BOTTOM WATER AND BOTTOM CONFIGURATION OF THE GREAT ATLANTIC DEEPS. (1) (2).

(Extract from the Results of the German Atlantic Expedition)

by

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The problem of the origin and distribution of bottom water has been discussed from early times, and often. This results from the fact that more abundant materials of observation exist for the bottom than for the deep layers, because measurements of bottom temperature have been taken not only by exploring vessels, but also by hydrographic and cable-laying ships. The remarkably low temperatures of nearly 0° C. on the bottom, which were confirmed on each occasion, also early served as the principal foundation of the hypothesis of the polar origin of the bottom water. The polar bottom currents are consequently members of the deep oceanic circulation, the existence of which had been deduced from the distribution of the temperature before the *Challenger* expedition. If it had been thought before that time that the Arctic and Antarctic currents showed roughly the same development and met at the equator, it became clear, after the *Challenger* and *Gazelle* observations, that the principal mass of the bottom waters of the great oceans comes from the Antarctic Basin; that in the Atlantic Ocean this bottom current chiefly leads into the western trough; and that it can still be detected in the form of a cold stream as far as the equator (in its last ramifications it even passes the equator and reaches the North Atlantic). These expeditions have also shown the value of bottom temperatures for revealing the first magnitude shapes of the ocean bottom, a value which has been proved for the Atlantic Ocean by two examples which have become classic.

The existence of a central rise running through the middle part of the Atlantic, and dividing this ocean into two parallel depressions of the sea bed, has been revealed by the differences in the bottom temperatures although this ridge had only been sounded at a few spots. The hypothesis of a transverse junction on the bottom between the central rise and South Africa (*i. e.* of a transverse rise to which SUPAN (1899) gave the name of *Walfischrücken* (Walfisch Ridge) and the existence of which was confirmed by the soundings of the German exploring ships *Valdivia*, *Gauss* and *Planet*), deduced at that time solely from the bottom temperatures, was even bolder. By this large transverse elevation the cold Antarctic bottom current is isolated from the East Atlantic depression from about 25° S. on; on the other hand, in the western depression it reaches as far as 12° N. because the western counterpart of Walfisch Ridge, namely the lateral rise discovered at that time and later called by SUPAN the *Rio Grande Ridge*, evidently has outlets deep enough for the Antarctic bottom water.

The most recent chart of the bottom temperatures is the one made by SCHOTT (1902) which appears in the atlas of the *Valdivia*. It clearly shows the difference between the eastern and western depressions. Further, thanks to the activity of expeditions and of cable ships, copious observations of depth and temperature have been obtained, and indications of new transverse rises have appeared, particularly in the eastern depression; but the most outstanding feature of this activity has been the more accurate surveying of the lie of that formidable chain of central mountains, the Mid-Atlantic Rise, the crest of which has been sounded in all latitudes at depths from 2500 to 3500 metres (1370-1910 fathoms). At only one point was there any doubt about the continuity of this central barrier, namely near the Romanche Deep (Tizard Deep), the hole 7370 metres (4030 fathoms) deep sounded by the *Romanche* in 1883 exactly at the position of the equatorial elbow and confirmed by the GAUSS expedition in 1902. E. VON DRYGALSKI (1904) propounded the hypothesis that this Romanche Deep must be accompanied by a

(1) *A paper read at the special meeting of the* Gesellschaft für Erdkunde, *19th Dec. 1932.*

(2) *A comprehensive treatment of this problem, giving the sources examined and the bibliography consulted, appeared simultaneously as the first part of Vol. VI of the Report of the Expedition*: Wissenschaftliche Ergebnisse der Deutschen Atlantischen Expedition auf dem Vorschungs- und Vermessungsschiff *Meteor*, 1925-1927. *Published by order of the* Notgem. der Deutschen Wissenschaft *by A. Defant. Vol. VI, Part I, Berlin & Leipzig,* 1933, 107 *pages,* 8 *plates and* 16 *figures.* (*Edition of W. de Gruyter & Co*).

complete rupture of the central ridge, a conception afterwards supported by SCHOTT and SCHULTZ (1914) as well as GROLL (1912), but which VON DRYGALSKI (1926) himself ultimately discarded. Nevertheless, opinions agreed that even if there were a hollow in the central ridge, the bottom water of the eastern depression would be only locally affected.

The latest representation of the shape of the abyssal bottom of the sea, based on the critical exploitation of original materials, is due to GROLL (1912); his fine bathymetric chart on an equivalent projection is favourably distinguished from all other similar attempts by the extreme care taken over the construction of the isobaths from the morphologic point of view. True, GROLL is sceptical with regard to the use of bottom temperatures for the construction of lines of equal depth, and would like this proceeding to be limited in general to the case of closed oceanic basins (*e. g.* the Straits of Gibraltar), while for open oceans he rejects it in principle.

