SOME OCEANOGRAPHIC RESULTS OF THE *CARNEGIE'S* WORK IN THE PACIFIC.

THE PERUVIAN CURRENT.

by

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The surface-currents of the Pacific are fairly well known, and are represented schematically in figure 1. It is seen that the surface circulation is approximately symmetrical on both sides of the thermal equator, which is found in latitude 6° to 8° North. The equatorial counter-current runs towards the east along the thermal equator and North and South of this line we find two enormous vortices. The southern part of the vortex on the Southern hemisphere is formed by the West wind-drift, which when striking the coast of South America is deflected to the North following the coast as the conspicuous Peruvian Current.

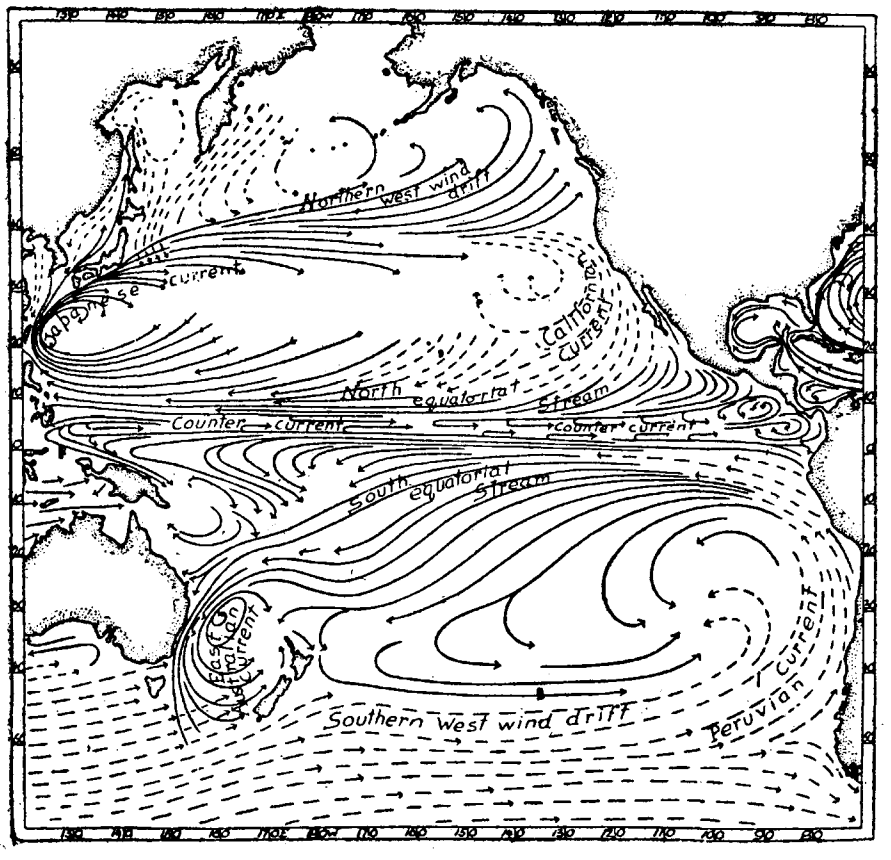

FIG. 1.

The Peruvian Current carries cold water of low salinity along the coasts of Chile and Peru and is the most outstanding current on the Southern hemisphere. The relation of this current to the surface-currents has been recognized a long time ago, but the relation of this current to the sub-surface circulation has not been established. However, it is generally assumed that the low salinity and low temperature of the surface-waters off the coast of Peru are due to upwelling of the deep water, but nothing has been known definitely as to the depth from which the water comes. The observations of the

Carnegie show clearly that the possible vertical upward motion is a relatively small-scale phenomenon within the Peruvian Current and is limited to the upper 200 to 300 metres.

