | | 38.486 | 4,3 | | 29.112 | 61 | 9 |
| | | | 58 | | | 16 | | | |
| 13.040 38.490<br>13.060 38.510 | 13.053 | 2,5 | | 38.502 | 4,0 | | 29.112 | 75 | 8 |
| | | | 67 | | | 15 | | | |
| 13.110 38.510<br>13.130 38.530 | 13.120 | 2,4 | | 38.517 | 3,7 | | 29.110 | 28 | 7 |
| | | | 67 | | | 17 | | | |
| 13.180 38.525<br>13.200 38.545 | 13.187 | 2,7 | | 38.534 | 4,6 | | 29.109 | 36 | 6 |
| | | | 98 | | | 23 | | | |
| 13.270 38.545<br>13.290 38.565 | 13.285 | 2,3 | | 38.557 | 4,1 | | 29.106 | 22 | 5 |
| | | | 74 | | | 15 | | | |
| 13.350 38.560<br>13.370 38.580 | 13.359 | 2,0 | | 38.572 | 4,1 | | 29.102 | 12 | 4 |
| | | | 105 | | | 25 | | | |
| 13.450 38.590<br>13.470 38.610 | 13.464 | 2,5 | | 38.597 | 3,9 | | 29.100 | 9 | 3 |
| | | | 46 | | | 14 | | | |
| 13.500 38.600<br>13.520 38.620 | 13.510 | 3,4 | | 38.611 | 4,4 | | 29.101 | 20 | 2 |
| | | | 112 | | | 21 | | | |
| 13.615 38.620<br>13.635 38.640 | 13.622 | 3,5 | | 38.632 | 4,0 | | 29.092 | 19 | 1 |

both before and after each cruise, and checked *in situ* with Nansen casts. Details of the calibrations are given in the table below:

*STD calibration*

| Cruise | Temperature error (°C) | Salinity error (‰) |
|---|---|---|
| May 1972 | 0.0±0.01 | +0.05±0.02 |
| May 1973 | 0.0±0.01 | 0.0 ±0.02 |
| October 1974 | 0.0±0.01 | 0.0 ±0.02 |

All the data, about 200 profiles, were edited for errors due to salinity spikes filtered and subsampled every 2 dbar.

Figure 2 shows a typical potential temperature and salinity profile together with the corresponding $\theta$–$S$ diagram. The ten most pronounced layers, numbered 1 to 10, are described below.

## CHARACTERISTICS OF THE LAYERS

Expanded sections of the Fig. 2 profiles are given in Fig. 3. The temperature gradient in the homogeneous layers was essentially adiabatic within the resolution of the STD. On the $\theta$–$S$ diagram the cross accumulations (1 cross every 2 dbar) represent the homogeneous