These brief and incomplete historical remarks (1) are made by way of preamble to show the progress made as a result of the new materials obtained, which will be appreciated from the charts and sections, although the latter are only partly reproduced here. The treatment depends from two points of view on the basis laid down by Alfred MERZ: in the first place, on the system of preliminary work, introduced by him, consisting of the critical study and uniform reduction of the materials of previous expeditions; and, in the second place, on the systematic explorations of the *Meteor* herself, the general instructions for which had been given by MERZ (1925) when the programme and organisation of the expedition were being drawn up. Certain partial results are already contained in the provisional reports of the expedition and the communications of the members of the expedition; this holds good principally with regard to the origin of the bottom water and the shape of the abyssal bottom, in the two longitudinal profiles of the eastern and western depressions published by the author (1928), as well as in a communication by BÖHNECKE (1927), from which the fact emerges that an effective interruption of the central ridge exists in the region of the Romanche Deep and that the bottom temperatures show traces of Antarctic water in the basin of the eastern depression situated below the equator.

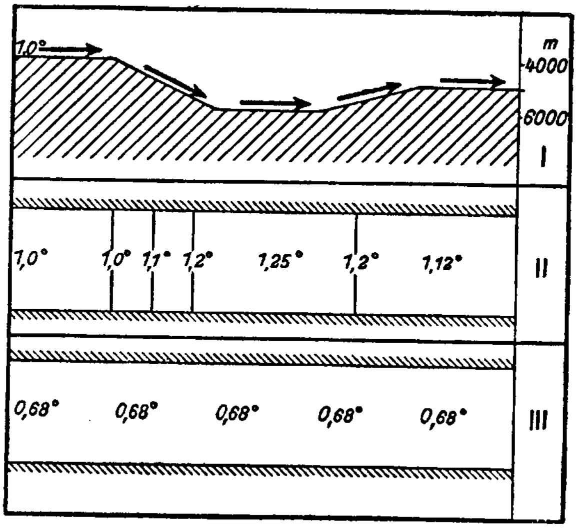

FIG. 1.

Propagation of bottom water of an initial temperature 1. 0° C (in situ) *in an ocean of varying temperature.*

I. *Profile*; II. *Scale of temperature* in situ; III. *Scale of potential temperature.*

For the proposed study, intended to obtain a complete bird's-eye view of the Atlantic abyssal bottom of more than 4000 metres' (2190 fathoms') depth by the use of all the results of observations available from other expeditions, 852 bottom temperature stations (2) and 378 bottom salinity stations (3) were established, giving a substantial

(1) *A complete historical account will be given in the Report of the Expedition.*

(2) *Of this number* 537 *stations are those of exploring vessels (particularly the* Challenger *and the* Meteor *with a total of* 197), 315 *from cable ships and surveying ships.*

(3) *The most abundant material on bottom salinity* (110 *stations) was furnished by the* Meteor *(the old values based on aerometric measurement more often than not could not be used, chiefly owing to imperfections in the water-sampling bottles).*

quantity of material, part of which (1), it is true, after critical examination could not be taken into account, owing to the size of the errors, for constructing isotherms and isobaths.

HELLAND-HANSEN (1930) showed that it is very useful, especially in the matter of the origin of the bottom water, to use the potential temperature instead of the real temperature *in situ* — *i. e.* the temperature which a liquid particle would assume if it were displaced adiabatically up to the surface. For this temperature is a kind of constant, observing that for all the displacements, even vertical, of a mass of water, as very often produced at the bottom on account of perturbation due to submarine relief, it does not vary as long as there is no mixing with water of another type. Let us show by a diagrammatic example (Fig. 1) this advantage arising from the use of potential temperatures for a study of the bottom water.

Let us suppose a mass of water to be flowing at constant speed along the bottom of an oceanic basin whose depth, starting at 4,000 metres (2190 fathoms), gradually increases to 6,000 metres (3280 fathoms), finally rising again to 5,000 metres (2730 fathoms). Assume also that the mass of water starts with a temperature of 1.0°, and that it does not undergo any mixing during its later journey (Section I). In the middle (Section II) can be seen the scale of real bottom temperatures which would be obtained in this case. We will see on it an increase of temperature to 1.25° in the middle of the basin, and a slight decrease to 1.12°; we must conclude from the crowding of the isotherms that the bottom current at this place shows certain variations of speed or heat content. The scale of potential bottom temperature (Section III) immediately shows us the true state of affairs: the whole basin is full of a homogeneous mass of water with a constant potential temperature, which if displaced adiabatically for this purpose would have a temperature of 0.68°. We must place the scale of potential bottom temperature among the first of our considerations (Fig. 2). The first and certainly the most surprising result (2) which we find from the diagram is that *at these great depths of* 4,000 *to* 6,000 *metres* (2190 *to* 3280 *fathoms*) *the bottom water shows very considerable differences of temperature, not only between the Antarctic and the North Atlantic* (*which we knew before*) *but also in a relatively restricted space within particular abyssal basins.* The conception of a high degree of consistency in the conditions of the abyssal depths, as we still often find supported in these days, particularly by THOULET (1924) to an extreme degree, is seen to be incorrect to an even more marked degree than we could have expected; on the contrary, exactly at the deepest part of the ocean, there is more difference in the masses of water than in the deep layer above it, both as regards temperature and salinity; they do not remain in any way immobile, but are clearly animated in most of the deep basins by an appreciable flowing movement which we can deduce directly from the path of the isotherms. The coldest water, with temperatures below 0.8°, is found in the deepest depressions of the South Polar Basin. Let us first follow the propagation of the Atlantic water (3) in the *western depression.* We see that in its coldest and deepest parts it is first checked in its journey through the Argentine Basin by a shelf which we will call the *South Sandwich Shelf* (4). It enters that basin with temperatures of — 0.4° and — 0.5°; is forced to the left on a large scale by the deflecting force of the rotation of the earth; continues first in zones towards the West, then, under the influence of the bottom relief, in the direction of the meridians towards the North; traverses the *Rio Grande Ridge* which clearly offers a deeper passage due West, and, always preferring the left-hand side, enters the Brazilian Basin in the form of a narrow North-going band; where, on account of the barrier formed by the northern boundary of this basin, it begins to reduce its extension in the northern part and uniformly fills the crevices of the northern part. One branch goes by the *Parà Shelf* into the North American Basin; its extension is accelerated by the considerable narrowing of the cross-section, as shown by the run of the isotherms. The bottom current divides at the latitude of the *Puerto Rico Deep,* and passes round the