Before treating the *Carnegie* observations from the Peruvian Current, it is necessary to draw attention to the general character of the sub-surface circulation in the Pacific which recently has been disclosed by the investigations of MERZ, WÜST, and DEFANT. who principally used the salinity observations of the *Challenger* Expedition of 1874-1875. In the distribution of the salinity in a vertical section through the central part of the Pacific, it is seen that the distribution is fairly symmetrical around the thermal equator; indicating a symmetrical sub-surface circulation within both hemispheres. We are here not concerned with the currents near the surface, but shall fix attention at the conspicuous salinity-minimum which can be followed in both hemispheres from high latitudes towards the equator. In high latitudes the low-salinity values are found at the surface, but approaching the equator they are met at a depth of about 700 metres. The two tongues of water of low salinity indicate beyond doubt that water, which has been at the surface in the sub-arctic or sub-antarctic regions where the salinity has been reduced on account of excessive precipitation, is carried back to the equator at a depth of 600 to 1,000 metres. The salinity within this current increases when approaching the equator on account of admixture of saltier water from above.

It has not been possible to arrive at any results as to the character of the deep-sea currents in the Pacific because of lack of observations from the great depths. We shall confine ourselves to a study of the relation between the Peruvian Current and the intermediate Antarctic Current which evidently is characteristic of the entire Southern Pacific.

The *Carnegie* crossed the Peruvian Current several times in the course of its oceanographic stations. Stations 40 to 80 are located within or in the neighbourhood of the Peruvian Current. On the basis of the observations from these stations it is possible to construct five sections, showing the vertical distribution of the salinity. Three of these sections, from stations 40 to 45, 70 to 80, and 60 to 50, run approximately at right-angles to the Peruvian Current and may be termed cross-sections, while two, from 50 to 45 and from 60 to 70, are almost parallel to the Current and may be called longitudinal sections.

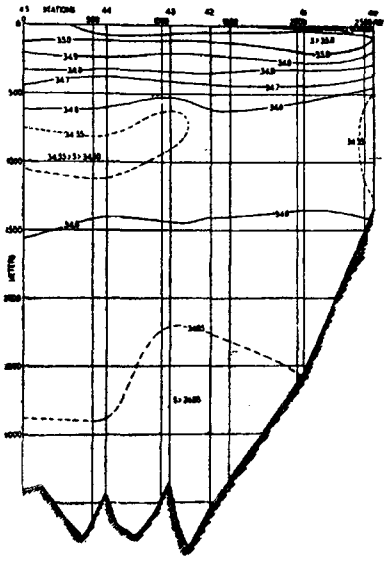

FIG. 2

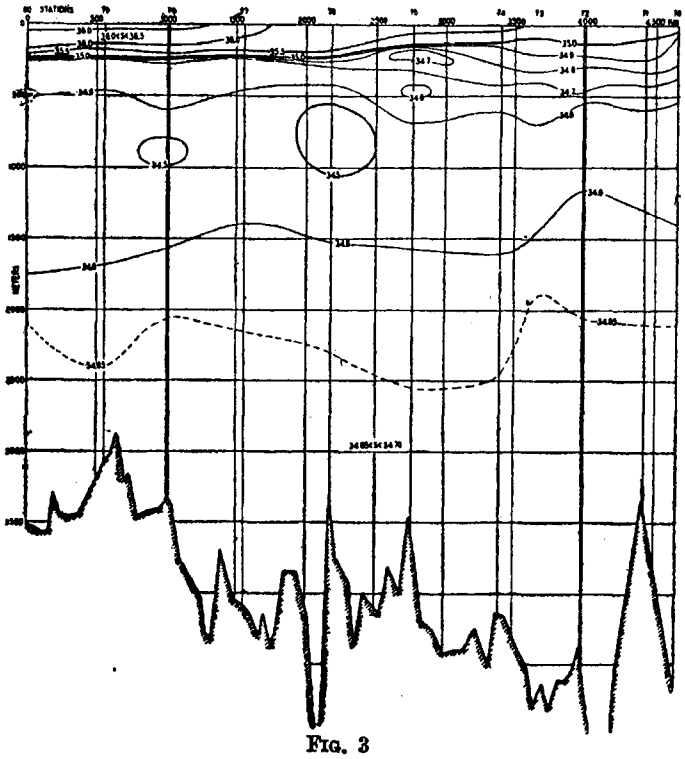

FIG. 3

Let us first examine the cross-sections, beginning with the most northerly (fig. 2). In this section we immediately recognize the intermediate layer with low salinity, representing the intermediate Antarctic Current. It is of interest to note that the axis of this body of water is horizontal.

