THE SUBTROPICAL UNDERWATER OF THE EASTERN GULF OF MEXICO

By Reed S. Armstrong*

The R/V "Geronimo," Bureau of Commercial Fisheries, Galveston, Tex., occupied 20 hydrographic stations over the continental slope off the Florida Gulf coast between June 30 and July 13, 1966. One purpose of the cruise was to examine the SUW (Subtropical Underwater), which is characterized by a subsurface salinity maximum. This water enters the Gulf of Mexico through the Yucatan Channel and is the major component of the upper waters over a large portion of the Gulf.

The predominant features in July were the extensive penetration of the SUW into the part of the Gulf surveyed and the presence of an intense core far to the north (figs. 1 and 2). The circulation of the SUW can be deduced from the topography of the salinity maximum layer (fig. 3). In the eastern portion, a flow to the south southeast is indicated. A clockwise curvature prevails in the north producing an area of convergence and a deepening of the water, thereby increasing the persistence of the high-salinity core. Another clockwise curvature is apparent in the southern part of the sampling area.

The circulation in the eastern Gulf of Mexico has by no means been established, but what now seems to be one of the best representations was prepared by Drummond and Austin, 1958[1/]). They showed a tongue-shaped flow entering the Gulf through the Yucatan Channel, spreading out through all the eastern Gulf, and then exiting through the Florida Straits. Superimposed on this flow was a separate, clockwise-circulating cell in the northeast Gulf--and another clockwise cell off the western tip of Cuba. Presumably, these gyres and those noted from data gathered from the Geronimo are the same. Our information indicates, however, that the area of the northern gyre is at times more restricted.

About a month after the Geronimo cruise, the R/V "Alaminos" (Texas A&M Research Foundation) cruised in the eastern Gulf of Mexico (August 4-18, 1966). Waters with salinity maximums >36.4 p.p.t. (parts per thousand) were encountered at 43 stations in the eastern Gulf. The water of 36.7-p.p.t. salinity (to the north) was a separate cell and its center was at least 83 km. southwest of its position during the Geronimo cruise (fig. 4). The high-salinity water (>36.6 p.p.t.) in the south (fig. 2) was displaced to the south about 110 km. by the time of the Alaminos cruise.

The circulations deduced from the topography of the salinity-maximum layer (fig. 5) indicate that these waters were associated with clockwise rotating gyres. Also, the depth of the 36.7-p.p.t. salinity water in July (northern gyre) was about 15-25 m. less than the depth at the same location in August. The depth to the 36.6-p.p.t. salinity cell, however, was about the same in July as in August.

The significant question concerns the cause for the change in position of the gyres over the month period. The possible causes are:

1. Varying intensity of flow entering the Yucatan Channel.--This explanation requires a stronger flow into the Gulf during July to produce a greater penetration and greater volume of SUW in the Gulf. The results would be to push the 36.7-p.p.t. water and the northern gyre farther north, and the southern gyre farther northeast in July than in August.

This assumption could explain the southern gyre. In the northern gyre, however, the greater flow would deepen the SUW. It should have been at a deeper level in July than in August, but the opposite occurred.

2. Waters with different salinity characteristics were entering the Gulf in the two periods.--This possibility requires that water of 36.7 p.p.t., or greater, salinity was entering the Gulf before the July cruise and that less saline water was introduced before the August period. Thus, the 36.7-p.p.t. salinity

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1/Drummond, Kenneth A., and George B. Austin, Jr.: Some aspects of the physical oceanography of the Gulf of Mexico, 1958. U.S., Fish and Wildlife Serv., Spec. Rep. 249, pp. 5-13.

