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WATERMASS STRUCTURE IN THE BAY OF BENGAL

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ABSTRACT

The distributions of temperature, salinity, thermosteric anomaly, density flux function and stability along 88° E in the Bay of Bengal are presented. The surface salinities showed strong gradients both horizontally and vertically in northern Bay of Bengal. Two isolated high salinity pockets coinciding with the 400 cl/t steric surface have been identified as the remnants of the Arabian Sea High Salinity Watermass. The salinity maxima in the depth range of 200-900 m have been explained as due to the penetration of the isohaline layer which forms (at the boundary) when Persian Gulf watermass and Red Sea watermass come in contact in the Arabian Sea. The geostrophic flow pattern shows that the flow is primarily westward except between 12° and 14° N and at extreme southern and northern regions of the section. The mass transport relative to 1000 db is also estimated.

Key-words : Hydrography, Watermass, Bay of Bengal, density flux function.

INTRODUCTION

The structure of the watermasses in the Indian Ocean was first given by Sverdrup, Johnson and Fleming (1942) and was later modified by Mamayev (1975). Indian Ocean Central Watermass, Indian Ocean Equatorial Watermass, Antarctic Intermediate Water, Red Sea Water, Persian Gulf Water and the Bottom Deep Watermasses could be clearly distinguished in the neighbourhood of their source regions. These watermasses while participating in the general circulation mix and the resultant watermass structure differs from place to place. In the northern Indian Ocean, the Arabian Sea watermass structure is quite complex with the Persian Gulf and Rea Sea watermasses penetrating at different levels where they can be identified by their salinity maximum. In a recent study Premchand (1981) and Premchand, Sastry and Murty (1985) mentioned that an isohaline layer forms at the boundary of the Red Sea and the Persian Gulf watermasses and they have opined that this isohaline watermass further spreads southward and into the Bay of Bengal which could be identified by a salinity maximum around 200-900 m depth. On the otherhand, the above authors also discussed the possibilities of salinity maximum in the Bay of Bengal as a result of freshwater discharges from the various rivers into the Bay of Bengal. They assumed that the T-S structure uninfluenced by different watermasses in the Indian Ocean could be identified by a straight line which was named as Indian Ocean Common Watermass, with thermohaline indices as follows :

$T = 25°C$ $S = 35.3$ ppt
$T = 0.6°C$ $S = 34.7$ ppt

When freshwater mixes with this water at surface the T-S structure would develop a hypothetical salinity maximum at subsurface layers. Several investigators have discussed the origin of the salinity maximum attributing it primarily to either the Red Sea water or Persian Gulf water (Varadachari, Murty and Reddy, 1968 and Premchand, Sastry and Murty, 1985a, 1985b) In this paper the watermass characteristics along a section on 88°E in the central Bay of Bengal are discussed.

MATERIALS AND METHODS

For the present study a section along 88°E running from 4° N in the south to 20.5°N in the north, centrally located in the Bay of Bengal has been selected (Fig. 1). Hydrographic data collected on board ORV Sagar Kanya in

