RESEARCH INTO THE NATURE AND STRATIFICATION OF THE SEA BOTTOM BY MEANS OF HIGH FREQUENCY "ECHOLOTS"

by

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Quite recently, thanks to the introduction of *directional* emission by manufacturers of echo sounding apparatus, a new stage has been reached in the technique of sound measurement. While hitherto, with the instruments in use both for great and small depths (Atlaslot, Signallot, Behmlot, etc., to quote merely a few of the German productions), one could, on account of the non-directional and consequently spherical production of the sound, only obtain a *single* useable echo from the point on the bottom nearest the transmitter or the receiver, nowadays instruments are made which can direct the sound ray to a certain extent and give also a second and even a third echo. Appliances of this kind are known as magnetic impulse or piezo-electric sounders. There already exists a whole series of very interesting reports on these new appliances, into the details of which we need not enter here (1).

One of these new appliances, the "Debeg-Radiolot", has been installed, among other places, on board the surveying ship *Meteor* of the German Navy (Reichsmarine). The author has had the opportunity, thanks to the kindness of the Nautische Abteilung der Marineleitung, and particularly of Captain BENDER and Oberregierungsrat Dr. LANGE, of becoming acquainted with this instrument in the course of some trial trips of the *Meteor* in the Baltic and the North Sea, in collaboration with Dr. RUST of the "Debeg" (Deutsche Betriebsgesellschaft für drahtlose Telegraphie, Hardenbergstrasse 43, Berlin), to make some observations which we shall presently discuss in more detail. We may, however, remark at once that phenomena analogous to those described here have been found with the other high-frequency-oscillation, i.e. ultra-sonic, sounders, such as the new "Atlaslot".

The transmitter of the "Debeg-Radiolot", consisting of a system of quartz plates, emits the ultra-sonic rays, the radiating surface being very much bigger than the wave length used, in the form of a cone with an angular spread of 10°. With the ship horizontal, the sound waves are reflected from a point perpendicularly below the ship, and give the echo depth at this spot, even if the bottom is on a slope (Fig. 1). The picture of the returning echo in the indicating instrument may present various aspects.

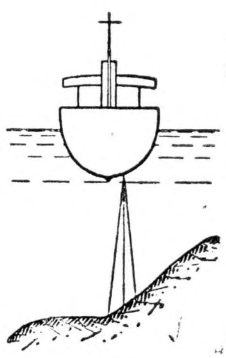

FIG. 1

Sketch of the directional sound emission when the bottom is sloping

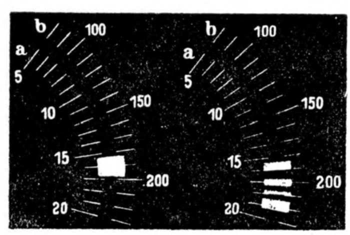

FIG. 2 FIG. 3

Single and multiple echoes

FIG. 2. *One* clear echo ; depth of bottom, 182 m. (Scope of measurement *b*, 50-650 m.)
FIG. 3. Multiple echoes ; depth, 15.5 m. Scope of measurement *a*, 1.5-65 m.) Depth of last reflecting layer, 18.5 m.

(1) *Among others*, W. KUNZE, *Fortschritte in der Entwicklung der Echolote*. Z. VDI. 1933, pp. 1265 et seq. W. SCHNAKENBEK, *Versuche zur Feststellung von Fischschwärmen durch das Echolot*. Der Fischmarkt, 1934, pp. 204 et seq. W. JOHNS, *Das Echolot in der Fischerei*, ibid. 1934, pp. 255 et seq.

