BATHYTHERMOGRAMS—AN OCEANOGRAPHIC TOOL

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BATHYTHERMOGRAMS—the Temperature *versus* Depth graphs made automatically by the bathythermograph as it is lowered into the sea, provide a wealth of information about the secrets of the sub-surface layers. These T-D data are easily acquired in a matter of a few minutes, and produce results with a remarkable degree of accuracy. When the various T-D data are studied and compared with other oceanographic factors they reveal many of the processes taking place in the sea.

The bathythermogram is important to every branch of oceanography. The marine biologist is aided in his efforts to determine the environment in which plants and animals flourish. The marine chemist requires the temperature structure in order to determine chemical reactions and the saturation point of the salts and gases. The physical oceanographer is especially concerned with the T-D character of the water, for the physical properties of the water itself are dependent upon its temperature For example, water density, surface tension, viscosity, sound velocity, etc, are a direct function of temperature For these many reasons, the study of the temperature of the sea has become an integral part of the oceanographic research programme at the Andhra University

The vertical temperature structure of the sea off the Indian coasts may be described as a three-layer system, somewhat analogous to layers in the atmosphere. The upper or surface layer is called the "thermosphere" and consists of a changing zone of relatively warm near surface water It is separated from the lower psychrosphere by the thermocline, a layer in which the temperature changes most rapidly with depth. The psychrosphere remains a comparatively stable colder region (see Fig. 1).

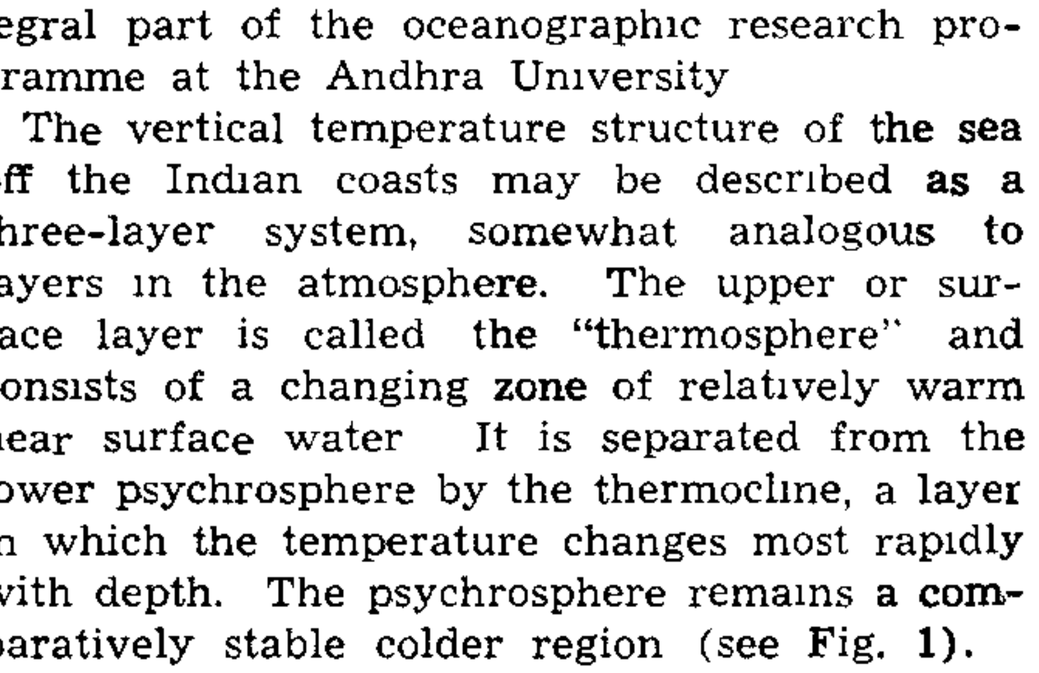

FIG. 1. Common type of bathythermogram and the related layers of the sea.

In this simplified version of the temperature structure, changes are continually taking place through external and internal forces such as tide, current, wind, etc. Also, heat exchange to and from the atmosphere occurs at the sea surface, which in turn, modifies the temperature structure in the thermospheric layer. Some of these environmental factors have a characteristic effect on the shape of the bathythermogram. These are sometimes discernible and reflect the history of the physical processes that have taken place in the water[1] Several different types of bathythermograms are presented in Fig. 2 and their probable formation is discussed.