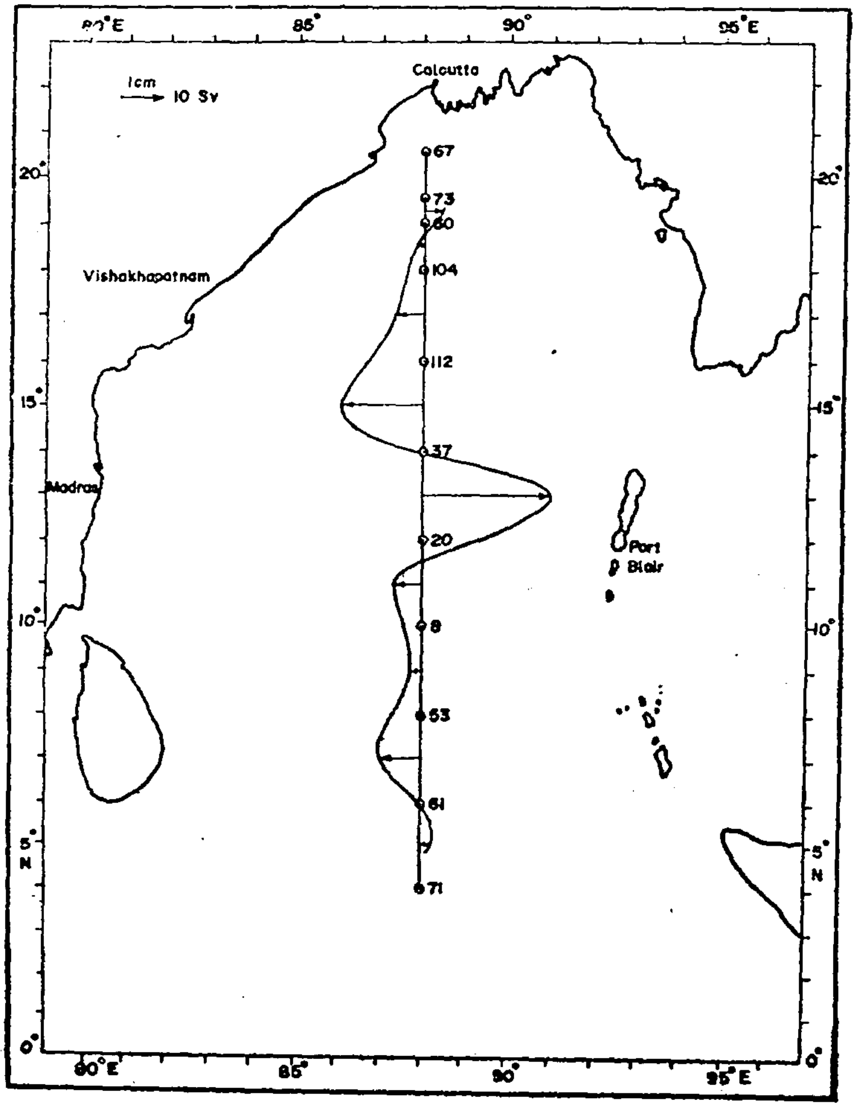

Fig. 1. Station locations and volume transport (Sverdrups).

the Bay of Bengal from 15th July to 10th October, 1984 have been utilised for these studies. The data were collected using ME-Multisonde CTD profiling system installed onboard. The accuracy of measurements of the system is, temperature, ± 0.02°C and salinity, ± 0.01 ppt. The digital data obtained from this system has been processed after applying corrections for pressure, temperature and salinity. The dynamic computations were done on onboard HP computer.