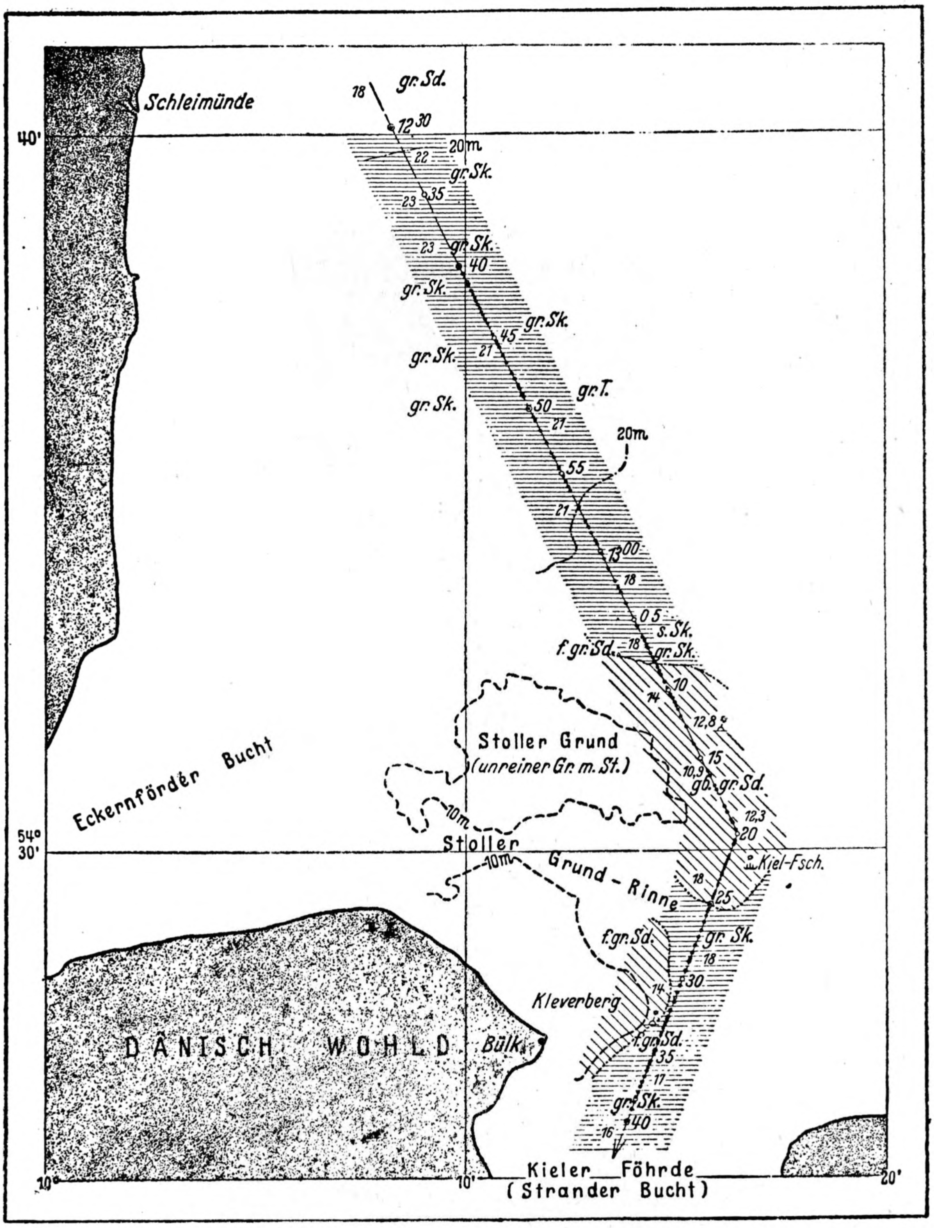

FIG. 4.

Sketch map of the track and position of the soundings (see above, para. 1)

Croquis de la route suivie et emplacement des sondages.(Cf. ci-dessus, 1er paragraphe)

Time	○ 12/30	Heure
Position of sounding	●	Position du sondage
Oozy bottom	≡	Fond de vase
Sandy bottom	///	Fond de sable
Sand	*Sd.*	Sable
Ooze	*Sk.*	Vase
Clay	*T.*	Argile
Stones	*St.*	Pierres
grey	*gr.*	gris
fine	*f.*	fin
coarse	*gb.*	grossier
Scale	c. 1:200.000	Echelle

Either a single wide band appears (Fig. 2), the upper edge of which is the echo depth at the place where the sounding is taken. Or else the strip breaks up into several larger or smaller fragments, of which the number and the distance apart may vary in the picture of the echo (Fig. 3). In the latter case, the upper edge of the first strip gives the echo depth, and we presume that in the second and following strips of light we are seeing echoes from the reflecting layers, which are becoming denser and denser, of the bottom deposits, or of the hard sub-soil.

During these *Meteor* trials, the "Radiolot" gave both kinds of pictures, and the change from one type to the other is, as shown by the diagram (Fig. 5), clearly subject to certain laws which seem to corroborate the supposition *that the bottom deposits, accordinq to their nature and thickness, find their expression in the echo picture on the indicating apparatus.*

The itinerary followed during the trials, which took place between Schleimünde and the Kiel Fjord, with a small alteration of course at the Kiel Lightvessel, passed over different natures of bottom, particularly over ooze, clay, sand and stones (Fig. 4). The reading of the instrument did not follow a set plan, but took into account the characteristic variations of depth, observed continuously on the indicator, as well as the last echo. Fig 4 shows the positions of the soundings. On account of the frequency of successive soundings (10 per second), only the characteristic echoes have been plotted, i.e. only some 0.4 %.