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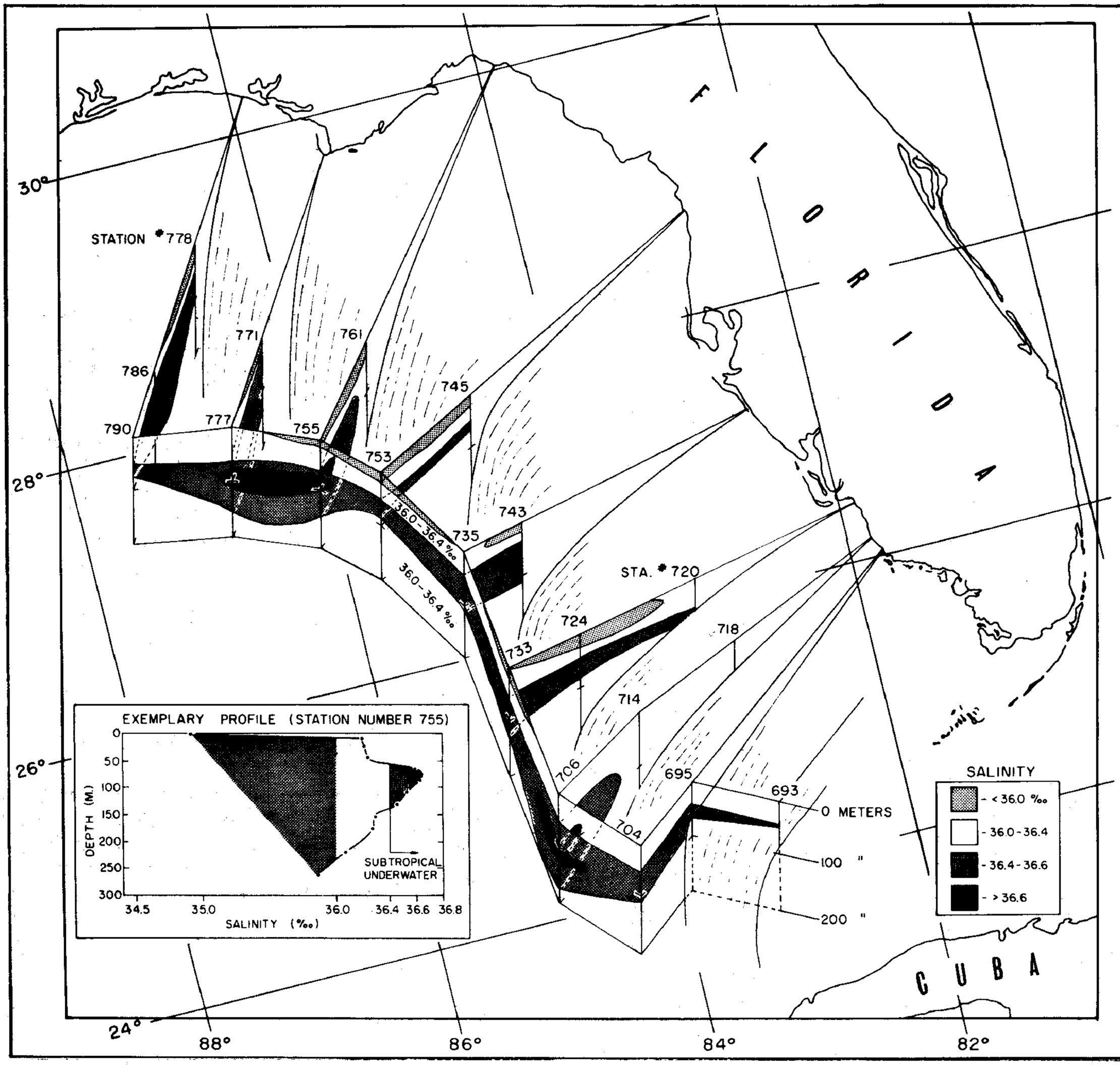

Fig. 1 - Three-dimensional salinity distribution from cruise 9 of the R/V "Geronimo" (June 30-July 13, 1966).

water would have covered a more extensive area in July and would have been "eroded" somewhat by August.

This concept is supported by the presence of low-salinity (<36.6 p.p.t.) water, which apparently entered the Gulf during early August. Water of such varying salinity would probably enter the Gulf as isolated bubbles.