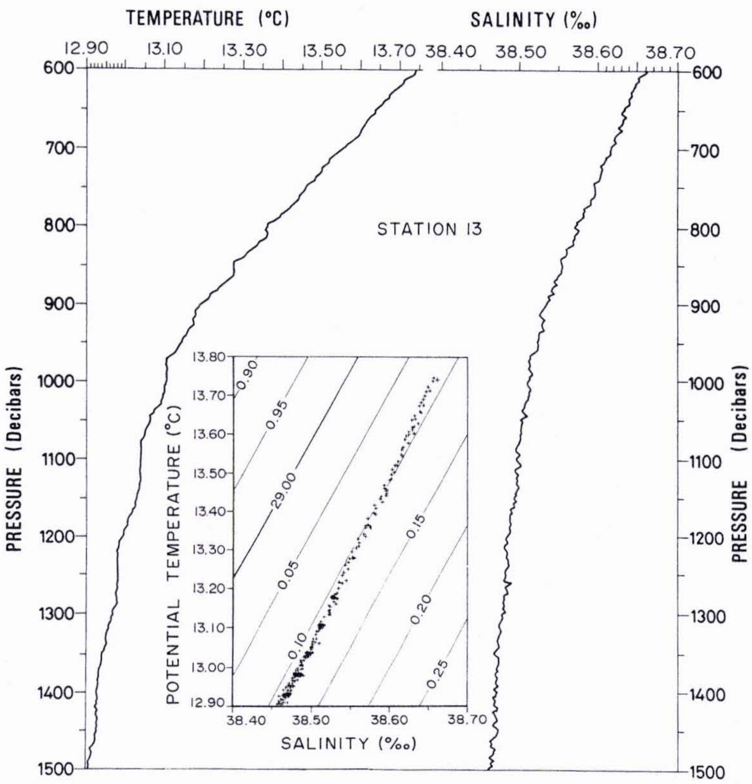


Fig. 4. Potential temperature and salinity with $\theta$–$S$ diagram from 600 to 1500 m for Sta. 13, 1973 (39°46′N; 11°10′E).

layers. Table 1 shows an histogram, in $\theta$–$S$ space, which records the number of measurements, again at 2-dbar intervals, within a 0.01‰ × 0.01°C 'window'. The ten homogeneous layers are easily identified as an accumulation of higher numbers enclosed by rectangles. A larger window, 0.02‰ × 0.02°C, was then determined in which mean values of temperature $\bar{\theta}_i$ and salinity $\bar{S}_i$ were calculated for each layer $i$, together with the standard deviations $\hat{\sigma}$ and the number of points $N_i$ within each window. The layer thickness is approximately $2N_i$ metres. The difference in temperature $\triangle\theta$ and salinity $\triangle S$ between adjacent layers, and the potential density $\sigma_\theta$ for each layer were also determined. These data are given in Table 2.

*Intensity of layering*

Let us define a 'perfect' step-layer system as one in which the interfaces have a thickness less than 2 dbar, and within the homogeneous layers, $d\theta/dz = 0$. In order to quantify, in terms of this criterion, the quality of the stratification observed on any profile, the following procedure was adopted.

The sum of temperatures at 2 dbar increments was calculated from 500 to 1500 dbar giving a quantity $Q$ (proportional to the total amount of heat in the water column). Then