The wire soundings shown on Fig. 4, which is a reduced reproduction of part of German Admiralty Chart No. 30, appear in Fig. 5 as a pecked curve. Further, in the sketch-map, also from data given by the German charts, regions with a muddy or sandy dominant bottom, along the route, have been distinguished by different hachures, and their respective limits inserted in the diagram (Fig. 5). It is easy to recognise in the sketch-map the Stoller Grund region composed of sand or gravel, and the submarine continuation of the Dänisch-Wohld peninsula, which, with Bülk Point and its continuation the Kleverberg, runs far eastward into the Kiel Fjord. The run of the bottom of the western part of Kiel Bay, rising gradually from north to south and covered with ooze, also stands out clearly, as well as the Stoller-Grund Rinne, also full of ooze, and the Strander Bucht.

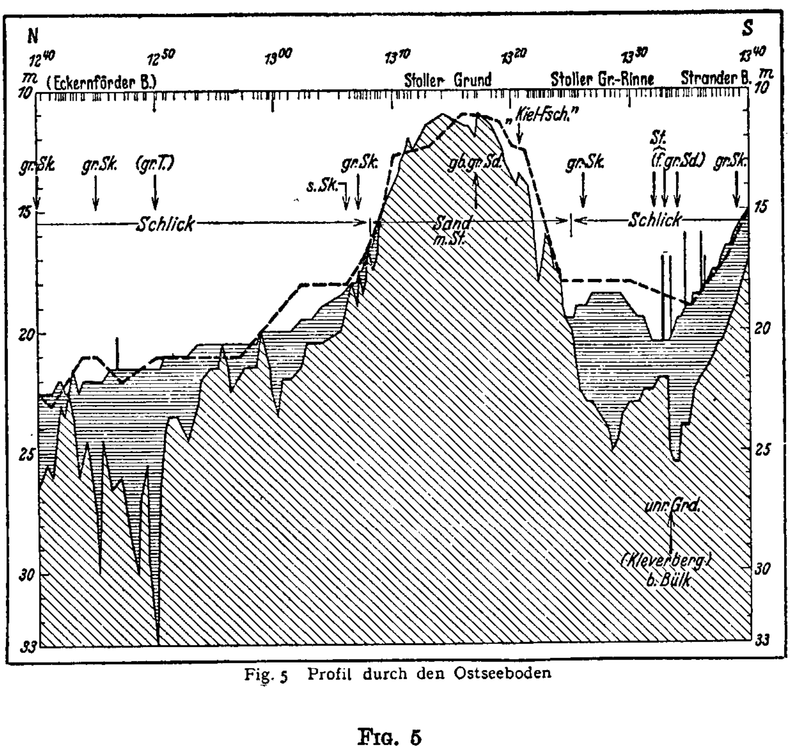

Fig. 5 Profil durch den Ostseeboden

FIG. 5

Profile of the bottom of the Baltic

Scale of length, c. 1: 200 000. Heights exaggerated about 800 times. For abbreviations referring to nature of bottom see Fig. 4. Drawn by Th. STOCKS, 1934

We find these data from the chart repeated in Fig. 5. They can be compared here with the graphic representation of the readings of the indicator of the echo sounder. These readings show by fine continuous lines the depths from which the first, or principal, echo and the lowest echo are received. Where both echoes appear, the space between them has been lightly hachured. The agreement of the first echo (bottom echo proper) with the contour lines of the chart is remarkably good, considering that in taking the readings we only approximated to half a metre, a degree of accuracy which could easily be improved.

For greater simplicity, the values read to within a half metre have been joined by straight lines; this has resulted in formations of steps and peaks which of course do not exist in reality. With 10 echoes per second this bottom echo proper was quite recognisable during the whole of the observations, and every modification was quickly noticed. On this depth curve the Stoller Grund, at the southern extremity of which the Kiel Lightvessel is moored, can be clearly recognised; its minimum depth, obtained with the "Radiolot", is 11 metres. The basin to the northward of this shoal can also be very well seen, as well as the Stoller-Grund Rinne between the Stoller Grund and the Dänisch-Wohld peninsula, and south of this the rise towards the submarine continuation of Bülk Point, the Kleverberg, at the eastern angle of which is moored a buoy as a navigational mark.

The lower curve shows the last echo which appeared on the indicating apparatus; it comes evidently from one of the bottom layers lying below the sea bottom proper. In Fig. 5 it has been plotted at the actual depth shown by the scale of the apparatus, i.e. without any correction. To know whether, and how, the velocity of sound varies in a given nature of bottom, e.g. in ooze, it will be necessary to carry out a thorough systematic research, which as far as I know has not yet been done. For our examination, none the less, it seems to be unimportant if the depth of the lower reflecting layer is somewhat modified, observing that, as stated above, the accuracy of the readings was not approximated closer than to half a metre, and that on the other hand corrections of the depth for the velocity of sound in ooze would presumably only entail very small alterations in the depth figures.