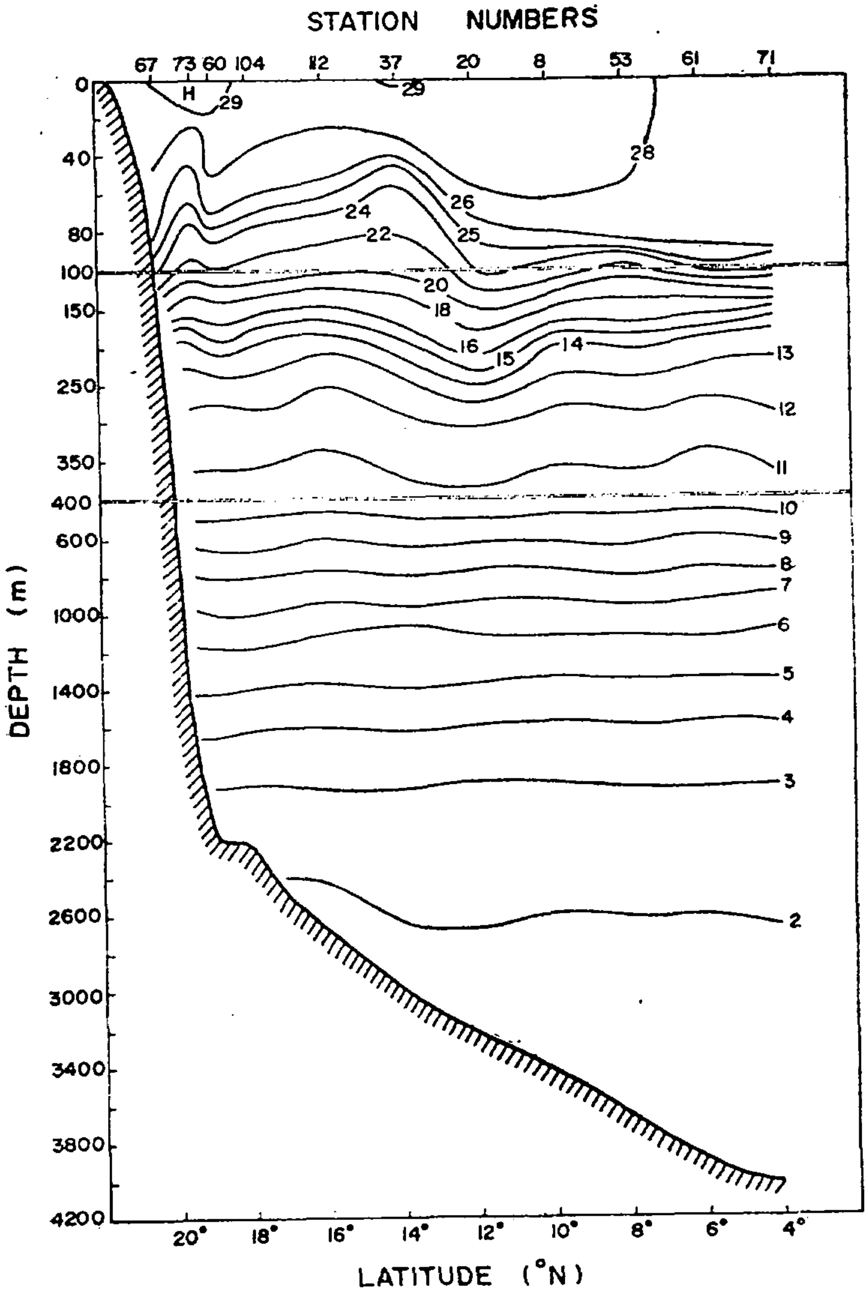

Fig. 2. Vertical distribution of temperature (° C).

Station curves for each station were drawn on T-S diagrams showing temperature, salinity and thermosteric anomaly. Depths of chosen isotherms, isohalines and isanosteres have been read from these plots and maps showing the vertical distribution of these parameters along the section were prepared and presented in Figs. 2, 3 and 4 respectively. The density flux function is computed and is plotted in Fig. 4 (dotted lines) on the mass distribution

