THE SOUNDINGS OF THE EXPLORING VESSEL "METEOR" AND NAUTICAL SCIENCE

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The expedition of the "*Meteor*" was a scientific one, and the principal results obtained were of a purely scientific nature. The enormous quantity of soundings which she took (exactly 67,430), will nevertheless be applicable to practical navigation also and this so much the more as the method of sounding by echo comes more and more into use.

As it is a matter of indifference to the navigator whether he has more or less water under his keel so long as he does not have so little as to be in danger of grounding or of losing speed, he is chiefly interested in shoals and banks. The "*Meteor*" has searched for certain shoals of doubtful existence, obtaining most often, it is true, the result: "Not found"; but as time was lacking to carry out long researches in their region, their non-existence cannot be deduced.

The result: "Not found" is applicable:

1° To the bank reported by the S/S "Niederwald" in the Channel:

2° To the bank reported as lying to the West of Cape Finisterre:

3° To the Bom-Felix, Doric, Birkenhead and Santa Rita Banks, as well as to a sounding of 49 meters to the south of Doric Bank.

4° To a sounding of 95 m. to the North-west of Capetown:

5° To a large number of shoals off the coast of Albardao (South Brazil).

6° To a sounding of 119 m. to the west of the Rocas and to a sounding of 95 m., known as "Nicktheroy".

7° To the *Busbridge* and to the *Fly-Bank* off the Brazilian coast.

Besides, it is not astonishing that on some known banks the "*Meteor*" should not have found the smallest depths indicated on the charts: the "*Meteor*" obtained:

At the Gettysburg Bank,	894 m.	(smallest depth shown on the chart,	42 m.)
At Dacia Bank,	142 m.	(« « « « « «	85 m.)
At Hotspur Bank,	117 m.	(« « « « « «	42 m.)
At Rodgers Bank,	117 m.	(« « « « « «	44 m.)

A special edition on shoal soundings published for the correction of German Admiralty Charts concerned soundings:

1° Around Fernando Po, Ascension and St Helena Islands;

2° In the port of Sâo Paulo de Loanda and determination of the North point of Loanda Island;

3° Between Capes Sta Maria and Sta Martha (West Africa);

4° In Espiegle Bay;

5° On the plateau off the Great Fischbucht;

6° At Fernando Noronha and St Paul.

The "*Meteor*" refound Bouvet Island 54°26' S. and 3°24' E. This island had already been reported in 1898 by the vessel "*Valdivia*" which had been sent out on a research expedition. By systematic searches the "*Valdivia*" established that, instead of the three islands indicated on the British Admiralty Chart N° 2202 A (July 1913) as to be found at this spot, namely:

Bouvet	54°19' S.	5°20' E.
Thompson	53°50' S.	5°23' E.
Lindsay	54°25' S.	3°20' E.

there really existed only one island 54°26' S., 3° 24' E., which should be named "Bouvet" Island, after the name of its first discoverer and in spite of the inaccuracy of his calculations. The 1913 Admiralty Chart, while indicating these three islands, gave at the same time on a chartlet a rough plan of Bouvet Island made by the "*Valdivia*" but calling it "Lindsay" Island. On subsequent editions of the Admiralty Chart N° 2202 A (1923), as well was on the German Admiralty Chart N° 384 (1925), Lindsay Island is no longer found, only Bouvet Island 54°26' S. 3°24' E. and Thompson Island 45°56' S., 4°16' E. being shown, with the remark, however, on the English chart that its position is doubtful and on the German chart that its existence is uncertain. Since the "*Meteor*" has passed over the presumed position of Thompson Island and has obtained by sounding there a depth of 6000 m., it is time that Thompson Island should be erased from nautical charts. In this region, really only one island exists; the others are only illusions due to inaccurate determination of position or to the presence of icebergs.

Apart from the search for shoals, more and more attention is being given in our days to the determination of lines of equal depth (Isobaths), a knowledge of which is very useful for determining the position of the ship. The ocean depths could thus be used as soon as we have profiles and accurate depth charts, and when our ships are fitted with echo-sounding apparatus. With this apparatus it is possible to know, without loss of time and at any depth whatsoever, the distance to the bottom of the sea; sound passes through water, in round figures, at the rate of 1 ½ kilometers (4920 feet) per second. In order to ascertain the composition of the sea bottom and to determine the pecularities of form favourable for fixing the position of the ship, the measurements of the "*Meteor*" have laid down bases and demonstrated that the bottom of the ocean is not at all a slightly inclined horizontal plane but, on the contrary, consists of high mountains, plateaux, troughs, and pinnacles of characteristic outline.

