G5-2

THEORIES OF BOTTOM WATER FORMATION, RECENT INVESTIGATIONS IN THE WEDDELL SEA AND THE EFFECTS OF SUPER COOLING BY THE ICE CAP

Håkon Mosby

Geophysical Institute, University of Bergen, Bergen, Norway

As early as 1906 Nansen presented the two foremost ideas on the bottom water formation. One of these was that in certain areas of the North Atlantic the cooling of the surface in winter would create a vertical convection that, due to the low stability of the water column, might penetrate to the bottom of the deep sea. For this process the present author developed a model (1959) which has been supported by observations in the area between Jan Mayen and Spitsbergen (1960, 1961) and in the Mediterranean (Tchernia and Saint-Guily 1959), where the cooling is mainly due to evaporation, and where careful studies (Medoc '69) have disclosed a complicated effect of the wind (Anati and Stommel 1970).

The other idea of Nansen was that the formation of ice on the shallow waters of the Barents Sea would produce a salty water which might be so heavy as to flow down the slope to the deep sea. This idea was considered by Brennecke (1921), in his study of the drift of the *Deutschland* in the Weddell Sea 1911–12. In 1934 the present author discussed the existing views and concluded that the bottom water of the South Atlantic Ocean was formed mainly due to the freezing of ice in the Weddell Sea and that the water on the shallow shelf would need a salinity of more than 34.62% at its freezing point to sink to the bottom of the deep sea.

In 1956 Fofonoff demonstrated that due to the nonlinearity of the equation of state the shelf water of a salinity between 34.51 and 34.63‰, when meeting the intermediate Atlantic water, would give mixtures heavier than both components and thereby hamper sinking. On this basis the present author in 1966 suggested that the shelf water, when passing the critical salinity limit of 34.63‰ might suddenly begin to flow down the slope. It was estimated that in this case the speed of the bottom current might be sufficiently high to be observed. This was a reason why in February 1968 from the USCGC Glacier four submerged current meter arrays were mounted on the slope of the Weddell Sea shelf (74°S, 40°W, 700 m of depth). Unfortunately the difficult ice-conditions both in 1969 and in 1970 made retrieval impossible.

From the Glacier the oceanographers have discovered large columns

of heavy water near freezing point, filling below sill depth (5–600 m) the basin off and presumably under the Filchner Glacier. (Expedition Reports by Elder and Seabrooke and by Foldvik and Kvinge). There are good reasons for believing that cooling from the glacier may be a factor of importance for the formation of bottom water. Farther west they also have observed heavy waters (up to 34.84% salinity) in areas where bottom topography can hardly be believed to prevent sinking. A possible explanation of this phenomenon is indicated as being an effect of the dynamical balance of the north-going current. This may complicate the picture but hardly contradict the generally accepted considerations, where in principle only the components of the outflow across the isobaths of the bottom are discussed.

It was shown by Wüst in 1933 that in the South Atlantic the Antarctic bottom water flows northwards mainly in the west, while in the east it can pass only to the Walfish ridge. In 30°S it flows through a narrow passage through the Rio Grande Ridge into the Brasilian Bassin; here it is nearly trapped, only parts of it slipping out in the north. A study of its transformation by vertical diffusion has been carried out by the present author using Meteor data. Adopting a speed of 0.3 cm sec⁻¹ of the northward flow, as estimated by Wattenberg (1935) in his study of the northward increase of the specific alkalinity, the following values were found: for the coefficient of vertical diffusion 8.6 g cm⁻¹ sec⁻¹, for the vertical component of motion 57 m year⁻¹ and for the amount of bottom water transformed 12·10⁶ m⁻³ sec⁻¹. The total amount of bottom water transformed by vertical diffusion in the South Atlantic may then be estimated at some $20 \cdot 10^6 \,\mathrm{m}^{-3}\,\mathrm{sec}^{-1}$. This is 2/3 of the total amount of Antarctic bottom water formed according to estimates by Munk, Stommel, Arons a.o. on heat balance, freezing of ice and vertical diffusion.

From the bathymetric map of the *Glacier* expedition the probable area of the Weddell Sea shelf area of less than 500 m of depth, may be estimated at some 0.6 mill. km². With an average depth of 400 m this would correspond to a volume of 0.24 mill. km³ or about 1/3 of the amount transformed per year in the South Atlantic according to the above estimate.

However, our understanding of diffusion and our knowledge of convection in the area is still rather poor.