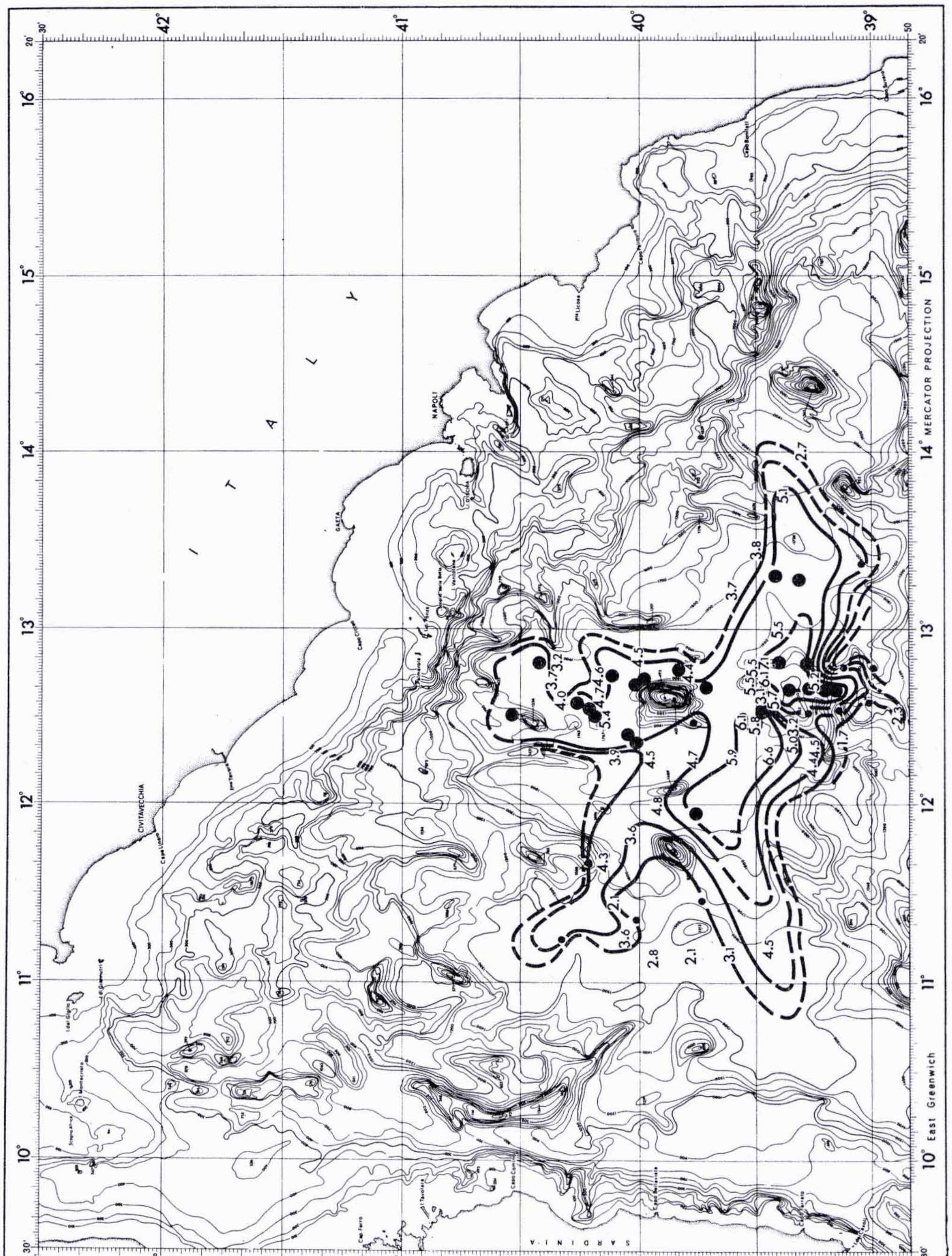


Fig. 5. Iso-intensity contours. Intervals of 1 intensity unit.

*Table 3. Layer parameters corresponding to the profile shown in Fig. 4*

Position 39°46′N 11°10′E

MAY 1973 (9 MAY 73) Intensity 2.2

| θ-S interval | $\bar{\theta}_i$ °C | $\hat{\sigma}\times10^3$ °C | $\Delta\theta\times10^3$ °C | $\bar{S}_i$ ‰ | $\hat{\sigma}\times10^3$ ‰ | $\Delta S\times10^3$ ‰ | $\sigma_\theta$ | $N_i$ | i |
|---|---|---|---|---|---|---|---|---|---|
| 12.930 38.460<br>12.950 38.480 | 12.936 | 5,1 | | 38.470 | 4,2 | | 29.112 | 28 | 10 |
| | | | 49 | | | 13 | | | |
| 12.980 38.475<br>13.000 38.495 | 12.985 | 5,2 | | 38.483 | 4,6 | | 29.112 | 25 | 9 |
| | | | 64 | | | 16 | | | |
| 13.040 38.490<br>13.060 38.510 | 13.049 | 5,4 | | 38.499 | 5,2 | | 29.111 | 11 | 8 |
| | | | 71 | | | 16 | | | |
| 13.110 38.510<br>13.130 38.530 | 13.120 | 6,6 | | 38.515 | 2,1 | | 29.108 | 4 | 7 |
| | | | 66 | | | 19 | | | |
| 13.180 38.525<br>13.200 38.545 | 13.186 | 5,0 | | 38.534 | 3,5 | | 29.110 | 4 | 6 |
| | | | 89 | | | 19 | | | |
| 13.270 38.545<br>13.290 38.565 | 13.275 | 4,6 | | 38.553 | 4,1 | | 29.105 | 11 | 5 |
| | | | 86 | | | 19 | | | |
| 13.350 38.560<br>13.370 38.580 | 13.361 | 3,9 | | 38.572 | 4,6 | | 29.102 | 10 | 4 |
| | | | 98 | | | 23 | | | |
| 13.450 38.590<br>13.470 38.610 | 13.459 | 3,8 | | 38.595 | 2,6 | | 29.099 | 6 | 3 |
| | | | 47 | | | 11 | | | |
| 13.500 38.600<br>13.520 38.620 | 13.506 | 5,3 | | 38.606 | 4,9 | | 29.097 | 5 | 2 |
| | | | 116 | | | 26 | | | |
| 13.615 38.620<br>13.635 38.640 | 13.622 | 5,5 | | 38.632 | 2,1 | | 29.093 | 5 | 1 |