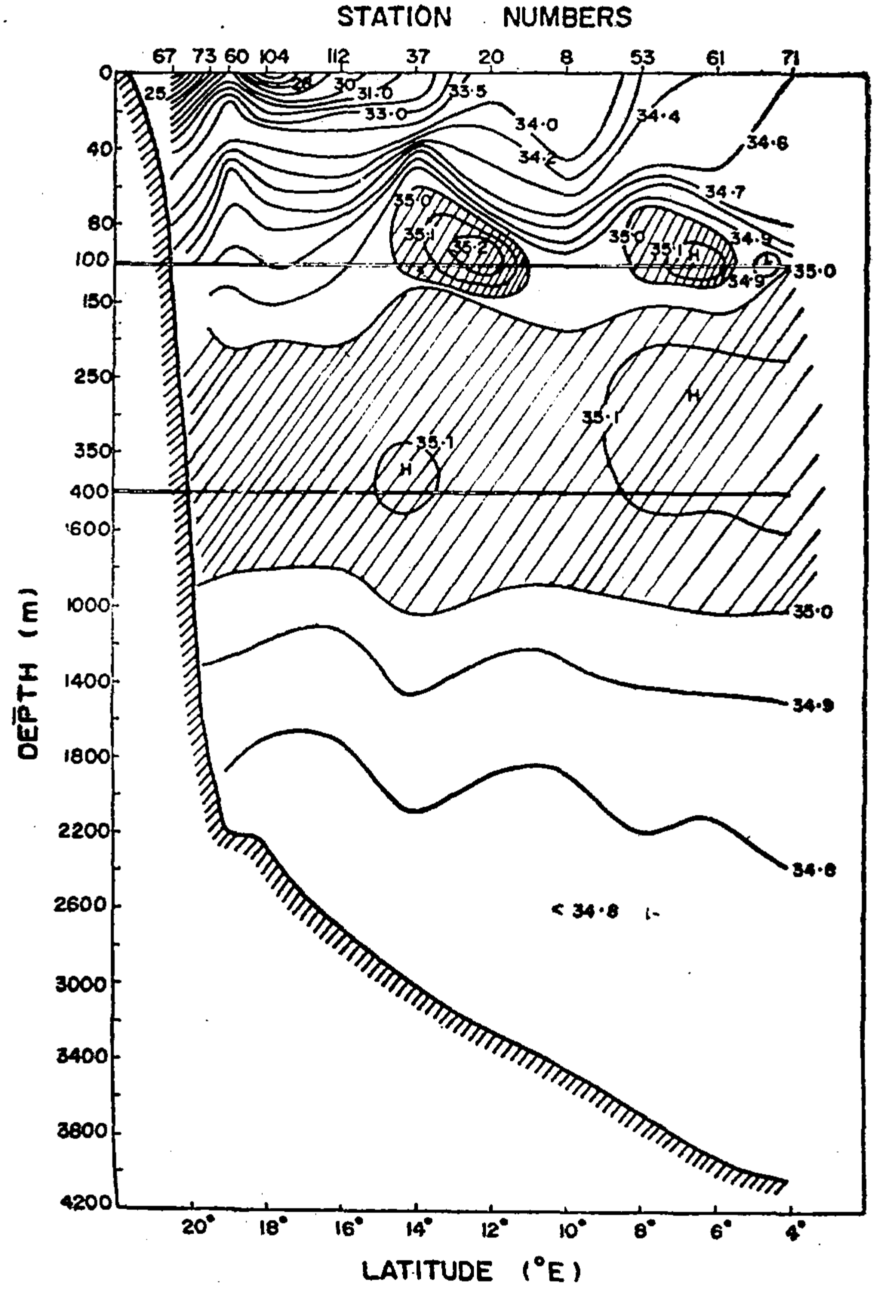

Fig. 3. Vertical distribution of salinity (ppt).