(1) *Out of the total measurements of bottom temperatures,* 123 *values* (i. e. 15 %) *were neglected, being obviously erroneous ; and of the bottom salinity determinations,* 100 *values* (i. e. 38 %) *were neglected.*

(2) *Helland-Hansen* (1930) *has already drawn attention to the presence of considerable differences of temperature at the same depth at the bottom of certain of the North Atlantic abyssal basins.*

(3) *The* 2° *isotherm approximately marks the limit of the Antarctic influence.*

(4) *There is not, as was previously thought, any communication between the Argentine and the South Polar Basins by a trench at a greater depth than* 5,000 *metres* (2730 *fathoms*).

insular shelf of Bermuda in two branches (on account of the rotation of the earth, the eastern branch is the stronger) ; we can follow the last ramifications of this Antarctic current as far as 40° N. *We must thus show this bottom current in the western depression as one of the grandest phenomena in connection with currents known in the world, for it can be followed over an extent of* 100° *of Latitude.*

The conditions in the *eastern depression* are quite different. Here also the coldest water is checked by a transverse shelf, the *Atlantic-Indian Shelf*. The masses of water

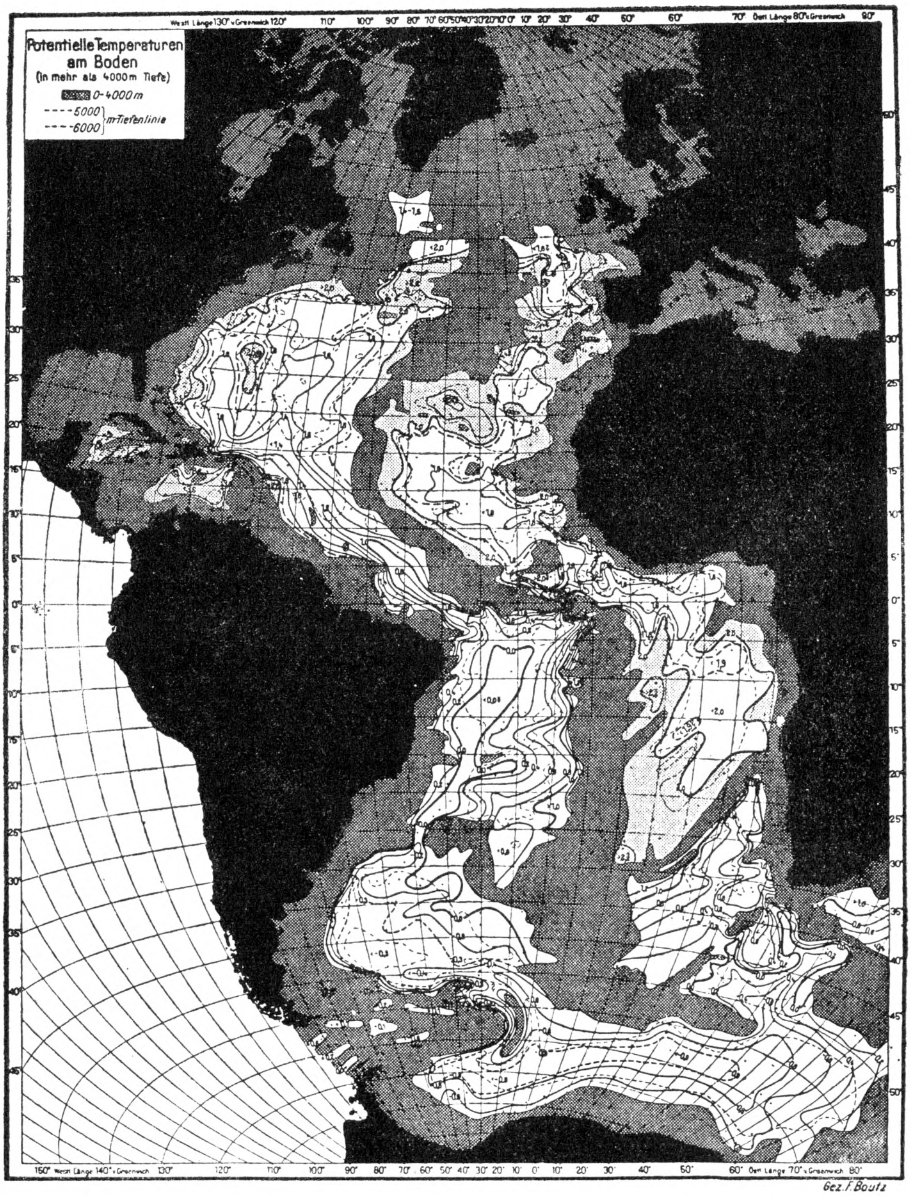

Fig. 2.