At the surface we find an increasing salinity when departing from the coast. At the coast the lowest salinity is met with at the surface, where values below 34.5 °/°° occur. The water of this low salinity must originate from the Gulf of Panama where the surface salinities are small on account of excessive precipitation. At some distance from the coast we find the highest salinity below the surface, but it can not be decided whether the high values indicate a transport of water towards the coast or is related to seasonal variations.

The second cross-section (fig. 3) in about 15° South reveals principally the same features. The intermediate Antarctic Current can be followed across the whole section and the salinity within this body of water is now slightly smaller, areas with salinities smaller than 34.5 °/°° occuring. The axis of the Antarctic Current is again horizontal. At the surface we find a great increase of the salinity when departing from the coast.

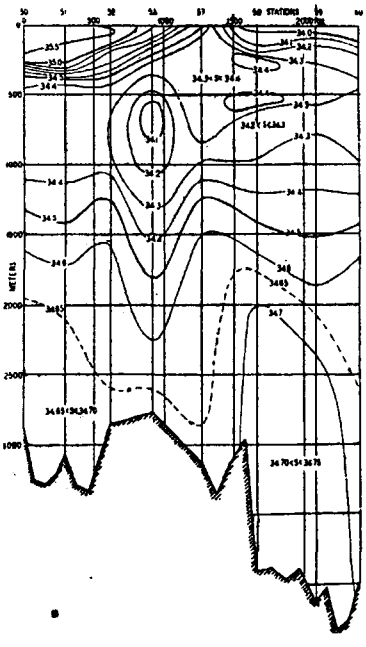

FIG. 4

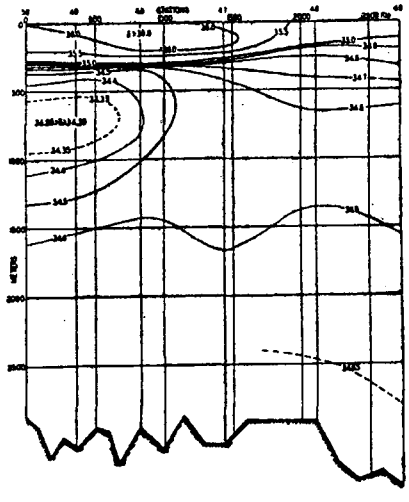

FIG. 5

In the third cross-section (fig. 4) which runs from Southeast to Northwest between latitudes 40° and 28° we find the intermediate Antarctic Current still more strongly developed and still horizontal. The salinity has now values around 34.3 and values as low as 34.1 occur. At the right-hand side of the section we recognize the Peruvian Current at the surface where the salinity is about 34.0.

Turning next to the longitudinal sections we shall first examine the westerly section between longitudes 115° and 105° West and latitudes 25° and 5° South (fig. 5). In this section we can follow the intermediate Antarctic Current as a horizontal flow. The decrease in salinity towards the North is plainly seen and it can hardly be doubted that this increase is due to admixture from above because the salinity of deep water remains unaltered, the curve of 34.6 °/°° running horizontal.

In the last section (fig. 6) which runs from about 98° West longitude and 40° South latitude to Callao and cuts the Peruvian Current at a very small angle we find again the intermediate Antarctic Current very well developed with a minimum of salinity at about 700 metres. The salinity increases towards the North but the depth of the minimum values remains constant. It is furthermore evident that the increase is due to admixture from above because the salinity at 700 metres remains constant until the salinity of the water-layers above is appreciably greater, and does not increase as long as only the underlying layers have a higher salinity.

Within the surface-current the salinity increases towards the North on account of the evaporation of the surface, but it remains much lower than the salinity at greater distances from the coast, evidently because of a constant transport of water of low salinity from the South. The Peruvian Current appears thus as a surface-current which is independent of the intermediate Antarctic Current, with a lower salinity than the intermediate Current in the most southern part of our section but a higher one in the northern part.

