DEEP SEA CIRCULATION IN THE ALBORAN BASIN

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ABSTRACT

Alboran Sea circulation from 220 m to 1100 m is studied. Interaction between three types of water masses in this area causes the complicated flow pattern. Atlantic water flowing as a jet through Gibraltar Straits forms anticyclonic gyre to the depth of 200 m and its features are now well documented. A few works based on geostropic calculations and Bernoulli equation treat the deep flow. Nine free floats were released in different depths and locations from January to May and acoustically tracked every two hours for the period from 40 to 90 days. The acoustical tracking was done from three listening stations moored in the area. The tracks of the floats in all depths from 220 m to 1100 m revealed broad and slow (approx. 2 cm/sec) cyclonic circulation located under the surface anticyclonic gyre. Part of the flow, following the bottom topography, turns near the southern boundary as a jet (approx 10cm/sec) to Gibraltar and part turns to the east following the southern boundary of the deep channel to the Alboran Island. CTD data are used to identify water masses.

INTRODUCTION

The Alboran sea is an area to the east of Gibraltar Straits. Being the part of Mediterranean Sea the main source of dynamical forcing is the gradient of gravity geopotential due to the eccessive evaporation in the Mediterranean area. As a result, relatively fresh Atlantic water flows through Gibraltar Straits as a jet into Alboran, and deeper more saline and warm water of Mediterranean origin flows out of straits into the Atlantic.