Potential bottom temperature (below 4,000 metres (2190 fathoms)).
Greatly reduced scale.
Regions of more than 2° are hachured. The isotherms are 0.2° apart, with the whole degrees in heavy lines.

with temperatures from — 0.4° to 0° spread in two branches in the Agulhas Basin in conformity with the relief; but immediately to the North-west of this basin, the bottom current is obstructed more forcibly by a transverse shelf, the *Cape Shelf*, already presumed to exist by KRÜMMEL (1907) and now confirmed by the bottom temperatures. The exact position of this shelf cannot yet be charted, owing to the small number of soundings and the great inequality of the bottom shown here by the two sections of the *Meteor*. We have shown it on the diagram lying S.S.W. and N.N.E. and its datum points are the Meteor Bank, the Schmidt-Ott Rise and the Agulhas Rise; but there is no doubt that here also there are lines of rises perpendicular to these lines, as shown by the Valdivia Bank. The southern branch of the bottom current is obviously the stronger and it sends an off-shoot as far as the northernmost point of the Cape Basin where this direct extension finishes completely. It is a remarkable fact that, even in these two basins communicating widely with the South Polar Basin, the bottom current is far feebler than in the western basin, as we can see at once from the temperatures. For in the Cape Basin we have thermal conditions at the bottom which correspond to those of the Parà Shelf situated far to the North in the western depression. What is the cause of this phenomenon? According to SVERDRUP (1901) it must be attributed to the fact that the masses of water flowing northward in the South Polar Basin are taken in charge by the influence of the deflecting force of the rotation of the earth, and spread chiefly towards the west in the ring surrounding the South Polar continent, where they beat against the wall of the South Antilles Arc and the Antarctic Archipelago. There, in the Weddell Sea, the Antarctic water of the whole ring is blocked, and for this reason it escapes with particular strength in the bottom current of the western depression.

But, in spite of the stoppage due to the Walfisch Ridge, we can show Antarctic influences contrary to prevalent conceptions in the greater part of the eastern depression; true, it is a question of the indirect Antarctic influence by a détour over the *Romanche Trough*, as we shall henceforth call this passage which is probably wider and deeper than has hitherto been realised. We estimate the depth over the sill (1) of the central ridge at 4,500 to 4,800 metres (2460 to 2620 fathoms). The influence of this Antarctic flow is thus not limited solely to the equatorial basin as BÖHNECKE (1927) assumed, but in the South reaches as far as the Angola Basin (West African Basin), passing over the *Liberian Shelf* and the *Guinea Swell*; more in the North, in the Cape Verde Basin, passing over the *Sierra Leone Shelf*; and, by a feeble ramification, into the northern basin of the Canaries passing over the *Cape Verde Shelf* and the *Canaries Shelf*. Here again we recognise the influence of the deflecting force due to the rotation of the earth, in this propagation towards the North which here displaces the axis of the current to the right, *i. e.* eastward. The distribution of temperature in this part of the eastern depression shows a considerably rougher configuration of the sea-bottom than has hitherto been supposed. We should note the high temperatures in the southern basin of the Canaries which can only be explained by a very distant Mediterranean influence (2). *Consequently in the eastern depression the Antarctic influence can also be detected as far as* 35° N; *we see here a paradoxical phenomenon in the shape of a secondary source of cold directly below the equator.*

But where is the northern counterpart of the Antarctic bottom current, *i. e.* the *Arctic bottom current?* For there is also a descent of cold water from the surface of the Arctic into the depths. We can see that this branch of the circulation is only very rudimentarily developed, and that for two reasons — first on account of the lesser extent of the region of penetration at the surface, owing to the less favourable distribution of sea and of land, and secondly from the fact that raised shelves separate these Arctic basins from the great depths of the high seas. To the West we find relatively cool water, 1.4° in the Labrador Basin, but immediately South of 50° N. the bottom temperatures are 2° and more. Taking this fact as a basis, I concluded in 1928 that there existed at this place a rise, the *Newfoundland Ridge*, which is still missing from all the modern bathymetric charts but which is fully confirmed by the soundings (3). This rise mounts from depths of more than 4,500 metres (2460 fathoms) to a height of

(1) *By* depth over the sill *we mean the deepest depression in a shelf, through which an exchange of water can take place.*

(2) *Always supposing that the old measurements of the* Challenger *and* Princesse Alice *are beyond criticism at this spot, which is always doubtful.*

(3) *It has since been found that the ridge appeared on the first edition* (*Monaco,* 1912) *of the Bathymetric Chart of the Oceans but that it was suppressed on the last edition* (1930) *of this chart.*

3,600 metres (1970 fathoms) depth over the sill. The development of the Arctic bottom current is even more rudimentary in the eastern depression. We can imagine *the dividing line between the Arctic influence and the Antarctic influence to be disposed asymmetrically on the bottom, to the West at about* 40° N. *in the Newfoundland Basin, to the East at about* 35° N. *on the Azores Plateau.*

It is noteworthy from the historical point of view that similar conceptions had already had adherents in the past. If we look far enough back in the history of research we find a precursor to them in the person of Freiherr VON SCHLEINITZ (1874), the captain of the *Gazelle*, who as early as 1874 drew, from the increase in bottom temperature in the North and South as far as 36° N, the bold conclusion that this parallel of Latitude in the Atlantic Ocean seems to be that at which the Arctic and Antarctic bottom waters meet at about 17° to 18° W. Longitude. But this conclusion was abandoned when, by the discovery of *Walfisch Ridge*, it had been established that the end of the Antarctic influence occurred from 25° S. in the eastern depression.