This concept alone does not account for the changes in the circulation that took place in the northeastern part of the Gulf between July and August.

3. Different configuration of the flow pattern.--It is probable that in the oceans the flow pattern at any moment does not necessarily follow the pattern of the mean flow. Rather, both direction and speed of currents vary from time to time. As information continues to collect, such conditions seem to be the more typical state of the system. This explanation, combined with concept (2), can describe the changes encountered in the two cruises.

4. Isolated cells which move about.--This explanation would be a specific form of the variations discussed in (3) above. It is con-

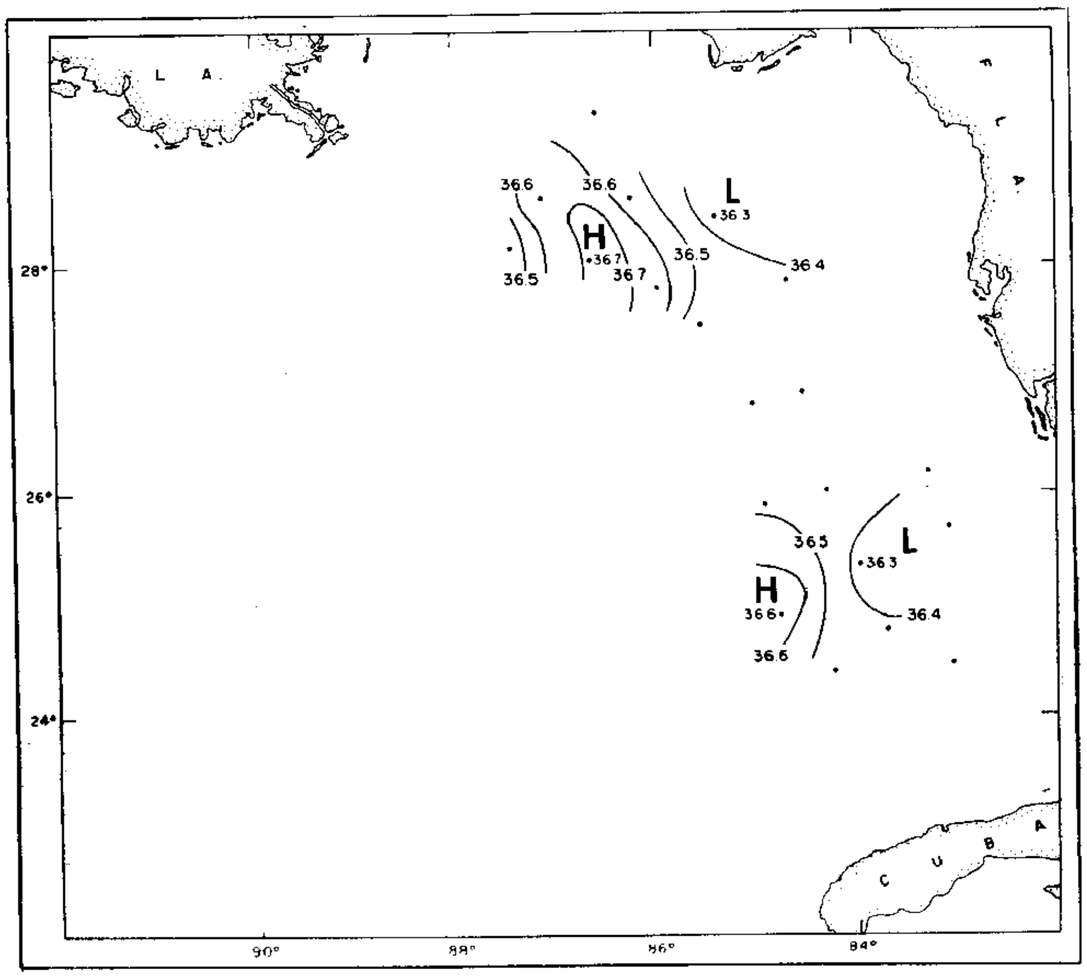

Fig. 2 - Value of salinity maximum in p.p.t. (parts per thousand) Subtropical Underwater from cruise 9 of R/V Geronimo.