*Table 4. Mean parameters for all the stations made in 1973 with intensity greater than 3*

MAY 1973 (88 Stations)

| θ-S interval | $\bar{\theta}_i$ °C | $\hat{\sigma}\times10^3$ °C | $\Delta\theta\times10^3$ °C | $\bar{S}_i$ ‰ | $\hat{\sigma}\times10^3$ ‰ | $\Delta S\times10^3$ ‰ | $\sigma_\theta$ | $N_i$ | i |
|---|---|---|---|---|---|---|---|---|---|
| 12.930 38.460<br>12.950 38.480 | 12.938 | 3.8 | | 38.471 | 4.6 | | 29.112 | 4127 | 10 |
| | | | 55 | | | 14 | | | |
| 12.980 38.475<br>13.000 38.495 | 12.993 | 4.1 | | 38.485 | 4.5 | | 29.112 | 4875 | 9 |
| | | | 59 | | | 15 | | | |
| 13.040 38.490<br>13.060 38.510 | 13.052 | 3.6 | | 38.500 | 4.5 | | 29.111 | 6306 | 8 |
| | | | 65 | | | 17 | | | |
| 13.110 38.510<br>13.130 38.530 | 13.117 | 3.4 | | 38.517 | 4.0 | | 29.111 | 2058 | 7 |
| | | | 68 | | | 16 | | | |
| 13.180 38.525<br>13.200 38.545 | 13.185 | 3.7 | | 38.533 | 4.4 | | 29.109 | 2305 | 6 |
| | | | 99 | | | 22 | | | |
| 13.270 38.545<br>13.290 38.565 | 13.284 | 4.1 | | 38.555 | 4.8 | | 29.105 | 1437 | 5 |
| | | | 78 | | | 17 | | | |
| 13.350 38.560<br>13.370 38.580 | 13.362 | 4.3 | | 38.572 | 4.5 | | 29.102 | 993 | 4 |
| | | | 99 | | | 25 | | | |
| 13.450 38.590<br>13.470 38.610 | 13.461 | 4.6 | | 38.597 | 4.6 | | 29.100 | 543 | 3 |
| | | | 50 | | | 11 | | | |
| 13.500 38.600<br>13.520 38.620 | 13.511 | 4.8 | | 38.608 | 4.8 | | 29.098 | 565 | 2 |
| | | | 112 | | | 22 | | | |
| 13.615 38.620<br>13.635 38.640 | 13.623 | 5.3 | | 38.630 | 4.6 | | 29.091 | 604 | 1 |

*Table 5. Stability calculation for adjacent layers which characteristics are determined from Table 4*

| Layer No | Pressure (db) P | $\sigma_{\theta,S,P}$ | $\Delta\sigma$ $\times 10^{+3}$ |
|---|---|---|---|
| 10 | 1335 | 34.989 | 2 |
| 9 | 1335 | 34.987 | |
| 9 | 1170 | 34.270 | 3 |
| 8 | 1170 | 34.267 | |
| 8 | 1000 | 33.528 | 3 |
| 7 | 1000 | 33.525 | |
| 7 | 940 | 33.263 | 2 |
| 6 | 940 | 33.261 | |
| 6 | 850 | 32.867 | 6 |
| 5 | 850 | 32.861 | |
| 5 | 800 | 32.642 | 4 |
| 4 | 800 | 32.638 | |
| 4 | 750 | 32.419 | 4 |
| 3 | 750 | 32.415 | |
| 3 | 730 | 32.327 | 2 |
| 2 | 730 | 32.325 | |
| 2 | 675 | 32.084 | 8 |
| 1 | 675 | 32.076 | |