We have mentioned that the South Antilles region is of decisive importance as regards the conditions in the whole of the Antarctic maritime ring. The new study of the soundings by STOCKS (1932) and the geological discussion of the problem by WILCKENS (1932) leave us in no doubt as to the existence of a direct submarine junction between South America and the Antarctic, formed by the *South Antilles Arc*. Owing to the insufficient density of the soundings, the question of the depth over the sill of this relatively steep ridge has remained unsolved, though of capital importance for the

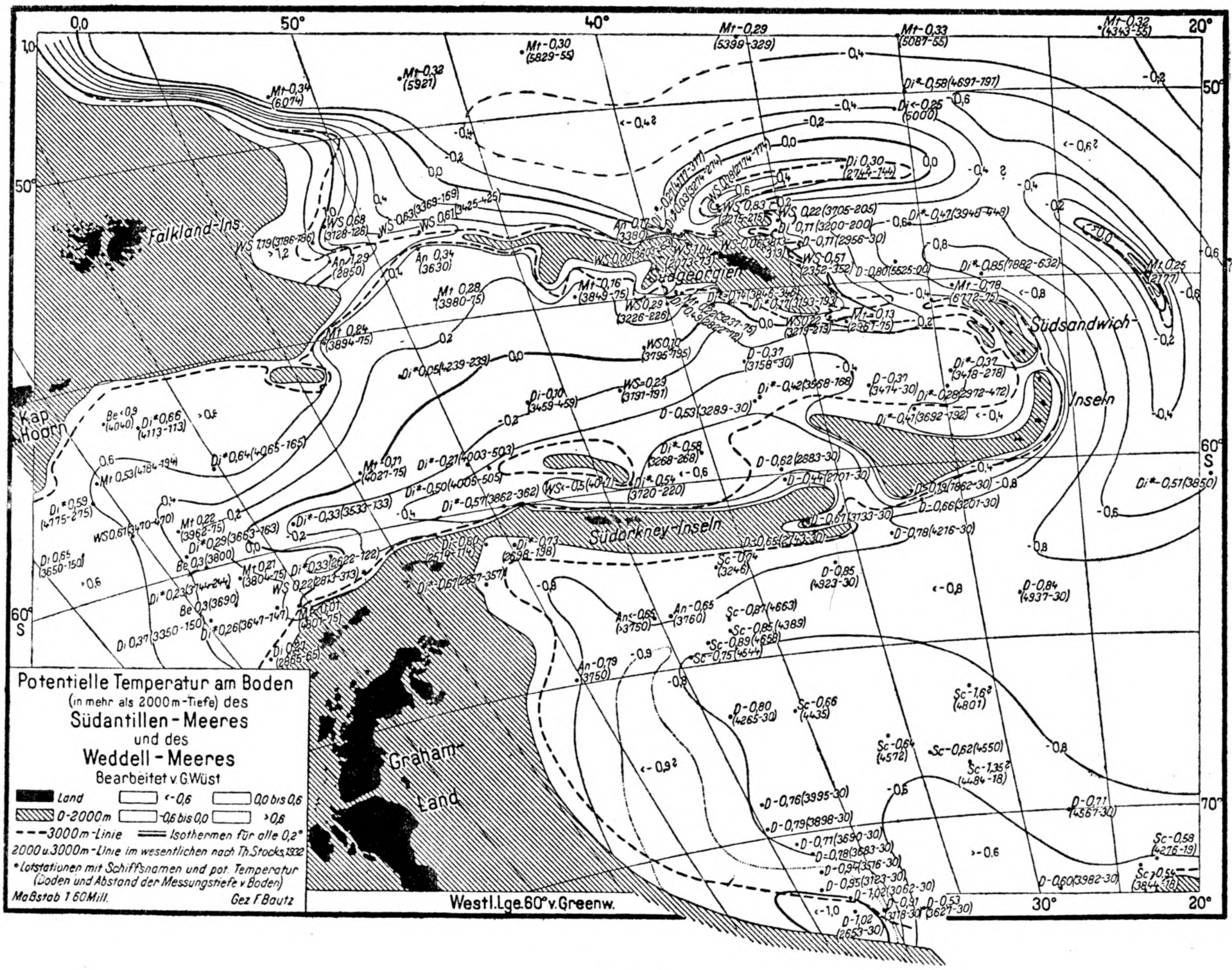

FIG. 3.

Potential bottom temperature in the South Antilles and Weddell Seas.

exchange of water between the Atlantic and Pacific Oceans. The treatment of the potential bottom temperatures (1) in this chart of the South Antilles Sea and the Weddell Sea provides the solution of this question (Fig. 3).