We should, however, have clearly in mind some peculiarities of echo-sounding. In reality it does not measure a distance but a time which, multiplied by the velocity of sound, gives the measure of the distance traversed. The apparatus is provided with a scale of length based on time, and of which a constant velocity of sound is the basis. But the true velocity of sound varies with the temperature, the salinity, and the pressure; it increases at the same time as each of these factors. Consequently one should know the value of these three factors, at the moment of sounding, for the different depths of the sea, in order to be able to determine the depth, according to the time taken by the echo to return. In all the seas of the world, the velocity of sound at different depths varies from 1400 to 1620 m/sec. and the mean velocity at the surface of the sea and at the bottom between 1450 and 1540 m/sec. The correction of the mean value will be between -3% and $+3\%$.

In sounding by echo, with the diffusion of sound in all directions, that is to say, undirected, such as has been carried out up to present for great ocean depths — it is possible that the point of reflection of the first echo may not be absolutely vertically below the vessel, and consequently the distance of the point of reflection will not represent the depth. On a flat bottom inclined at an angle a one would find the oblique distance $h \cos a$ instead of the depth h and even this, with slopes of 15° which have been frequently found, gives a result which is too small by 3 %.

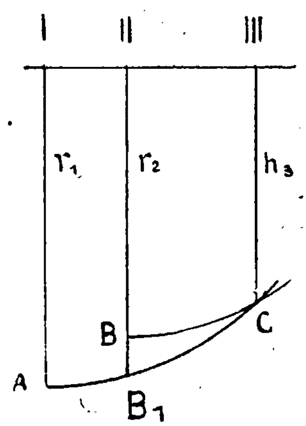
The bottom of narrow deeps do not return any echo at all, when everywhere above their bottoms the distance of the vessel to the sloping sides, is less than the greatest depth. The two sources of error, due to the differences in the speed of sound and the inclination of the bottom, should be taken into consideration, when constructing a geophysical chart, giving the true depths of the sea. But, if the soundings shown on marine charts are to be used for determining the position by echo sounding, the navigator desires to know what will be the figure which his echo sounding machine, the scale of which supposes an equal velocity at all times, will give him in this position.

For this reason, on German charts, the results of echo soundings are indicated by upright figures (the figures in italics being used exclusively for soundings by wire) and these represent, in a given position, the distances that a sounding by echo would give, with a scale constructed for a velocity of sound of exactly 1490 m/sec.

Whoever sounds in this position by echo sounding, whose scale has for base a velocity of sound v, will find the echo figure $hv : 1490$ instead of the echo figure h, shown on the chart. It is assumed here that, at the position in question, no temporary or seasonal variations occur in the velocity of sound. On this subject, information is almost completely lacking.

If at the position in question, the true velocity of sound is u (and if the point of return of the echo is situated exactly vertically below the vessel) the actual depth would be hu: 1490.

From a total of approximately 67,400 soundings taken by the *Meteor*, 500 have been inscribed on the German Admiralty Charts N° 384 and N° 540. For the construction of a geophysical depth chart, those data which have so far been published can not be used because they do not represent 1 % of the soundings taken, and besides the figures have not been corrected for the velocity of sound and inclination. This is a work which the *Meteor* will do later on.



In reality the inclinations of the bottom are so great that it is necessary to make corrections. In Fig., at points I and II, the " echo-distance " $r_1 = \text{I}A$ and $r_2 = \text{II}\,B$, found by sounding, the point of echo for I is found on the circumference of a circle with centre I and radius r_1 and for II on the circumference of a circle with centre II and radius r_2. Suppose A to be the point of echo for I — and that the " echo-distance " r_1 is equal to the depth h_1 at I. Consequently B cannot be the point of echo, since $\text{I}\,B < r_1$. The depth h_2 at II is then at least equal to $\text{II}\,B_1$, and the point of intersection C of the two circles, gives at I and II the greatest depth h_3, from which the echo is able to return. It is possible to see from the examples given in the tables below, composed from soundings of the *Meteor*, how much the depth may be in error, from distances obtained by echo. In the column " Positions " i indicates the figures obtained by interpolation, and e those by an extrapolation analogous to h_3, in the diagram. It may be seen that in absolute value and in percentage, the correction to be applied to the " echo-distance ", to obtain the depth, may be great, and that for a given point the point of echo may be very far away.