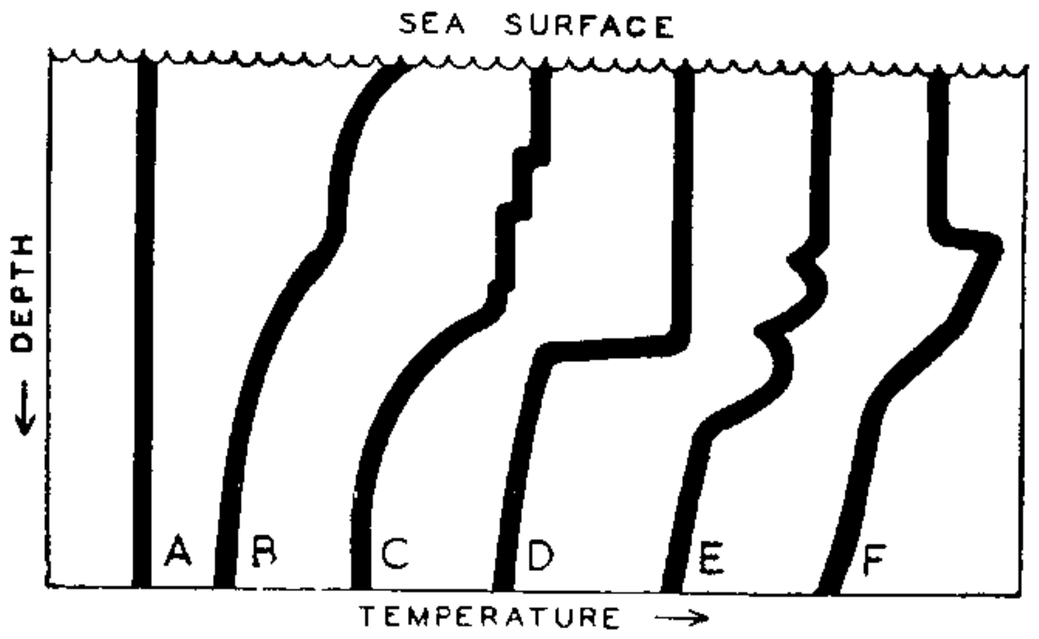

FIG. 2. Various types of bathythermogram observed in the Indian Ocean.

If the bathythermogram shows a continual vertical trace, *i.e.*, isothermal water, from the surface to a depth of a few hundred feet, as shown in Fig. 2 A, it indicates that the water has been vigorously mixed by a strong wind, or that vertical advection by cooling at the surface has taken place. In the winter both processes frequently occur. A tropical hurricane in the Arabian Sea or Bay of Bengal will produce such isothermal bathythermograms.

In Fig. 2 B, the usual three-layer system is present. The thermocline has a gradual slope which is caused by diffusion and gradual mixing at that level. The increased temperature at the surface represents conduction of heat to the water from the atmosphere under low wind conditions. This type of T-D curve may be commonly found in the summer whenever the wind is light and the air is relatively warm and moist.

The step-like structure in the thermosphere depicted in Fig. 2 C is usually the result of successive surface heatings and wind mixings. Spring is the favourable season for such sur-

face water heating, through increased solar radiation and conduction and, coupled with irregular winds, produces this type of T-D structure.

The sharp thermocline boundary between thermosphere and psychrosphere, as shown in Fig. 2 D, occurs when one adjacent water-mass of different temperature flows over another at a different rate of speed or in a different direction. The diffusion of water and heat at the boundary of two such water-masses under these conditions is small. A similar T-D structure may also occur when a warm water type flows over a sub-surface depression or when a large river enters a colder sea. In each case the lighter water flows over the more dense layer without appreciably mixing at the thermocline.

Irregular wiggles in the bathythermogram, as illustrated in Fig. 2 E, are indicative of turbulence at current boundaries. These occur in the stronger current systems. For example, off promintories like the Godavari Delta, the alongshore current increases in speed and at the same time intermingles with coastal waters This type of irregular and variable temperature structure is the result.

In Fig. 2 F is shown an increase in temperature below the surface, usually the result of cooling at the surface. In this case, the surface layer must contain low salinity water in order that the vertical column may remain in stable equilibrium. Along the east coast, immense quantities of fresh-water mix with Bay of Bengal water, producing a dilute thermospheric layer. In the fall, the surface cools by evaporation and conduction of heat to the atmosphere, causing vertical advection in the low salinity layer. Due to the higher salinity in the thermocline the stability of the water is maintained, even with higher subsurface temperatures. Actually, the T-D structure of both Figs. 2 C and 2 F could indicate horizontal advection of a different shallow water-mass into the sampling area However, the cooling and mixing process is the more common.

Various other shapes or combinations of shapes exist along the Indian coasts. Most can easily be explained. However, the cause of one feature shown in the deepest part of Fig. 2 C, namely, an isothermal layer near the bottom, is not apparent. Such a water structure exists on the edge of the continental shelf off Visakhapatnam in the spring. It might be caused by, (1) turbulence as the water flows across the bottom, or (2) by selective infiltration of water of a single temperature. This latter may be connected with upwelling along the continental slope at this time of year.[2]

These deductions are from a single bathythermogram. With many bathythermograms much more information can be ascertained. For example, repeated lowering in one location will give a measure of the wide variability and time cycles (diurnal, tidal, seasonal, etc.) in the water temperatures.[3] A line or network of observations will give two or three dimensional information. Consequently, from the character of a single bathythermogram, or group of bathythermograms, it is possible to deduce the processes that have taken place in a vertical water column in the sea. The bathythermogram is indeed a useful oceanographic tool.

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1. La Fond, E. C., *Memoirs in Oceanography*, Andhra University, **1**, 94.
2. —, *Ibid.*, 117.
3. — and Poornachandra Rao, C., *Ibid.*, 109.

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THE United Nations wishes to announce the forthcoming publication of the Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, held in Geneva, during August 1955, in their entirety.

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