We have seen how a ramification of the Antarctic-Atlantic water percolates into the South Antilles Sea and we can deduce from the bottom temperatures that, half way between the South Orkneys and the South Sandwich Islands, *there exists a dent in the ridge which here lies at a depth of over* 2,000 *metres* (1100 *fathoms*) ; *we get a depth over the sill of about* 2,750 *metres* (1500 *fathoms*) (2).

Traces of this Antarctic infiltration, which mixes with the Pacific bottom water, can be found in the whole of the South Antilles Seas. The other passage in the northern and western portions of this Arc probably only reach 2,500 metres (1370 fathoms) in depth (3). Further, we recognise a close connection between the isothermic lines and the relief, which conversely can be used to draw conclusions on the morphologic structure for the bathymetric chart. A spacial representation of the stratifications of the bottom waters and of the propagation of the bottom currents is given us by the vertical section which we have drawn, based on the *Meteor* stations but having recourse also to other observations originating in the East Atlantic depression and the West Atlantic depression for depths of 3,000 to 6,000 metres (1640 to 3280 fathoms). These longitudinal sections (Fig. 4) follow the axis of the bottom current, from which we can obtain the position of the bottom temperatures on the chart. The stations are plotted in accordance with their true distances ; the total length of the western section represents the conditions over an extent of 21,000 kms. (13,050 miles), that of the eastern section over an extent of 18,000 kms. (11,185 miles). The exaggeration of the heights is considerable, *viz.* 1000 times (4).

The *western section* clearly shows the contrary propagation of the two kinds of water. Starting from the South, the Antarctic abyssal water runs along the ocean floor to the North as bottom water ; starting from the North, the North Atlantic bottom water flows, contrariwise, as abyssal water over the Antarctic water. The Antarctic bottom current can be traced over the considerable extent of 16,500 kms. (10,250 miles), if we take the current as beginning at the northern edge of the South Polar Basin. Conversely we can follow the North Atlantic influence from 40° N. to about 50° S. The two chief kinds of water are separated by a *layer of demarcation, well defined by the temperature and salinity,* in which they gradually mix. This boundary layer falls towards the North, from about 3,200 metres (1750 fathoms) at 40° S. to 4,800 metres (2620 fms.) at about 10° N. where it nearly reaches the bottom. From the shape of the isotherms and, consequently, from both the position and shape of the boundary layer, we can recognise among other things a remarkable adaptation to the bottom relief. Wherever the bottom waters extend over rising submarine depths, *i. e.* on the front face of the shelves, the isotherms bulge like current streams. Above the shelves there is a strengthening of the layer passing over them, which in some places shows an astonishing temperature grade. Thus over the *Rio Grande Ridge* we find a drop in temperature of 1.1° per 200 metres, which is abnormal if we consider that in the layer of bottom water immediately above it the vertical temperature gradient is less than 0.1° in 200 metres. Beyond the shelves the isotherms fall more than 1,000 metres (550 fms.) and at the same time the layer that crosses them spreads out fanwise.

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(1) *This chart is based on a total of* 124 *temperature observations near the bottom* (*at a depth of over* 2,000 *metres* (1090 *fathoms*), *of which* 57 *values are due to the excellent work of the* Discovery *Expedition* (1925-31). *We would draw attention also to the most recent bathymetric chart of the South Antilles Sea lately published by Herdmann in the* Discovery Reports, Vol. VI (Cambridge, 1932), *which was not available to the present author when this paper was written. Like Stocks's chart it does not show the hole about* 2700 *metres* (1480 *fathoms*) *deep between the South Orkneys and the South Sandwich Islands, necessitated by the bottom temperatures.*

(2) *Owing to the small number of observations it is not possible to give this shelf an exact position.*

(3) *As Stocks has already shown in* 1932, *there are less marked shelves in the South Antilles Arc in the eastern part between Candlemas Island and Saunders Island, through which however only insignificant quantities of Atlantic-Antarctic water* ($< -0.4°$) *penetrate into the South Antilles Sea. In the northern part of the Arc also we find shelves rising to barely* 2,500 *metres* (1370 *fathoms*), *which need not be considered in connection with the passage of the Atlantic-Antarctic waters.*

(4) *The longitudinal sections and the charts are reproduced on a larger scale and coloured in the Report of the Expedition. For reasons of format we have had to use this very small scale here.*