Steep Slopes

Points.	Horizontal distances.	Echo distances.	Depth.	Correction. absolute.	Correction. %
	meters	meters	meters		
e	— 780	——	830	—	—
I	0	1150	1450	300	26.1
î	340	——	1590	—	—
II	510	1540	1700	160	10.4
III	770	1660	1830	170	10.2
IV	1280	1860	1975	115	6.2
V	1535	2000	2075	75	3.8
VI	2560	2320	2320	—	—
e	— 470	——	1250	—	—
I	0	1320	1790	470	35.6
II	1560	2380	2380	—	—
e	— 120	—	440	—	—
I	0	450	570	120	26.7
II	560	800	800	—	—
III	980	850	1010	160	18.7
IV	1540	1150	1150	—	—
I	0	3740	3740	—	—
II	930	3200	3640	440	13.8
III	1860	3000	3270	270	9.0
i	2350	——	2960	—	—
IV	2790	2690	2840	150	5.6
I	0	4570	4570	—	—
II	1780	3400	4210	810	23.8
e	3470	——	2970	—	—

The correction of the " echo-distances ", by means of the true velocity of sound at a given point, instead of that of 1490 m/sec. which has been used, may also be very considerable. For the greatest depths registered by the *Meteor* and which were approximately of 8000 m. the mean velocity of sound between the sea surface and the bottom exceeded 1520 m/sec. At the positions sounded by the cruiser *Emden,* where the depths are the greatest in the world it is more than 1540 m/sec. Whereas according to soundings by echo it is sometimes difficult to know the true depth at the point of sounding, and a certain uncertainty results, the " echo-distance " for constant velocities of sound (1490 m/sec.) gives at the point of sounding a characteristic increase, from which the variability with the position can be utilised to determine the position of the ship, observing that the range of equal " echo-distances ", (they may be called " Lines of equal echo " to distinguish them from the isobaths), can be used as the basic lines. It needs, evidently, great gifts of observation to be able to draw the " lines of equal echo ", with precision, but in the table below, it is possible to observe some of these particulars, which the profile of soundings taken by the *Meteor* will show, by the collation of groups from a profile in which the intervening soundings of a single run have been omitted.

Submarine mountains, table lands, isolated mountain ridges, as also narrow or large holes, may be noted and that in large variety. The differences in height for small differences of longitude are very great for sections in an *E* and *W* direction, for example 2100 m. for 6'0 and 825 m. for 1.3' long.

CHARACTERISTIC FORMS OF THE BOTTOM FROM THE PROFILES OBTAINED BY THE "*METEOR*"

Forms of the bottom.	*Number of soundings.*	*Echo Distance.*	*Geographical Long.*
		meters	
Rise from a plain at a depth of about 5.000 m.	12	4980 3650	3° 51. 3' E 3° 44. 2' »
Mountain	20	3880 2280 3155	3° 44. 1' E 3° 42. 0' » 3° 41. 1' »
Rise	2	3375 3095	3° 38. 0' E 3° 37. 0' »
Fall	20	2885 4275	3° 28. 1' E 3° 13. 0' »
Rise	18	3940 3075 2930 2500	3° 6. 6' E 3° 3. 1' » 2° 56. 5' » 2° 50. 3' »
Fall	5	2830	2° 44. 6' »
Fall	14	3240 3830	2° 35. 7' E 2° 23. 6' »
Mountain	8	4930 4345 4610	3° 37. 7' W 3° 43. 4' » 3° 50. 1' »
Mountain	22	4345 3680 4705	7° 9. 6' W 7° 17. 8' » 7° 40. 0' »
Hollow	6	3755 4180 3730	9° 3. 9' W 9° 6. 4' » 9° 12. 1' »
Mountain	7	2815 2450 2864	12° 48. 8' W 12° 49. 5' » 12° 55. 1' »
Hollow	12	2470 3385 2315	13° 16. 6' W 13° 22. 7' » 13° 33. 7' »
Fall	8	2340 3115	13° 37. 3' W 13° 48. 9' »
Fall	9	3940 4510	17° 49. 0' W 17° 56. 8' »

Forms of the bottom.	*Number of soundings.*	*Echo Distance.*	*Geographical Long.*
		metres	
Mountain	4	4270 3830 4480	18° 25. 0' W 18° 26. 5' » 18° 37. 0' »
Valley and Mountain	9	4705 5505 4705 5270	25° 48. 2' W 25° 50. 2' » 25° 55. 4' » 25° 58. 0' »
Hollow	4	4930 5345 4685	26° 8. 0' W 26° 10. 7' » 26° 12. 8' »
Rise to the plain	4	5050 4255	28° 5. 5' W 28° 9. 1' »
Fall	12	2860 4105	31° 36. 7' W 31° 45. 4' »
Mountain	8	4080 3105 3930	32° 8. 0' W 32° 13. 0' » 32° 14. 3' »
Rise	16	3380 2945	32° 20. 5' W 32° 29. 3' »
Rise	11	2655 855	36° 13. 4' W 36° 21. 1' »
Fall	6	1210 2300	36° 28. 2' W 36° 33. 2' »
Rise	8	4900 2805	39° 27. 5' W 39° 33. 5' »
Rise	18	2305 1175	46° 24. 0' W 46° 38. 3' »