for the ten layers, the sum of the products $\bar{\theta}_i N_i$ was determined and divided by $Q$ to give a number representative of the quality of the layer system observed: a perfect step structure would have a value of 1 while a profile devoid of steps would have a much lower number. We define the layer intensity $I$ as this quantity multiplied by 10. Thus:

$$I = \frac{10}{Q} \sum_{i=1}^{i=10} \theta_i N_i.$$

The profile shown in Fig. 3 and analyzed in Tables 1 and 2 has an intensity of 7.1 indicating a good series of step layers. In contrast Fig. 4 and Table 3 show the situation for an ill-defined profile with an intensity of 2.2. Salinity may also be used to find $I$, and values so obtained agree with those calculated using temperature to within $\pm 0.2$. However, as the salinity profiles were subject to higher noise levels, temperature was used for all estimates of intensity.

The most extensive survey of the Tyrrhenian Sea was made during the 1973 cruise, when $\approx 60$ stations positions were worked over a wide area (Fig. 1). For each station the intensity was calculated as outlined above. Iso-intensity contours were then drawn on a bathymetric chart of the area (Fig. 5). As corroborated by other measurements, the step-layer zone was confined to the deepest part of the Tyrrhenian Sea extending over an area of about 4000 square miles, a similar result to that reported for the Mediterranean outflow step layers (Tait and Howe, 1970). Even though the deepest layers were some 1500 m from the bottom the correlation of intensity with the bottom contours is striking, particularly near the boundaries.

Within the high-intensity zone the layers were found to have a high horizontal coherence, and no discontinuities were observed, indicating a continuous stratification extending over distances of the order of 60 miles. This result is again in general agreement with the Mediterranean outflow observations (Elliott, Howe and Tait, 1974).

Table 4 gives the mean values obtained from all of the 1973 stations whose intensity was greater than 3. The agreement with Table 2 illustrates the uniformity of $\theta$ and $S$ in the horizontal plain.

Position 39°47'N 12°46'E

MAY 1972 (11 MAY 72) Intensity 6.8

| θ-S interval | $\bar{\theta}_i$ °C | $\hat{\sigma}\times10^3$ °C | $\Delta\theta\times10^3$ °C | $\bar{S}_i$ ‰ | $\hat{\sigma}\times10^3$ ‰ | $\Delta S\times10^3$ ‰ | $\sigma_\theta$ | $N_i$ | i |
|---|---|---|---|---|---|---|---|---|---|
| 12.930 38.500<br>12.950 38.520 | 12.934 | 2,3 | | 38.507 | 2,3 | | 29.141 | 24 | 10 |
| | | | 53 | | | 14 | | | |
| 12.980 38.510<br>13.000 38.530 | 12.987 | 1,6 | | 38.521 | 2,9 | | 29.141 | 89 | 9 |
| | | | 62 | | | 17 | | | |
| 13.040 38.530<br>13.060 38.550 | 13.049 | 1,2 | | 38.538 | 2,5 | | 29.141 | 82 | 8 |
| | | | 71 | | | 17 | | | |
| 13.110 38.550<br>13.130 38.570 | 13.120 | 0,8 | | 38.555 | 2,1 | | 29.140 | 36 | 7 |
| | | | 69 | | | 19 | | | |
| 13.170 38.560<br>13.190 38.580 | 13.189 | 0,4 | | 38.574 | 2,6 | | 19.140 | 22 | 6 |
| | | | 102 | | | 23 | | | |
| 13.280 38.580<br>13.300 38.600 | 13.291 | 2,5 | | 38.597 | 1,3 | | 29.137 | 24 | 5 |
| | | | 81 | | | 18 | | | |
| 13.370 38.600<br>13.390 38.620 | 13.372 | 1,3 | | 38.615 | 2,7 | | 19.133 | 22 | 4 |
| | | | 90 | | | 22 | | | |
| 13.450 38.630<br>13.470 38.650 | 13.462 | 1,5 | | 38.637 | 2,4 | | 19.131 | 17 | 3 |
| | | | 68 | | | 16 | | | |
| 13.520 38.640<br>13.540 38.660 | 13.530 | 1,8 | | 38.653 | 2,8 | | 29.129 | 15 | 2 |
| | | | 113 | | | 27 | | | |
| 13.630 38.670<br>13.650 38.690 | 13.643 | 3,3 | | 38.680 | 1,8 | | 29.125 | 14 | 1 |