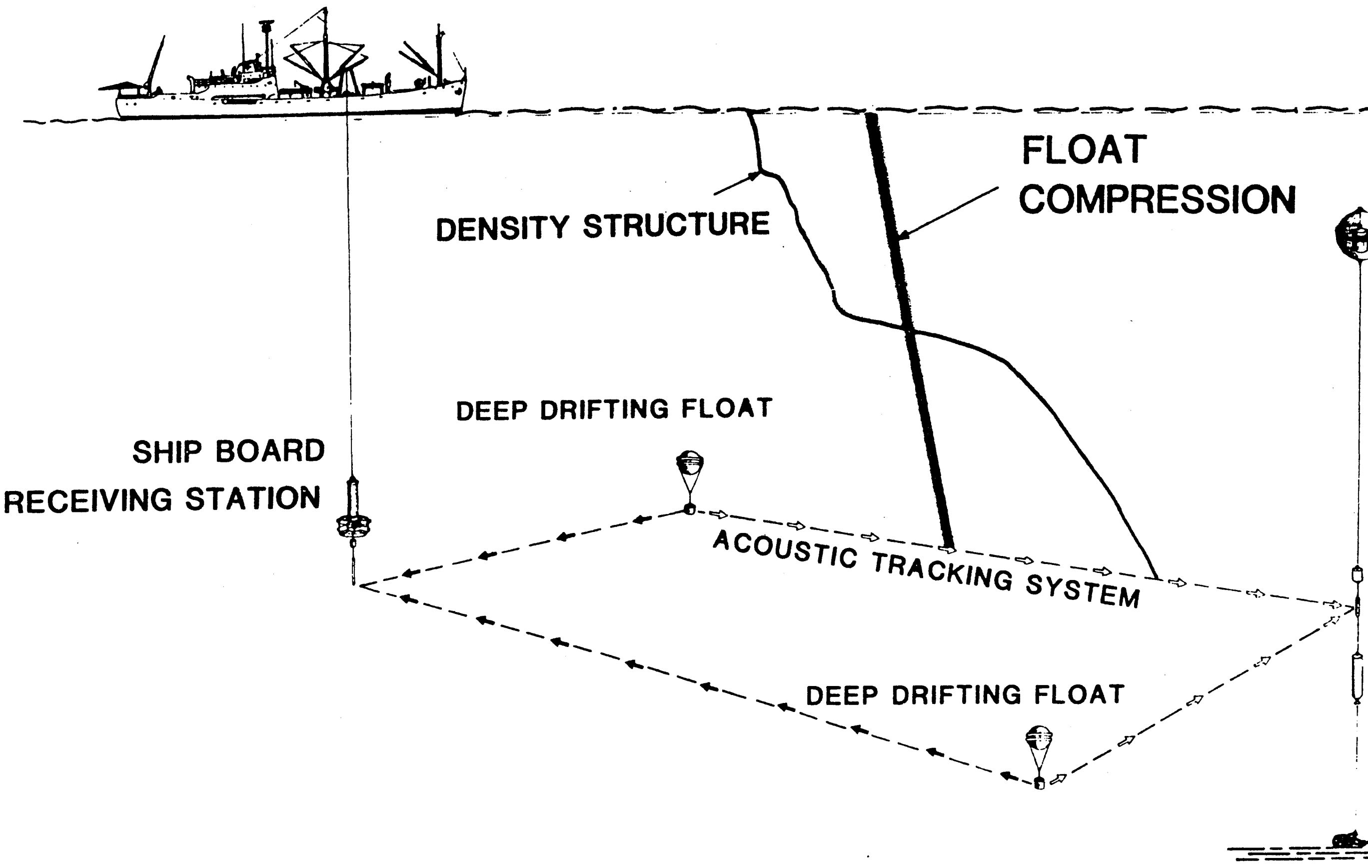

Fig. 1 Schematic diagram for deployment of equipment and the tracking of floats from listening stations. Density structure and compression of floats establish the deployment depth.

The interaction between the different water types in the Alboran, in highly energetic environment, causes a large variation of oceanographic features. Three types of water are distinguished, Atlantic, Levantine and deep Mediterranean.

Atlantic water in a top layer of approx. 150 m flows into Alboran as a jet of 30 km width with the speed of several knots/hour and characteristics of Atlantic water 36.00-36.30°/₀₀ and variable temp. depending on the season. This layer is very energetic. It creates anticyclonic circulation in the southern part of the Alboran. Its extension and depth are quite variable, more stable in the summer than winter. It is well documented already in older literature (1), (2), (3), (4), with laboratory (5) and numerical (6) modelling and is clearly visible on the satellite maps of the sea surface temperature (7).

Under the surface layer of 150 m is the water of Mediterranean origin, intermediate Levantine water with characteristic maximum of potent. temp. θ = 13.13°C and salinity of 38.475 - 38.480°/₀₀ around 300 - 600m, and deeper the deep med. water originating in western Mediterranean, less saline but colder.

Only a few papers address the deep flow (8), (9). Stommel and Bryden from CTD geostrophic calculation found the enhanced flow near the southern boundary. Our work is devoted to deep water circulation.

EXPERIMENTAL PART*

To determine the circulation pattern, free floats (Swallow type) were used. They were deployed in different locations and depths. Tracking was done automatically from three moored listening stations. Float's electronics is housed in glass sphere, cylindrical transducer is hanging outside of it. It transmits information about depth and can be released and retrieved by the acoustical command from the ship.

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* Part of equipment was constructed at SACLANT CENTER (floats) and part at COB-Brest (listening stations). Basic electronic design is of Woods Hole origin.