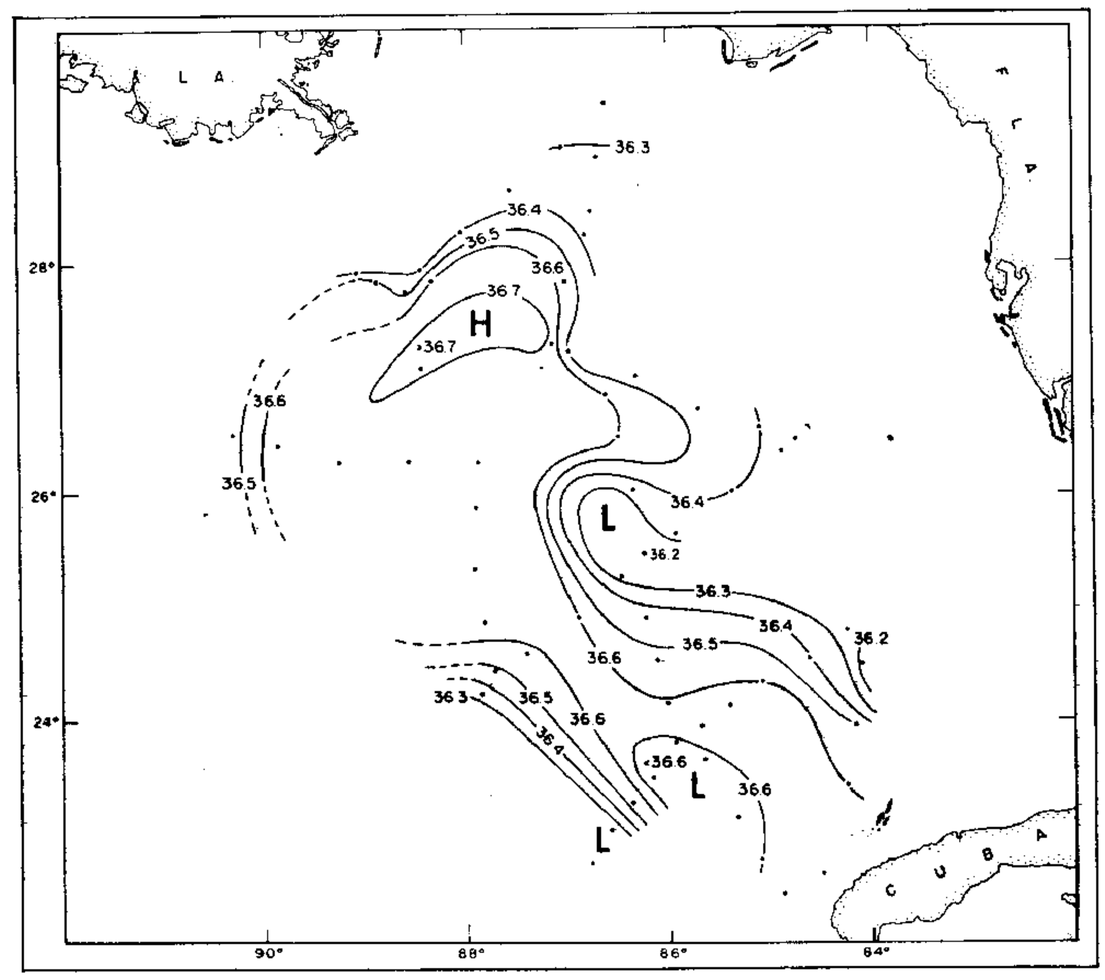

Fig. 4 - Value of salinity maximum in p.p.t. (Subtropical Underwater) from cruise 66 of R/V "Alaminos" (August 4-18, 1966).