Position 40°25'N 12°49'E

OCTOBER 1974 (7 OCT 74) Intensity 7.7

| θ-S interval | $\bar{\theta}_i$ °C | $\hat{\sigma}\times10^3$ °C | $\Delta\theta\times10^3$ °C | $\bar{S}_i$ ‰ | $\hat{\sigma}\times10^3$ ‰ | $\Delta S\times10^3$ ‰ | $\sigma_\theta$ | $N_i$ | i |
|---|---|---|---|---|---|---|---|---|---|
| 12.940 38.470<br>12.960 38.490 | 12.957 | 1,3 | | 38.475 | 2,5 | | 29.112 | 66 | 10 |
| | | | 55 | | | 14 | | | |
| 13.000 38.480<br>13.020 38.500 | 13.012 | 1,3 | | 38.489 | 2,5 | | 29.111 | 63 | 9 |
| | | | 54 | | | 13 | | | |
| 13.050 38.490<br>13.070 38.510 | 13.066 | 1,9 | | 38.502 | 2,9 | | 29.110 | 76 | 8 |
| | | | 68 | | | 17 | | | |
| 13.130 38.510<br>13.150 38.530 | 13.134 | 1,9 | | 38.519 | 2,9 | | 29.109 | 32 | 7 |
| | | | 63 | | | 16 | | | |
| 13.180 38.530<br>13.200 38.550 | 13.197 | 1,5 | | 38.535 | 2,5 | | 29.108 | 41 | 6 |
| | | | 99 | | | 21 | | | |
| 13.290 38.545<br>13.310 38.565 | 13.296 | 1,6 | | 38.556 | 2,4 | | 29.103 | 27 | 5 |
| | | | 81 | | | 19 | | | |
| 13.370 38.565<br>13.390 38.585 | 13.377 | 2,1 | | 38.575 | 3,8 | | 29.101 | 28 | 4 |
| | | | 112 | | | 25 | | | |
| 13.480 38.590<br>13.500 38.610 | 13.489 | 1,1 | | 38.600 | 3,1 | | 29.096 | 18 | 3 |
| | | | 42 | | | 10 | | | |
| 13.520 38.600<br>13.540 38.620 | 13.531 | 1,7 | | 38.610 | 3,1 | | 29.095 | 16 | 2 |
| | | | 116 | | | 27 | | | |
| 13.630 38.625<br>13.658 38.645 | 13.647 | 1,8 | | 38.637 | 3,3 | | 29.091 | 23 | 1 |

*Table 6. Layer parameters typical of the situation of each year of observation, corresponding to the composite θS diagram of Fig. 6. (See also Table 2)*

Data points from the 1972 and 1974 cruises are also included in Fig. 5 as solid circles. The larger circles represent stations whose intensity is greater than or equal to 5 while the smaller ones correspond to $5 > I > 2$. The general agreement with the 1973 contours indicates the overall permanency of the step layer zone.

## INTERFACIAL STABILITY

At the depths involved, potential density is an inaccurate indicator of the static stability (ELLIOTT, HOWE and TAIT, 1974). In order to evaluate stability more accurately the *in situ* densities, $\sigma_{S\theta P}$, were calculated for each pair of adjacent layers at the same pressure as their common interface. The values $S$ and $\theta$ were taken from Table 4. Confidence intervals for the estimation of the means are less than $10^{-3}$°C and $10^{-3}$‰ and the corresponding confidence intervals for $\sigma_{S\theta P}$ are of the same order. The third decimals on the sigma values listed in Table 5 are therefore significant. (The use of the potential temperature does not affect the calculation of $\triangle\sigma$ which depends mainly on $\triangle\theta$.) We can conclude that all the layers are statically stable. Differences of density for adjacent layers, adjusted to the same pressure, are of the order of $4 \times 10^{-6}$ g/cm$^3$, which for an average interface thickness of 10 m gives a Brünt–Väisälä frequency of $(1 \pm 0.2)$ cycle/hour.