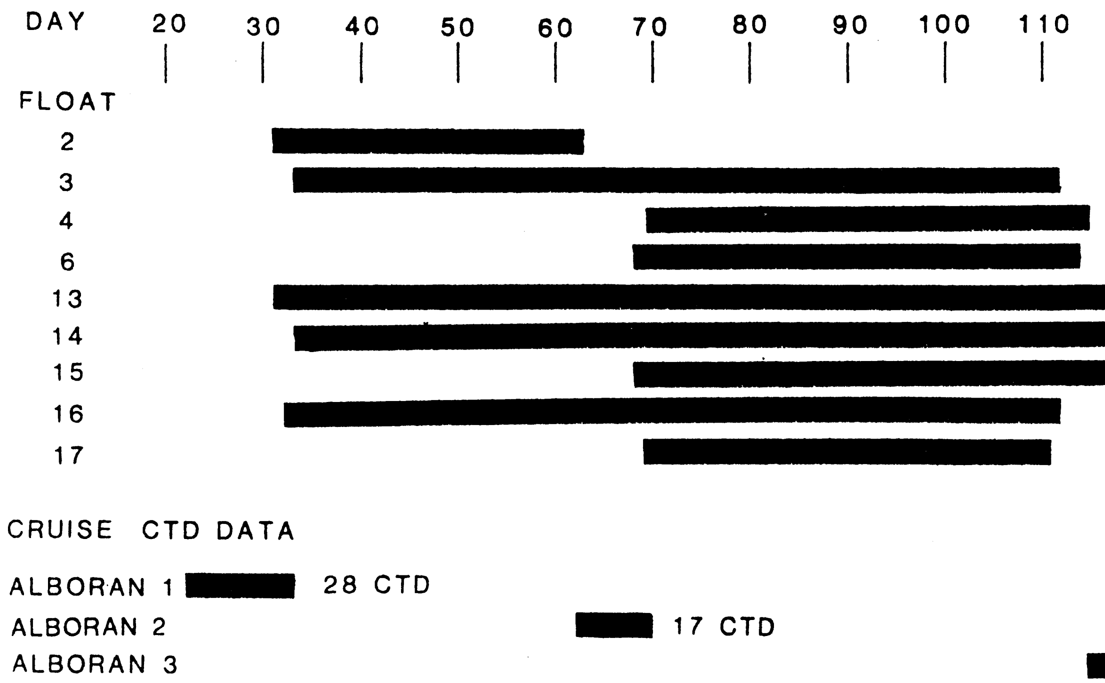

Fig. 2 Deployment schedule for floats and CTD data. Days are the Julian days. Change of the depth is due to the water penetration into releaser and subsequent change of the float density.

Listening stations were deployed on underwater moorings at 400 m depth. Its vertical array of four hydrophones receives signal every 25 msec and compares it with the original, stored in microprocessor memory. Four highest correlations are recorded on mag. tape every 4 minutes. All floats and stations are synchronized. Each float transmits at 2 hours interval the signal lasting 20 sec in frequency sweep from 1560 Hz to 1570 Hz. The transmissions of different floats are separated by 10 min interval. Delay in arrival time is proportional to distance of the float from station and simultaneously listening from three stations establishes the float position, Fig. 1.

Depth of the float deployment is checked by the listening station located on the ship. First five transmissions are repetitive with the delay of the second signal proportional to the depth. After deployment period the floats can be located from the ship and acoustically released to the surface.

Nine floats were released in two periods from the end of January till the beginning of May 82 (3 months). The schedule of deployment of floats and CTD measurements are on Figure 2.

RESULTS

Deployment location, depth and tracks of the floats are on the fig. 3.

All floats from 220 m to 1100 m show the broad cyclonic circulation. Motion is slow with the average approx. 2 cm/sec. Interesting point is the southern boundary. Floats 13, 14 are moving in the jet along the southern bottom slope to Gibraltar with the speed approx. 10 cm/sec. Floats 16, 17 are moving in the opposite direction to the Alboran Island. The dashed line for the float 16 (in 1100 m) schematically shows distance from listening station B because in these positions stations C and A are in an acoustic shadow. Float 3 is at southern boundary in a stagnation point. It is not clear if the float 2, moving in the northern part would move to Gibraltar or turn south. It is interesting to look at the surface layer above cyclonic circulation.

Satellite data show considerable changes of surface temperature structure. There are visible variations in a few days. Data from our casts from the end of January and end of April show the existence of extended and more persistent anticyclonic gyre. In the vertical