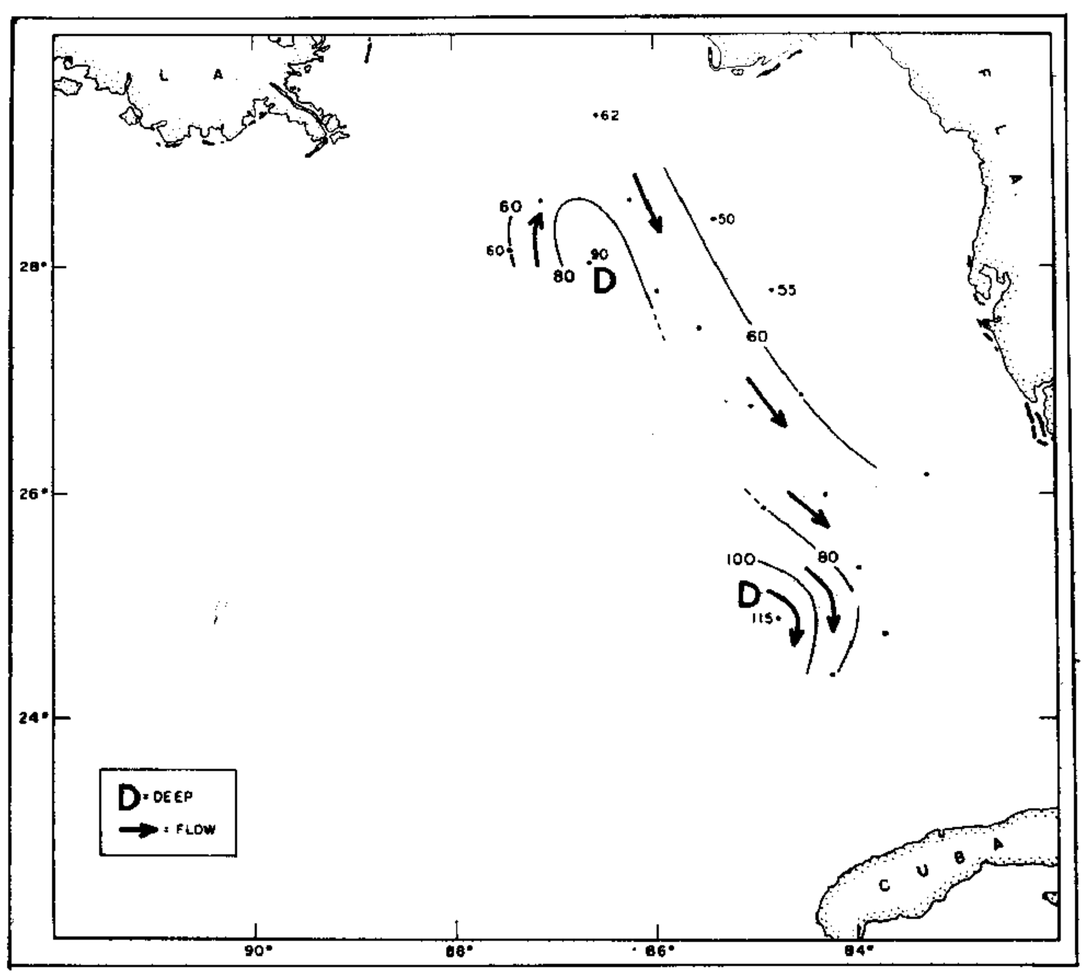

Fig. 3 - Depth to salinity maximum layer in meters (Subtropical Underwater) from cruise 9 of R/V Geronimo.