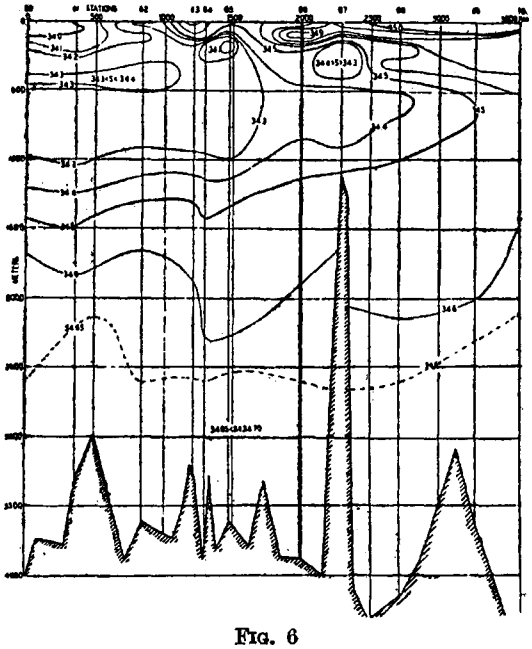

FIG. 6

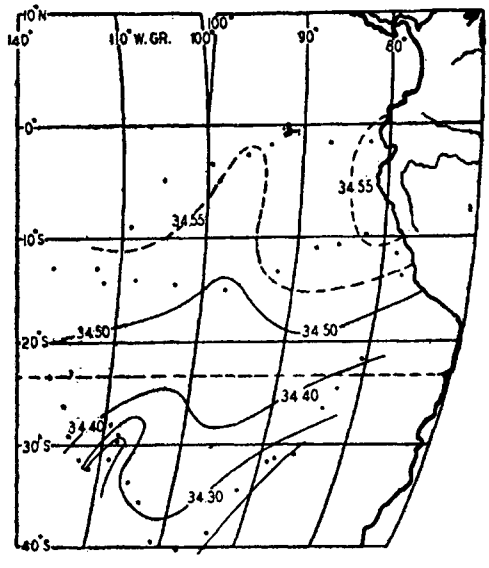

FIG. 7

The low salinity and low temperature of the surface-waters off the Peruvian coast, as already mentioned, frequently has been regarded as evidence for the presence of an upwelling of the deep water. However, in our sections we find no feature which supports this assumption. If an upwelling from depths greater than 1,000 metres took place, we should expect the intermediate Antarctic Current to disappear close at the coast, but we find it just as well developed here as at greater distances. The horizontal distribution of the salinity at a depth of 700 metres (fig. 7) shows a regular increase towards the North of the salinity of the intermediate current, indicating that this current is independent of the distance from the coast and effectively shuts off any communication between the deep-water and the surface-layers.

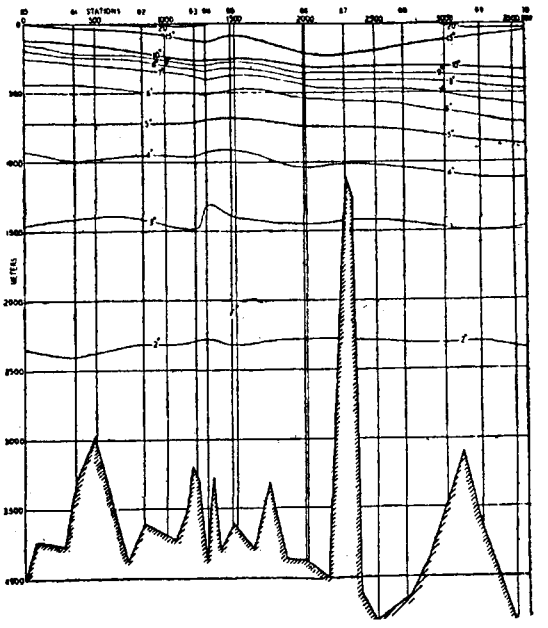

FIG. 8

The possibility exists that an upward motion is found within the surface-current itself, when this approaches the coast. Such an upward motion would bring water of low temperature and low salinity to the surface because only the uppermost layers of the Peruvian Current have high temperatures and high salinities. An examination of a temperature-section from stations 60 to 70 (fig. 8) indicates that such vertical motion is present within the Peruvian Current in the immediate vicinity of the coast. We find that the isotherm of 15° rises when approaching the coast, but all the isotherms from 10° down drop. This trend of the isotherms in my opinion must be regarded as conclusive evidence that the upwelling off the coast of Peru is a relatively small-scale phenomenon which is characteristic of the surface-current and that the water which is brought to the surface comes from depths less than 300 metres.

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