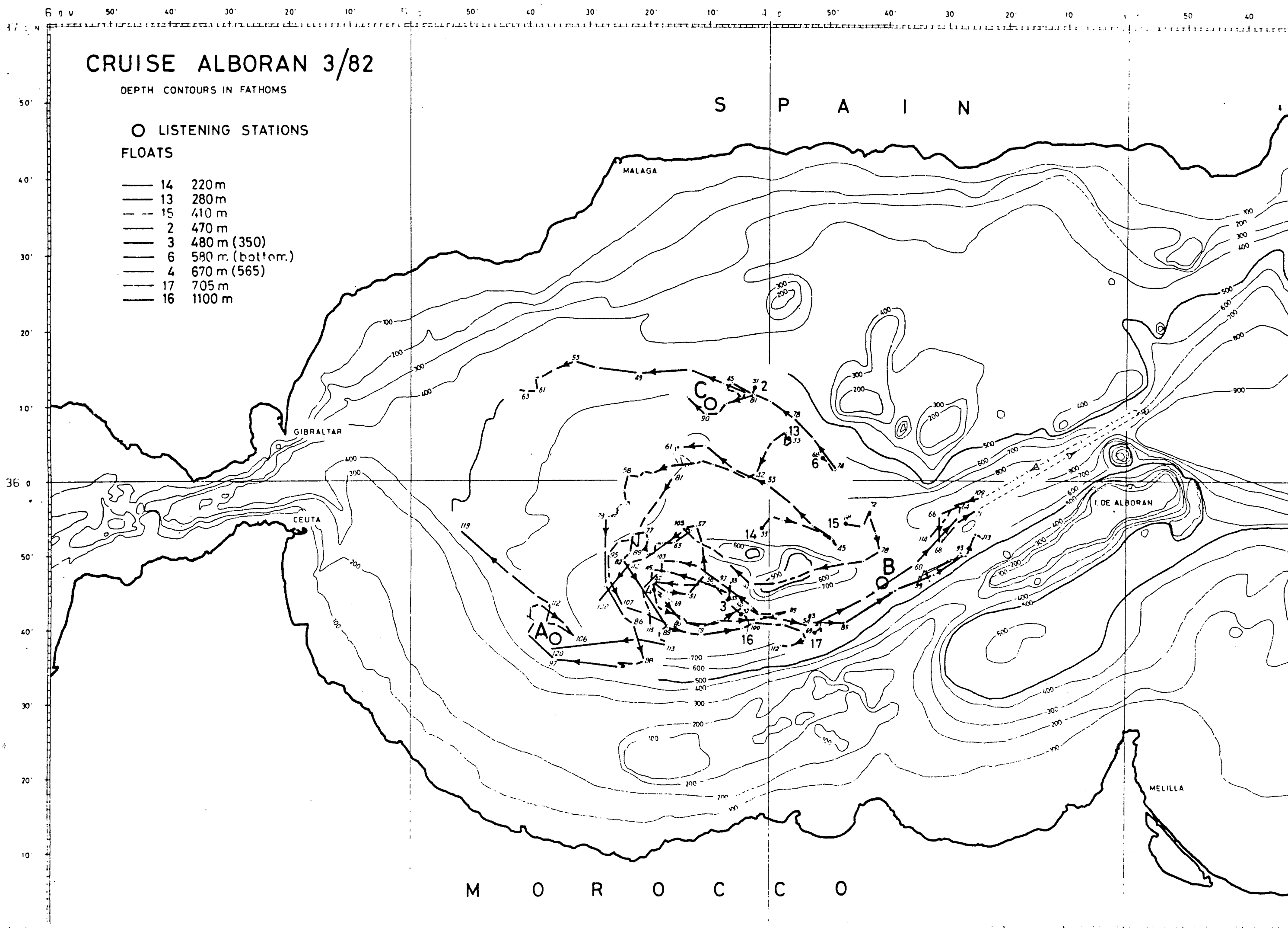

Fig. 3 Tracks of the floats: Deployment depth and location are marked by numbers. Numbers along the tracks show the days of Julian Calendar. The letters A, B, C mark the positions of the listening stations.