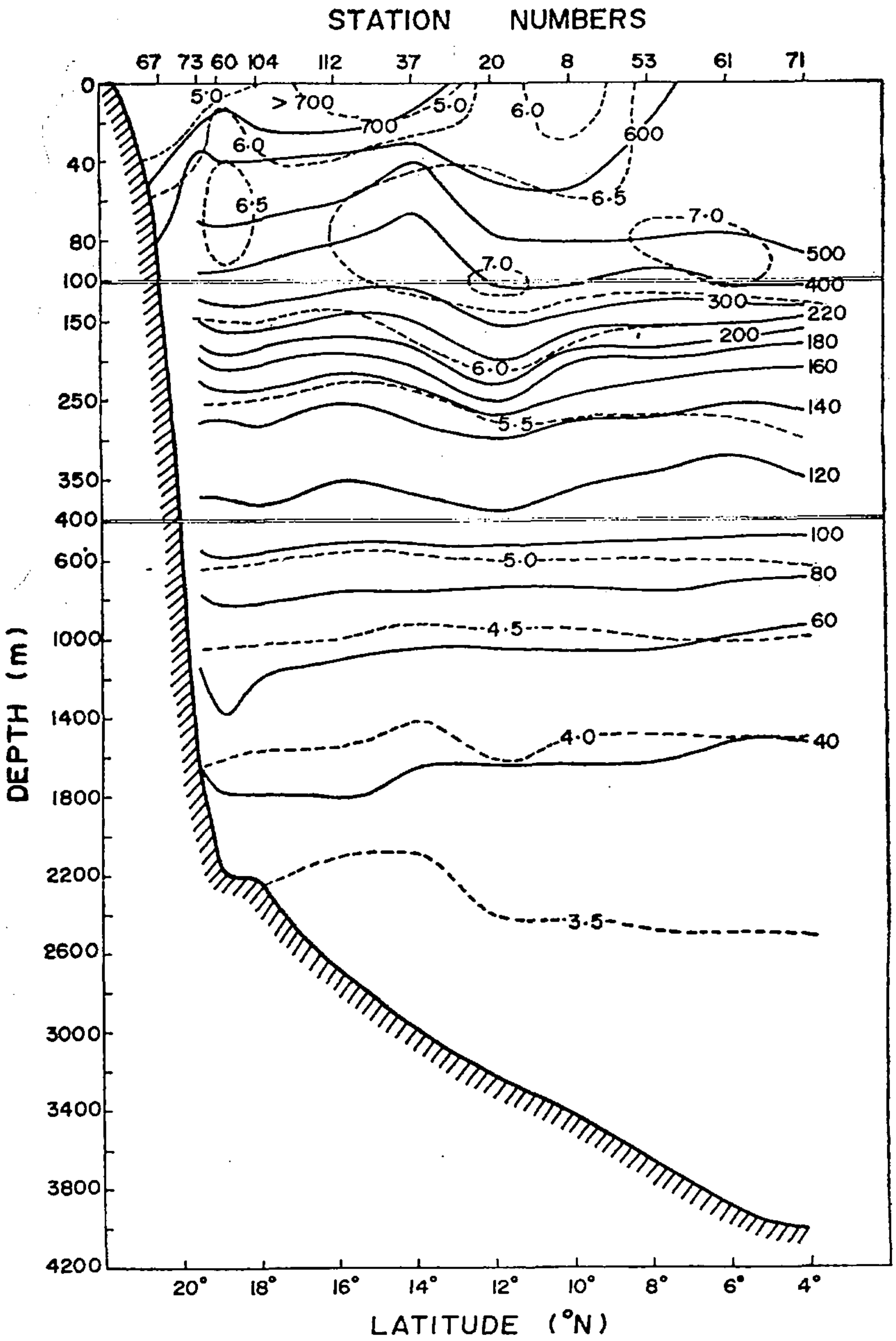

Fig. 4. Vertical distribution of thermosteric anomaly (cl/t) (solid lines) and density flux function (broken lines).

(thermosteric anomaly). Fig. 5 shows the vertical stability of water column. Geostrophic currents across the section relative to 1000 db surface have been computed and shown in Fig. 7.