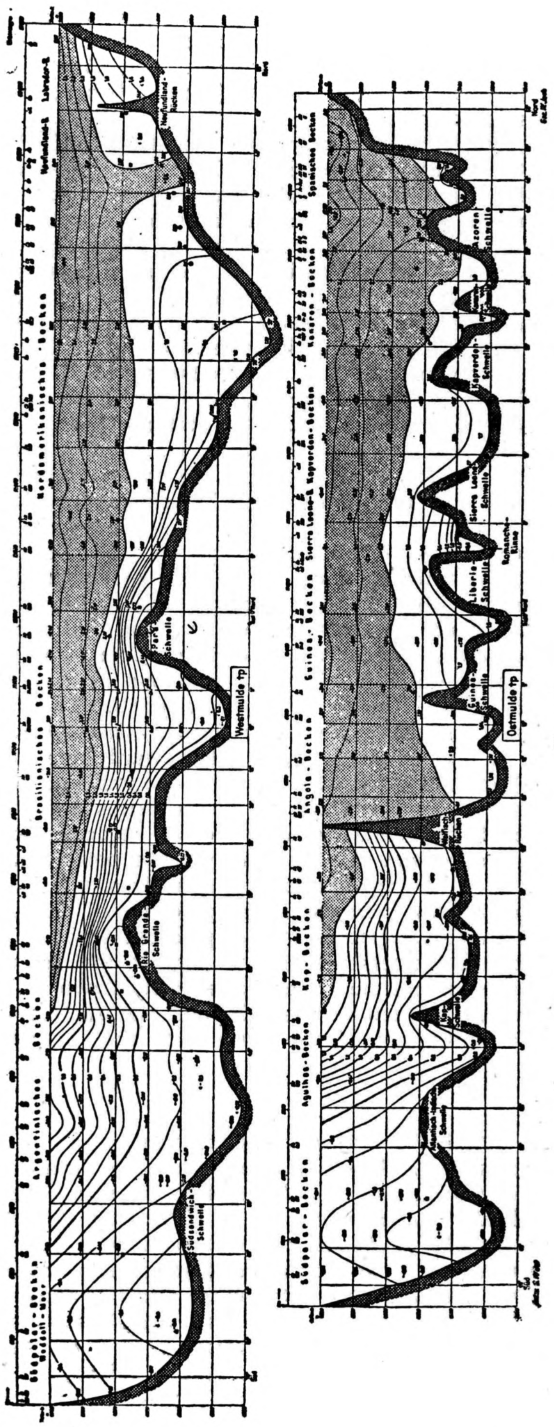

Fig. 4.

Longitudinal sections of potential temperature in the bottom water (of more than 3,000 metres (1690 fms.) in depth) of the western Atlantic depression and the eastern depression (along the axis of the bottom current). Temperatures above 2°; isotherms every 0.2°. (Greatly reduced scale).

This phenomenon is a particularly clearly defined case of the influence of the bottom relief on the boundary layer, and is in perfect harmony with the theories enunciated by DEFANT (1929) in answer to the question: "under what conditions and in what proportions can stationary oscillations in a boundary surface be produced in the presence of irregularities in the bottom configuration?" It follows from the mathematical study that considerable oscillations must be produced when the length of the bottom wave is large compared with the depth of the sea, and when dealing with relatively low speeds and stationary currents taking opposite directions in the water above and below. One could theoretically imagine the case where the oscillations of the boundary layer assumed a greater amplitude than the irregularities at the bottom, notably when the speeds of the current exactly fulfilled the conditions necessary for the production of large stationary waves. In the present case we are dealing with the oscillation of isotherms which, as regards their amplitude, correspond near enough to the irregularities at the bottom. As regards the water above them, these actions die away rapidly.

The sections also clearly show the difference between the western and eastern depressions — considerable extent of the Antarctic bottom current to the westward, a blockage by the *Walfisch Ridge* to the eastward, penetration of the indirect Antarctic influence into the eastern depression by the *Romanche Trough*; and secondary cold supply in the latter at the Equator.

We see how the cold water spreads northward on the much branching bottom of the eastern depression, and how each bottom wave forms a retaining wall for part of the underlying portions. With the aid of these sections, we are able to determine the depths over the sill of the following shelves, partly located afresh, partly confirmed afresh: to the West, four shelves — South Sandwich Shelf, Rio Grande Ridge, Para Shelf and the Newfoundland Ridge; to the East, nine shelves — the Atlantic-Indian Shelf, Cape Shelf, Walfisch Ridge, Guinea Swell, Liberia Shelf, Sierra Leone Shelf, Cape Verde Shelf, Canaries Shelf and Azores Plateau. The warmest column of water lies quite asymmetrically in the region where the two bottom currents converge, from 40° to 45° N. to the westward from 35° to 40° N. to the eastward, and particularly to the East; higher temperatures indicating the influx through the Straits of Gibraltar of dense Mediterranean water which apparently mixes right to the bottom.

The study which we have just made shows us that the Atlantic abyssal depth is more broken up than could previously have been realised on the strength of the soundings. It also enables us to determine the depths over the sill of the shoals on the bottom more accurately than can be done within close enough limits from the materials furnished by the soundings. It would seem desirable to collect on to one chart these morphological deductions, which do not depend on a new systematic exploitation of all the soundings, but on the use of the potential bottom temperatures in the bathymetric diagrams accessible to the author. This chart (Fig. 5) is drawn schematically both as regards the choice and the path of the isobaths; it only contains the isobaths of 4,000, 5,000 and 6,000 metres (2190, 2730 and 3280 fathoms). It is to some extent the fruit of a new working hypothesis on the configuration of the oceanic abyssal depth, and aims at ensuring that in future bathymetric charts greater consideration should be given to oceanographic points of view. Also in working up the result of the *Meteor's* soundings and of other material one should not fail to take these new points of view into consideration in constructing the lines of equal depth, especially in regions of newly discovered or recently confirmed shelves, thus helping to improve our natural schematic representation.