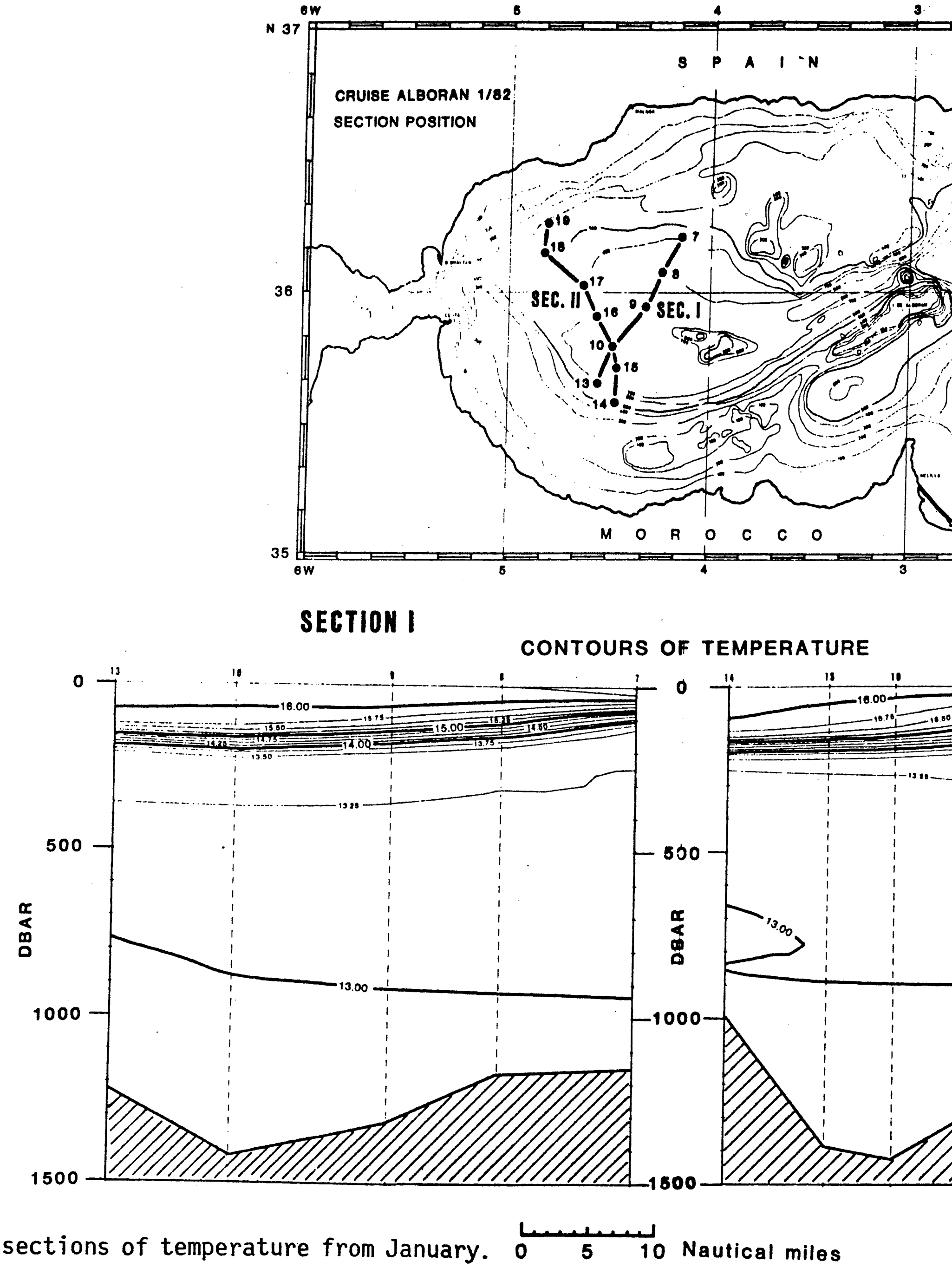

Fig. 4 Vertical sections of temperature from January.