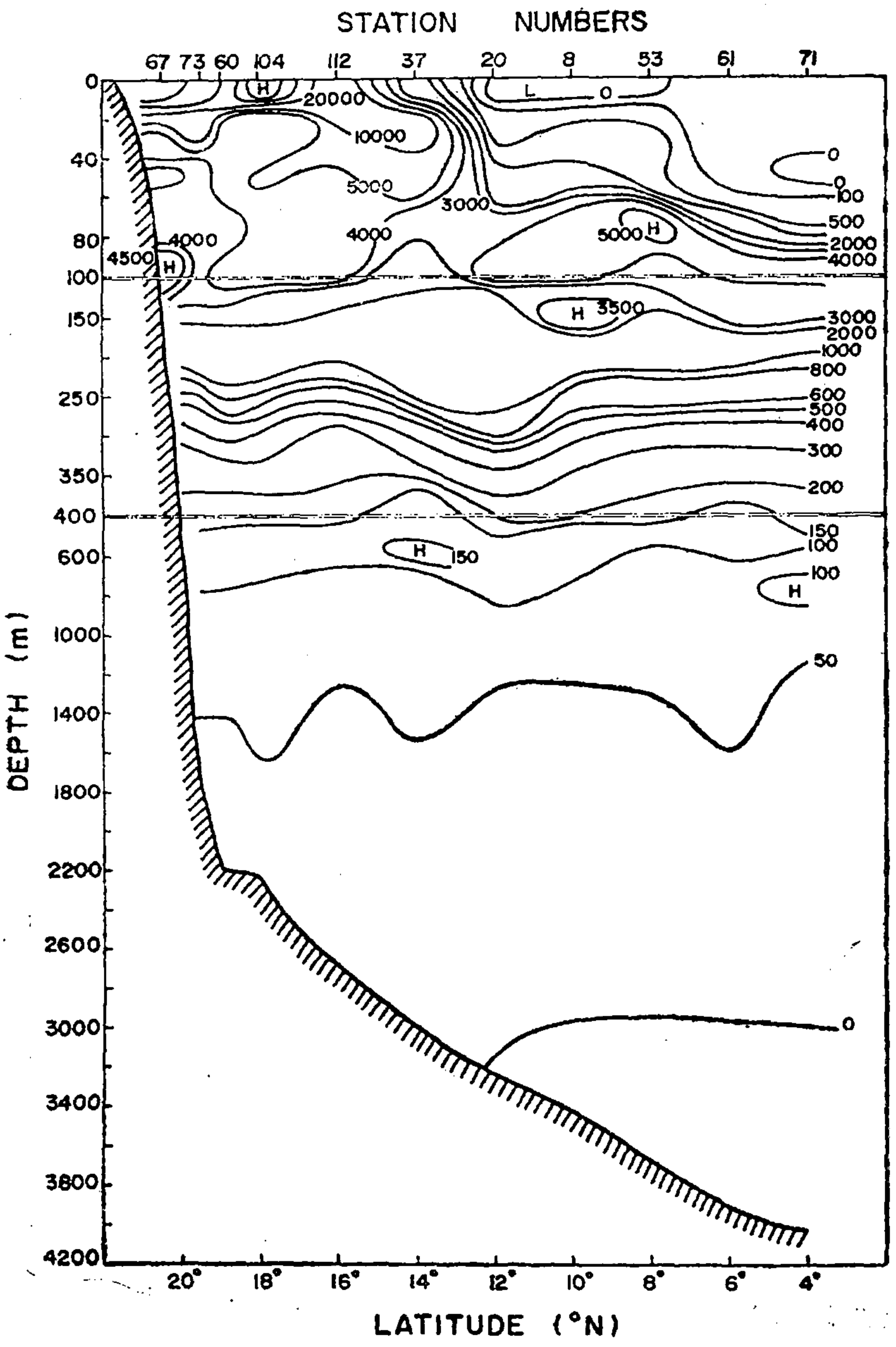

Fig. 5. Vertical distribution of stability (x 1^{-1} m^{-8}).

It may be noted that the data have been collected during the peak run off period from the rivers and the property distributions, especially the salinity in the upper layers show strong vertical gradients and to accommodate these features the figures are drawn to different scales to bring out clearly the basic structure of the properties.

RESULTS AND DISCUSSION

Fig. 2 shows that the isotherms (in the upper 100 m) slope upwards towards south, forming a ridge around 19°N. The isotherms form a dome like structure between 18° and 14°N. Further south, the isotherms are nearly horizontal. The surface layer in the south is fairly well developed with temperature around 27° C. The salinity structure (Fig. 3) shows strong gradients in the upper 100m. The salinity at surface increases from about 21.0 ppt in the northern regions to 34.6 ppt in the southern regions of the section, the gradients being stronger in the northern Bay. Two isolated high salinity pockets could be seen centered around a depth of 100m coinciding with 400 cl/t steric surface. In the depth ranges of 200-900m, a broad band of salinity maximum is seen along the entire section. Below the salinity maximum, the salinity decreases monotonically to less than 34.8 ppt.

Fig. 4 shows the thermosteric anomaly along the section. The basic features in the distribution are higher values exceeding 700 cl/t at the surface in the northern Bay, a result of very high fresh water discharges. The 400 cl/t surface occurrs in the depth range of 80-120m and is in the zone of seasonal wind influence. This surface has been identified as the Arabian sea High Salinity Water by Sastry, Premchand and Murty (1985). According to them, the thermohaline indices of the Arabian Sea High Salinity Watermass are: T = 26.8°C and S = 36.5 ppt. The dotted lines in Fig. 4 shows the vertical distribution of density flux function. According to Veronis (1972), vertical mixing will dominate if the isolines of density flux function intersect the isanosteres. Otherwise, isopycnal mixing is predominant. An examination of this figure shows that vertical mixing dominates in the upper 100-150m. Surprisingly, the high salinity pockets mentioned earlier coincide with zones of intense vertical mixing centred around stations 20, 61 and 60. In the subsurface layers (upto 100m), the salinity structure in the northern Bay indicates formation of a front with lower salinities to the north suggestng an estuarine type of circulation (Rao, 1977, Rao and Sastry, 1981). The presence of the two high salinity water pockets located on the 400 cl/t steric surface seem to be identified as the remnants of Arabian Sea High Salinity Watermass brought through the monsoon current into the Bay of Bengal. As already mentioned, the salinity structure shows a wide zone of salinity maximum. The peak values of salinity maxima exceeding 35.10 ppt. are located between 160-100 cl/t steric surfaces.