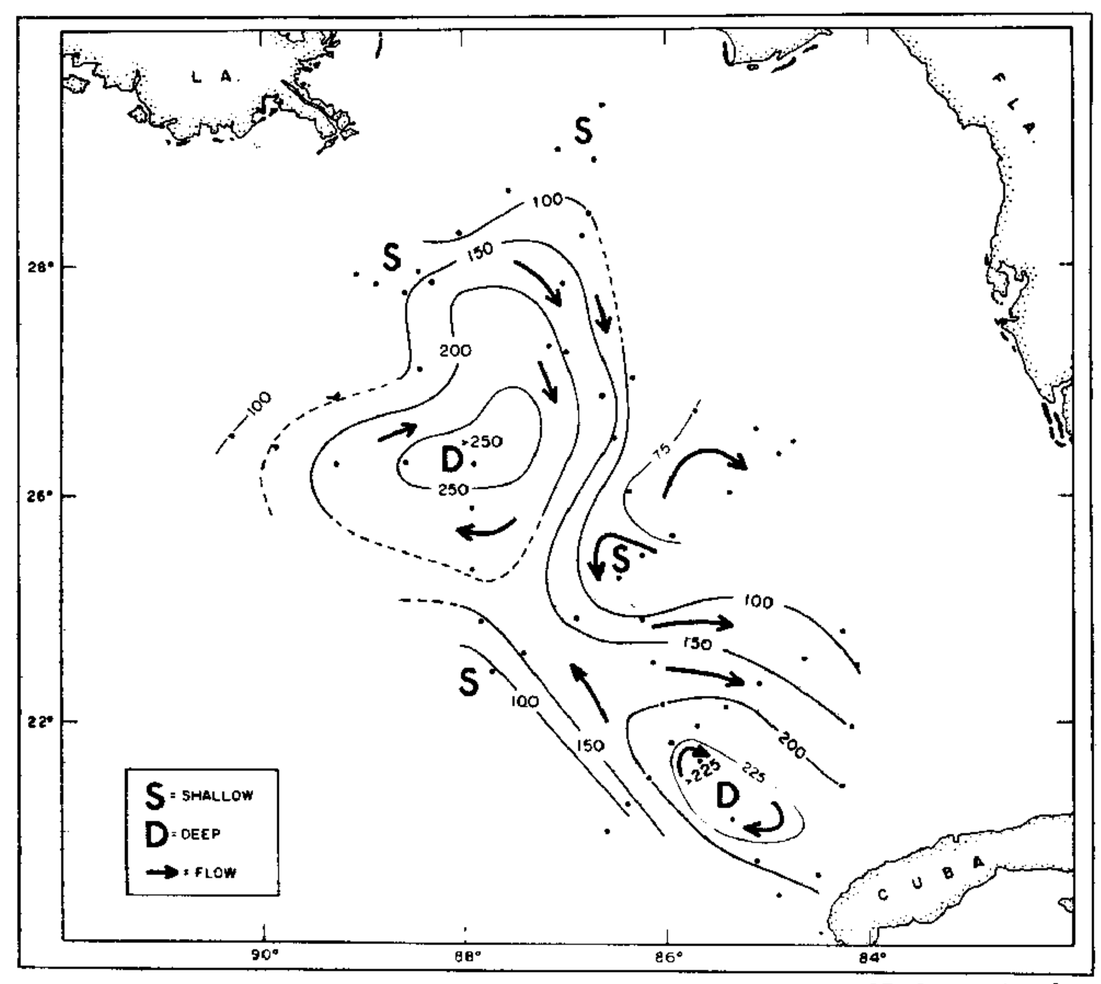

Fig. 5 - Depth to the salinity maximum in meters (Subtropical Underwater) from R/V Alaminos cruise.

ceived that the northern clockwise rotating gyre is accelerated northward by the main flow, hits the continental slope, and bounces southward toward the main flow. This possibility also seems to fit the data of the Geronimo and Alaminos cruises--particularly because, as the gyre moves northward, the clockwise motion should decrease and the depth to the salinity maximum in the gyre should also decrease. It is significant that when this gyre is located over the continental slope, the northern portion is over the shelf and, because of the circulation, this would be an area inducive to upwelling.

It is apparent from these data that flow in the oceans is not in a steady state, but varies considerably in time. The forces producing the currents are changing, and changing at a rate greater than the time required for steady-state motion to develop. The transfer of these forces through the waters can be likened to a pulsating system.