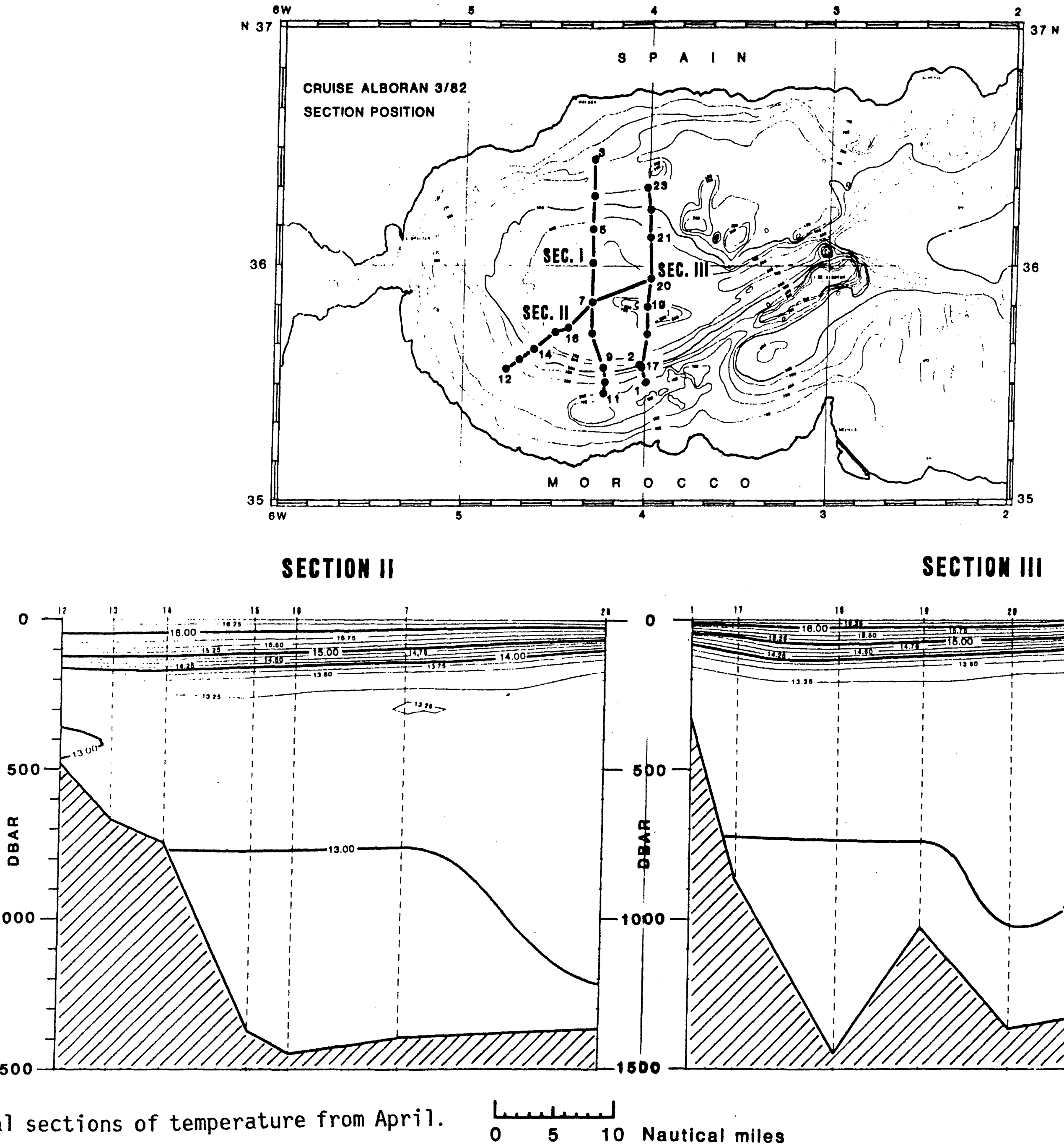

Fig. 5 Vertical sections of temperature from April.