In this connection, let us briefly recall the question of the terminology of submarine forms. As we know, SUPAN (1903), to carry certain international resolutions into force, elaborated a series of very clear fundamental principles, often quoted, but, as can be seen from a glance at the bathymetric charts so far produced, in general but incompletely followed. According to SUPAN's definitions there can be no doubt that *Mulden* (depressions) should be used to designate the two primary concave forms which are subdivided by *Rücken* (ridges) and *Schwellen* (rises) into oceanic abyssal basins. We only apply the name *Rücken* (ridges), according to SUPAN's definition, to the steepest rises with a marked linear extension; *i. e.* to the central North Atlantic Ridge, the central South Atlantic Ridge, and the Walfisch and Newfoundland Ridges, all of which rise above the level of 4,000 metres (2190 fathoms).

In the same way with regard to the precise nomenclature of these first magnitude forms of the oceanic abyssal depths, SUPAN has made it clear that it is not practicable to give them the names of people or of ships, a thing which still often happens in these

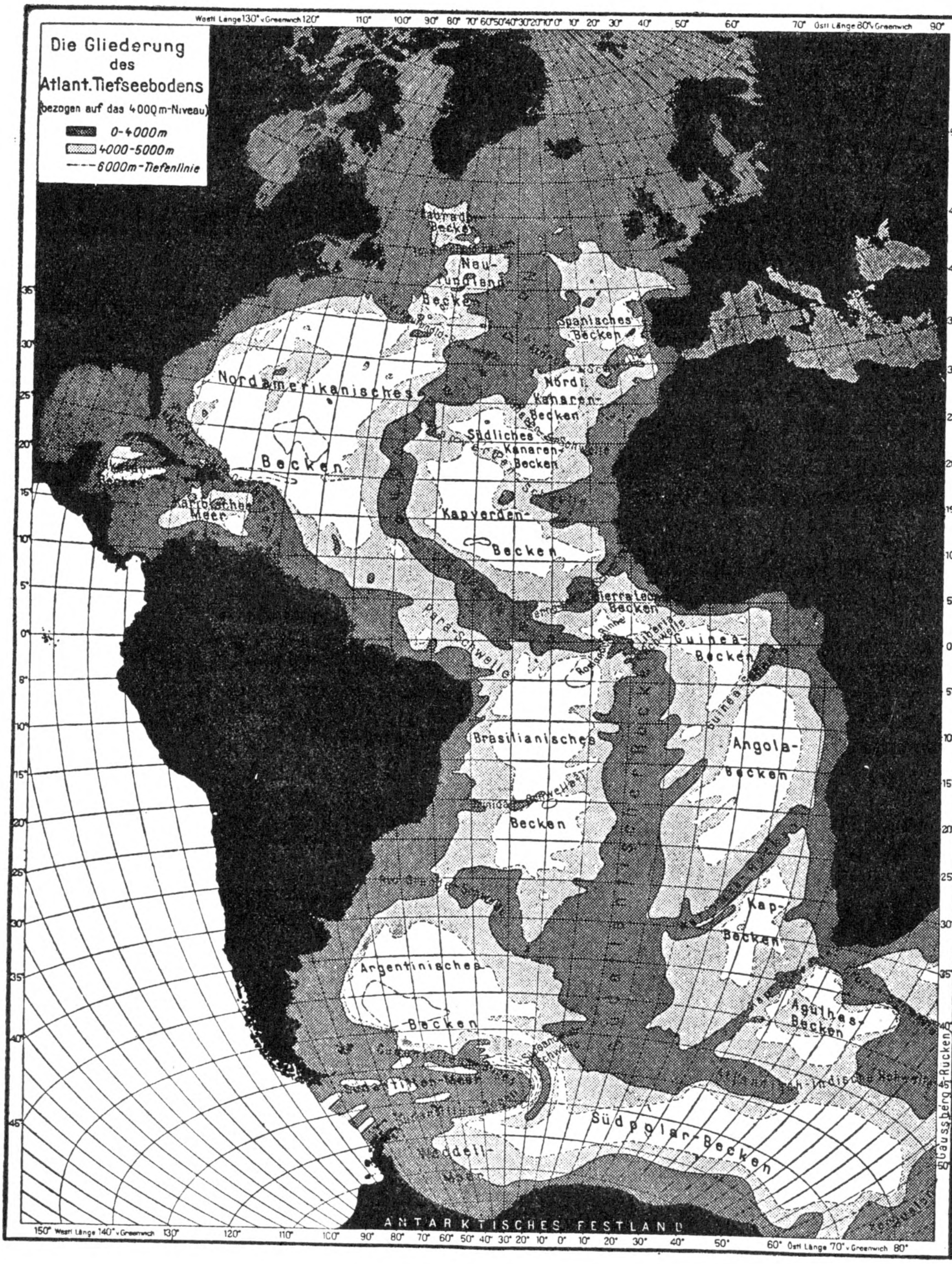

FIG. 5.

Configurction of the Atlantic Abyssal Depth.
(Greatly reduced scale).

days. It is better to choose geographical designations which at the same time contain an indication of the geographical position of the forms of sea bottoms in question. The names and designations which appear on our chart have been given in agreement with these fundamental principles, and will be used from now on in the further treatment of the material obtained by the *Meteor*.