As indicated earlier, this salinity maximum could be realised with freshwater at surface on a T-S curve representing the mass structure of the

Indian Ocean Common Water. However, the presence of higher salinities could probably be explained by the advection of isohaline layer which forms due to vertical mixing at the boundary of the Persian Gulf and Red Sea watermasses. The salinity of this layer is nearly 35.7 ppt in the Arabian Sea. The depth range of this isohaline layer is confined to 160-100 cl/t steric surfaces. Thus, as this isohaline watermass penetrates into the Bay of Bengal, its high salinity progressively decreases by mixing and the salinities exceeding 35.00 ppt below 200 cl/t steric surface may be attributed to the penetration of this layer. Fig. 6 shows the basic T-S structure for all the stations below 100m with the salinity scale expanded. In the region of westward flow (Fig. 7) in the south Bay, a salinity minimum appears below the surface layer, around

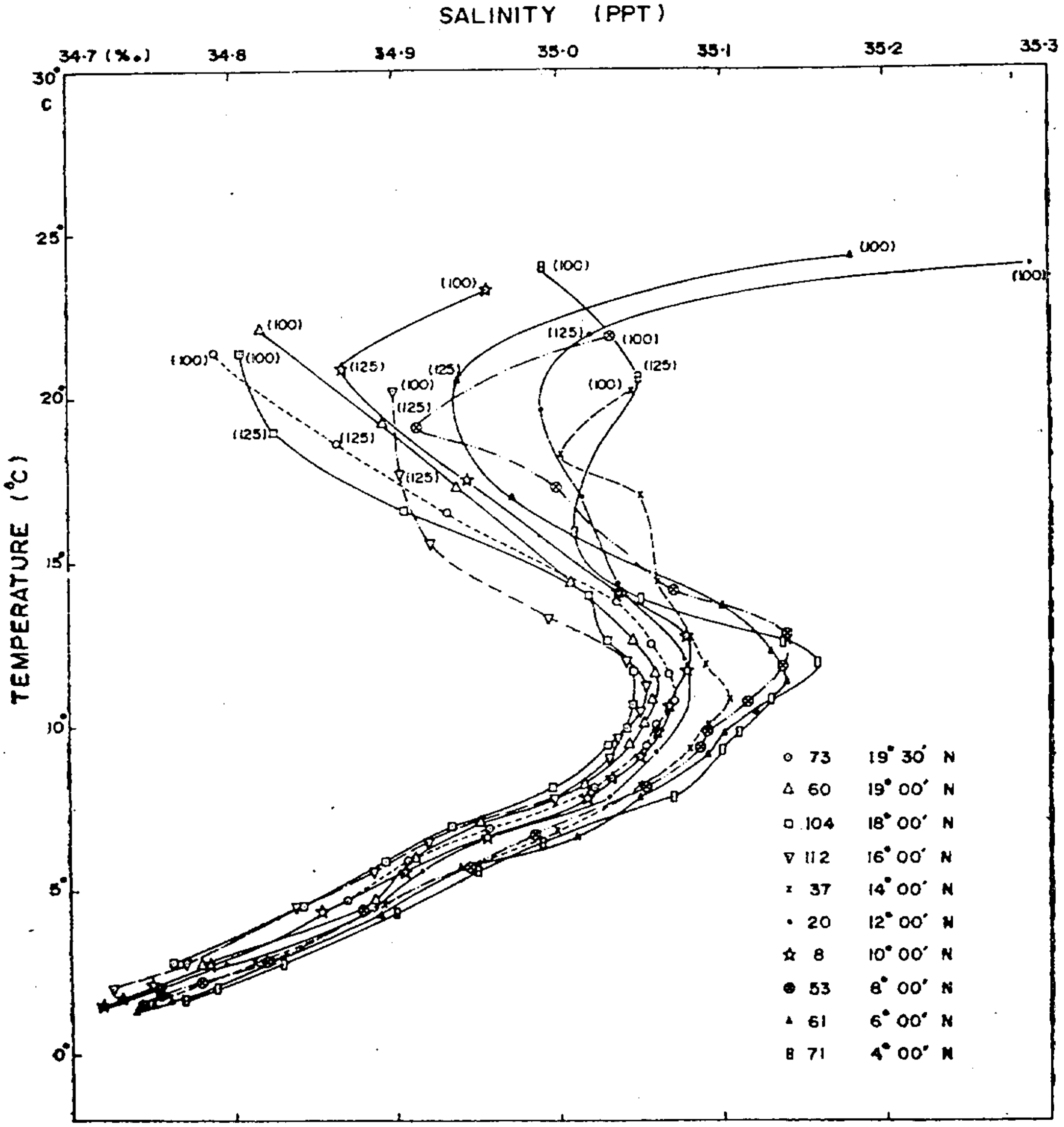

Fig. 6. T–S structure of the stations.

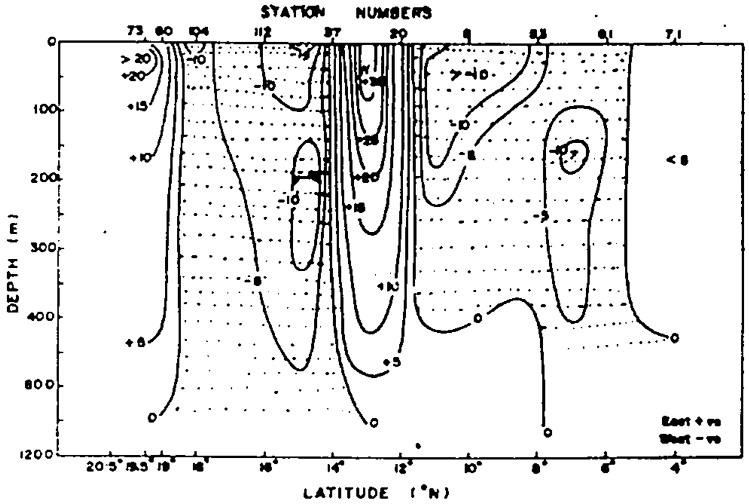

Fig. 7. Vertical current structure (cm/sec).

125 m which is conspiciously absent in the northern regions of the section. Further north, the salinity in the zone of salinity maximum appears to be dependent upon the easterly flow between 12° and 14°N. Because of the higher freshwater discharges the upper portion of the T-S curve shows high dilution, with salinity values less than 30.00 ppt in the northern regions. Inspite of the fact that strong stratification is present in the upper layers as could be seen from Fig. 5, vertical mixing seems to be dominating in the upper layers (Fig. 4). The T-S structure shows that the influence of freshwater could be seen upto 200m where the hypothetical T-S curve of the Indian Ocean Common Watermass cuts the T-S structure in the Bay of Bengal. Fig. 7 shows the geostrophic currents across the section. Westerly flow is dominent over the entire section except in the region between 12° and 14°N, north of 19°N and southern most region of the section where the flow was feeble. This figure agrees fairly well with the dynamic topographic charts prepared by Duing (1970) and Wyrtki (1971). The mass transport across the section relative to 1000 db surface is shown in Fig. 1. The transport across the section is given in Table I. From the table it is seen that the net transport across the section is westwards contributing to 11.00 Sv.

Table I. Volume transport (Sv) relative to 1000 db along 88°E.

	Between Latitudes (°N)								
	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-19	19-19.5
Transport	2.3	-9.6	-3.1	-6.7	30.0	-18.7	-7.5	-1.4	3.7

+. indicates eastward and —. indicates Westward.

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