From the lower echo it has also been possible to follow without difficulty the variations of depth of the reflecting bottom layer, and quickly to note characteristic values; consequently, when on the upper border of the diagram (Fig. 5), on which the positions of the soundings are shown by short dashes, larger intervals between two soundings are found, this only means either that the "Radiolot" did not show a change of depth between two echoes, or if such existed, that it took place in a continuous manner. It only remains to mention that we have marked in Fig. 5 the nature of bottom as read off the chart in the neighbourhood of the track or directly on it — the data far from the track, or doubtful, being shown in brackets.

Remarkable in this diagram is the fact that the lower echo only appears in the deepest parts of the bottom, as off the Stoller-Grund Rinne, while on the Stoller-Grund Rinne itself it entirely disappears. It is remarkable also that, as on approaching the Stoller Grund and on entering the Fjord, i.e. in shoaling depths, the profile of the lower echo appears to merge with that of the bottom echo proper, while in the continuation eastward of the Kleverberg a diminution of the depth of the lower echo is clearly seen. It is remarkable finally that the cause of the existence of the lower echo is clearly connected with the nature of the bottom: it is missing where according to the chart the underlying bottom consists of sand (Stoller Grund), but exists where the chart shows an oozy bottom.

We certainly shall not go far wrong if we assume that the high-frequency "Echolot" (in this case the Debeg "Radiolot") constitutes an aid to a first reconnaissance of the nature of the bottom (whether hard sand, rock or softer bottom, or ooze), capable of determining the thicknesses of soft bottoms of ooze. It is also permissible to hope that with the aid of this instrument one will be able to find out the situation in depth of certain layers of discontinuity in the ooze; for, besides the two echoes described above, there are very often other intermediate echoes above the bottom of the ooze which give the impression that the whole luminous band of the echo on the indicator is broken up into separate bands of light. This may be explained by assuming that under certain not yet determined conditions, a part of the sound beam is reflected to the surface from the bottom, i.e. from the first boundary between two mediums, while the remainder penetrates into the bottom and is itself in turn partly reflected by the next intermediate layers. Nevertheless we cannot say for the moment whether the last echo gives the depth of the hard surface under the ooze or merely that of the last reflecting layer in the ooze. It has even been stated that on certain occasions no echo has appeared on the indicating apparatus, (a case which however did not arise during the *Meteor* trials) ; from which it is deduced that perhaps, on account of the gradual passage from water to ooze, in a sufficient thickness of ooze the last traces of the sound may be totally absorbed.

The question of possible errors must naturally be the subject of constant preoccupation, particularly if the high-frequency sounder reacts to sound waves other than its own (ship noises, vibration from the turbines or motors, etc.). The objection that intermediate echoes are produced in the instrument capable of falsifying the conclusion on the thickness of the deposits, by repeated traversing of the path projector-bottom-hull-bottom-receiver, is, on the other hand, hardly justifiable. This phenomenon was indeed noticed also during the *Meteor* trials, but the occasional appearance of such an echo was quickly and irrefutably traced, the flash of light appears in fact on the scale of the indicating apparatus at twice the depth of the sea, less the difference of level between the projector and the bottom of the hull.

In the diagram (Fig 5) will be found at different points (e.g. to the right in the Strander Bucht) records of a few other echoes above the echo depth proper. These records appeared suddenly and sometimes appeared not as a *single* flash but as two successive flashes. The frequency of this echo (assuming that it really is one, which is quite possible) at the spot shown, i.e. in the neighbourhood of the Kleverberg, where the slope of the sea bottom from west to east is relatively steep, is remarkable and encourages the hypothesis that the cause of these echoes is perhaps connected with the stones found here. Similar phenomena have also been reported by steam fishing craft, which for some time have been using high-frequency sounders from choice.

To sum up, we can say :–

1. That it can hardly be doubted that the phenomenon of the second echo described above is *real* ; other observations agree also with ours.

2. That in the light of our diagram (Fig. 5) the hypothesis that the second echo, if it does not give a reading according to the thickness of the bottom of ooze, gives one according to the position in depth of the last reflecting layer, gains greatly in probability. It is true that for the moment soundings made with high-frequency sounders can only be qualitatively used ; the hope remains, however, that researches on the velocity of sound in ooze will enable quantitative results also to be obtained.

3. That modern geological-morphological exploration is interested in the highest degree by these results utilisable for the establishment of sections and charts (e.g. isohypsometric charts of the sub-soil, with lines of equal thickness of sediment, etc.).