### *Comparison over a 3-year period*

The observations made in 1972, 1973 and 1974, in which step layers of appreciable intensity could always be found within the general area delineated in Fig. 5, have enabled the situation to be compared from year to year. For each year's results no significant

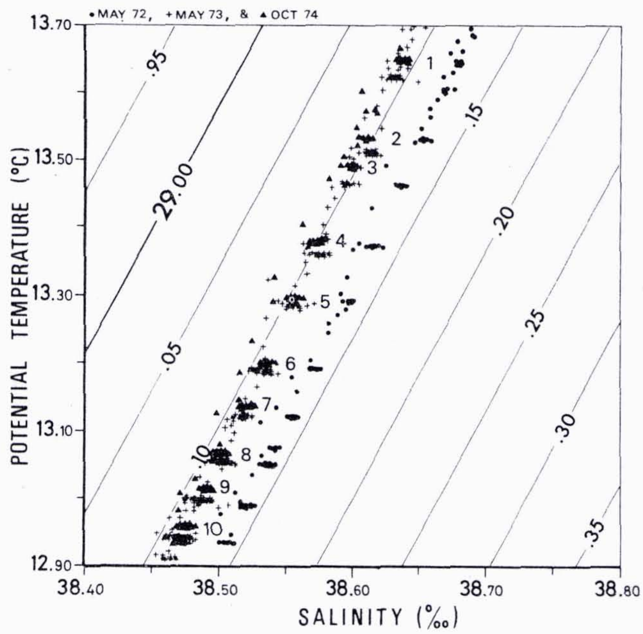


Fig. 6. Composite $\theta$–$S$ diagram of three stations, covering a period of 3 years.

spatial change in $\theta$–$S$ was observed (compare Tables 2 and 4), hence essentially any set of values representing one station from each year could be used for comparison.

Table 6 gives two such sets where the results for 1972 and 1974 may be compared with the 1973 station already discussed. It will be noted that the $\theta$–$S$ windows differ slightly between the three data sets. This is because in each case the window was chosen to encompass the mixed layer, but these differences are small and of the same order as the experimental error.

A comparison of the $\theta$ values shows the mean difference over the 3 years to be 0.013°C, i.e. within the experimental error and less than the interfacial temperature difference by a factor of about 6. This implies that we are indeed looking at the same mixed layers from year to year. Bearing in mind that the salinity figures for 1972 require a $-0.05‰$ calibration correction, a similar result is obtained using the $S$ values. In fact between 1973 and 1974 the salinity differences are negligible.

Figure 6 gives the 3-year composite $\theta$–$S$ diagram where the salinity offset for 1972 is clearly shown. From the point of view of density a more appropriate and legitimate correction for the 1972 salinity values would be $-0.04‰$. The marked accumulation of points representing the ten homogeneous layers illustrates the persistence of the stratification.

Two conclusions may be drawn from the above results: either the layer system remains essentially unchanged over a period of at least 3 years, or, if the stratification does not persist from year to year, then the layers must re-form at preferred values of temperature and salinity.

## DISCUSSION

If the Tyrrhenian Sea step structure has an observed lifetime of 3 years it is likely to persist over a much longer period. In any case, the layers must be considered to be in equilibrium with respect to the transports of salt and heat. Much evidence has been put forward in support of salt fingering as the basic mechanism responsible for the step structures (TURNER, 1967; STERN and TURNER, 1969). Using an optical technique, evidence for the existence of salt fingers, associated with the step structure, was in fact obtained during the 1973 cruise. It has been shown by MOLCARD and WILLIAMS (1975) and WILLIAMS (1975) that they are correlated with the microstructure within the interfaces. Hence whereas the double diffusion theory may adequately describe the situation within the interfaces its correlation with the deep convective layers wherein the temperature remains constant has yet to be established.

During the 1974 cruise, vertical and horizontal current measurements were also made. The results of this work, shortly to be reported, are expected to show that the advection processes, associated with internal wave activity, play a significant role in the maintenance of these homogeneous layers.

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