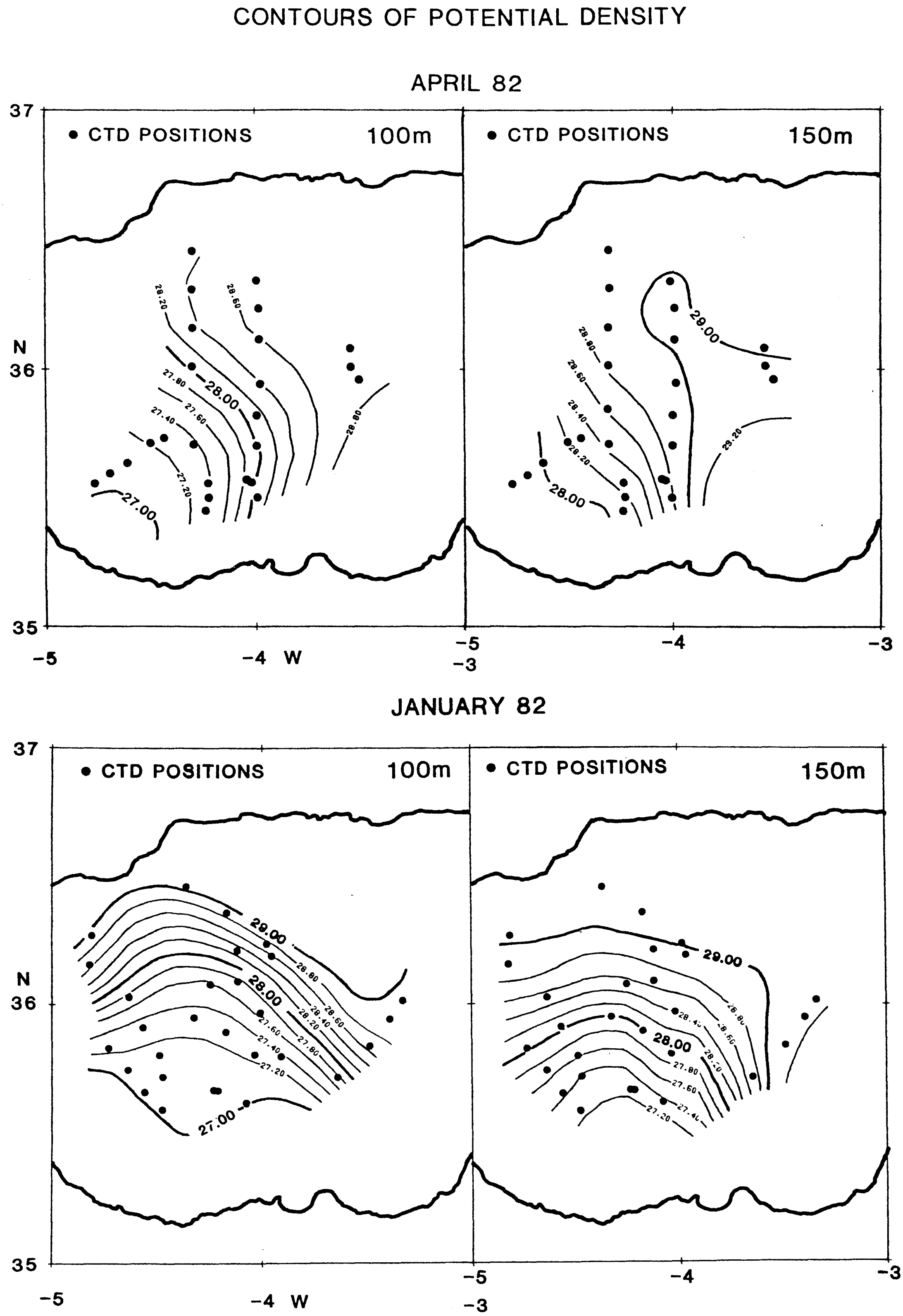

Fig. 6 Contours of potential density from April and January.

sections of temperature, there is a considerable deepening of isotherms, Fig. 4, Fig. 5. Even more pronounced effect is visible in the potential density contours, Fig. 6.

CONCLUSION

The two-layer division of Alboran water masses is extended also to its dynamics. It is possible that satellite sea surface temperature data indicated the changes in a very top layer of a few tens of meters while broader anticyclonic circulation extended to the depths of about 200 m.

From 220 m to 1100 the weak cyclonic circulation persisted for the period of measurements (3 months). The enhancement of currents appeared near the southern boundary along the sloping topography. In agreement with Stommel and Bryden there is one part of the current going to Gibraltar, but the other, weaker one, turns to Alboran Island.

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