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# ON OLDER METHODS OF DEEP-SEA SOUNDINGS AND WHAT IS KNOWN AS »THE SWEDISH DEEP»

By *AXEL HAMBERG.*

It was not until about the year 1800 — in connection with the interest then being shown in the exploration of the Arctic regions — that successful attempts seem to have been carried out to determine the depth of the sea at considerable distances from land. Amongst the pioneers are to be mentioned Phipps, Scoresby, Sir John Ross and Sir James Clark Ross. But the man who displayed more zeal than any one else in the exploration of the seas was Matthew Fontaine Maury, Director of the Nautico-Meteorological Bureau of the United States. In his work, which appeared in several editions, »The Physical Geography of the Sea» (first edition, 1855, printed in London), he complains that our knowledge of the conditions in the depths of the sea is much less than our knowledge of the stars in the firmament. And indeed the difficulties of carrying out any investigations there had proved considerable. Even an apparently so simple matter as the determination of the depth proved to be a difficult and well-nigh hopeless problem with regard to the greater depths. Nevertheless serious attempts were made. The method of taking soundings which was at that time most usual in America was the following. In order to avoid using the ordinary costly sounding-line they used strong packthread provided with marks at every hundredth fathom and rolled in lengths of 10 000 fathoms on easy-running reels. As a plummet there was employed a canon-ball of 32 or 68 pounds (= 14.5 or 30.8 kg). Every vessel belonging to the American Navy could obtain such an equipment. It was believed that when the ball touched the bottom, the packthread would cease to run out, and at that moment they had to cut off the packthread at the surface of the water. The depth was determined with the help of the remainder of the packthread. If it proved, however, that the packthread did not cease to run out, this was assumed to be due to submarine currents. But it was impossible to obtain trustworthy soundings by this method at very great depths, even if the sounding was undertaken from a rowing boat, which could be kept in one and the same place by means of the oars — a thing which was impossible with sailing vessels. That these soundings often gave extremely curious results appears from the following data, taken from O. Krümmel, »Handbuch der Ozeanographie».<sup>1</sup> An American

<sup>1</sup> Bd. I., Stuttgart 1907.

naval expedition stated that it had not reached bottom with 16 000 m of pack-thread at a point about 600 nautical miles east of the mouth of the La Plata, and in the same year a British expedition stated that it had determined the depth about 400 nautical miles further to the east at 14 100 m. In both cases the true depth is about 5 000 m.

Owing to the apparently very great difficulties in obtaining trustworthy soundings at great depths, and owing to the great interest shown in such work, a number of projects were put forward for the solution of the problem. Even at that time men hit upon the idea of making use of the echo of a loud explosion reflected from the bottom of the sea and measuring the interval of time between the explosion and the echo. These experiments failed, however, owing to the fact that no echo was ever heard. It was not until our own days that this idea was worked out in such a way as to yield practically usable results, and nowadays it is this method that is most widely employed for sounding operations on a large scale, inasmuch as it does not demand that the vessel should stand still.

After the project of uniting the Old and the New World by means of a submarine cable was seriously put forward about 1850, it became a matter of importance to know something about not only the depth of the sea but also the nature of its floor, in order to get some idea as to the surface on which the projected cable was to rest. This problem was solved by the American J. M. Brooke, who used as plummet a vertically hanging tube, on which a cannon-ball through which a hole had been drilled was threaded, which was kept suspended by means of cords in two hooks movable round horizontal axles in the upper part of the tube. When the plummet bored its way down into the ooze at the bottom of the sea or struck against hard stones, the cannon-ball was unhooked; and when the sounding-line was drawn up, it remained lying on the floor of the sea. Owing to the use of detachable weights the Brooke sounding apparatus became the prototype of all following deep-sea leads. It had the advantage that it was possible to recover the line and a sample of the bottom clay, without making it necessary to hoist up again the greater part of the weight that gave to the line its speed in running out. These weights are often so great that the line would not be strong enough to haul them up again. The clay sample made it possible to be sure that the plummet had really touched bottom; and after the introduction of this method it was possible to avoid unreasonable depth-figures accompanied by a statement that the bottom had not been reached.

The programmes of many of the Swedish Polar expeditions in the middle of the nineteenth century included the making of deep soundings in the sea round Spitzbergen. Probably it was Otto Torell who was interested in this work, mainly for the study of the ooze on the sea floor. During the great Torell expedition of 1861 there were taken both several specimens of the Brooke apparatus and what

was known as a Bulldog machine — a device consisting of two scoops which were sunk wide open, but which, when they touched the bottom, were brought together and enclosed bottom ooze with the organisms found therein. Torell even made approximate determinations of the temperature of the water at the sea floor by examining the temperature of the clay in the Bulldog apparatus immediately after it had been hauled up. In Chydenius' account of the Torell expedition mention is made of the soundings executed, but nothing else is said concerning the actual method, except that they were carried out from a row-boat put out from one of the vessels of the expedition, the schooner »Aeolus». A few soundings were taken between Spitzbergen and Norway on both the outward and the homeward voyage at quite considerable depths. Evidently they sailed over the relatively steep slope between the Barents Sea and the North Atlantic. Chydenius' work contains a mention of the following soundings:

Date 1861	N. Lat.	E. Long.	Depth in fathoms	Computed depth in meters (from Swedish fathoms)	Depth according to Nansen
17 May.....	75° 18'	11° 19'	1 200	2 124	—
18 » .....	75° 40'	12° 31'	1 000	1 771	—
16 Sept. ....	77° 46'	10° 32'	600	1 062	800
17 » .....	76° 43'	13° 15'	1 100	1 947	200 <sup>r</sup>
18 » .....	76° 17'	13° 54'	1 400	2 478	400 <sup>r</sup>

These soundings are to be regarded as first attempts in a department but little tried before. Evidently there has been no idea that any very great exactitude in the depth figures might be desirable, as the figures have been rounded off to even hundreds of fathoms. Still less, it would seem, did anyone imagine that these figures would come to be scrutinized closely 67 years after they had been obtained. As now our knowledge as to the depth conditions round Spitzbergen has been substantially increased by means of several expeditions sent out from Norway, Sweden and other countries, and as this paper mainly aims at giving an idea of the reliability of these old Swedish soundings and the methods according to which they were carried out, some comparison with more recent results may be regarded as permissible.<sup>1</sup> This comparison shows that the soundings of the Torell expedition of 17 and 18 May and 16 September agree quite well with the more recent results, but that, on the other hand, those of 17 and 18 September yield far too high results, due either to unreliability in the sounding or to a great mistake in the determination of the position. The fact is, these points lie on the somewhat steep

<sup>1</sup> Our present knowledge would seem, in the main, to be summarized in Plate I of the work of Björn Helland-Hansen and Fridtjof Nansen »The Norwegian Sea». — Reports on Norwegian Fishery and Marine Investigations. Vol. II., 1909, No. 2. Bergen 1909.

slope of the shallow bank of the Barents Sea towards the deep basin of the Greenland Sea. But we have to make a move of about  $2^\circ$  of longitude towards the west to come to a district with corresponding depths. Perhaps several mistakes have combined together.

More comprehensive were the deep-sea soundings made during the Swedish expedition of 1868, which was conducted on the mail-packet *Sofia* and was directed by A. E. Nordenskiöld. As is well known, this expedition succeeded in penetrating with its ship further towards the North than had hitherto been done. With regard to the way in which the soundings were taken it would seem that no further information can be obtained than that which is to be found in Fries and Nyström's popular description,<sup>1</sup> from which we take the following. Speaking of the occupations on board, they write on p. 114, »And in the first place we must speak of the deep-sea soundings, which as a rule were taken twice daily and kept varying between 390 and 2 200 fathoms. The procedure was this: the vessel was moored by an ice anchor to some fairly large icefield and one of the apparatuses on board that have already been described (Bulldog's or Brooke's) was let down, sometimes with a bathymeter attached. When line after line had run out over the gunwale and the reduced pull at length showed that the apparatus had touched bottom and had taken hold in the obscure depths amongst wondering crustaceans and starfish the hauling up began — a tedious performance to which the ship's engine attended».

Later in the course of the expedition, namely on 23 September, however, they found in  $78^\circ 26'$  N. lat. and  $2^\circ 17'$  W. long, according to the result of the sounding, a still more considerable depth, namely 2 650 fathoms,<sup>2</sup> which is especially mentioned as remarkable in Fries and Nyström's description of the voyage (p. 160).

During the years 1876—1878 a number of soundings were taken by the Norwegian North-Atlantic expedition with the »*Vöringen*» in the Polar Sea west of Spitzbergen. For the construction of the bathygraphical contour map, of course, use was also made of older soundings, including those obtained by the Swedes during the »*Sofia*» expedition of 1868. H. Mohn in his memoir on »*Nordhavets Dybder, Temperatur og Strömninger*» (»The North Ocean, its depths, temperature and circulation»), mentions the above named deep-sea soundings in the following words: »North of the 'transverse ridge' between Jan Mayen and Beeren Eiland, the greatest depth of the Greenland Sea, between Greenland and Spitzbergen, is upwards of 2 600 fathoms, a depth sounded by the »*Sofia*» expedition, in 1868. This deep I shall call the »Swedish Deep». From that time onwards the point named has been called Svenska Djupet».

<sup>1</sup> Svenska Polarexpeditionen år 1868. Stockholm 1869.

<sup>2</sup> The bathygraphical data, which in the Swedish expedition were given in fathoms, probably mean Swedish fathoms: 1 Swedish fathom = 1.7814 m. = 0.9741 English fathoms.

When preparations for the Swedish Polar expedition of 1898 with the *Antarctic* were being made under the direction of A. G. Nathorst, I was entrusted with the task of conducting the hydrographical work which could properly be done without obtruding too much on the land investigations that formed the main object of the operations of the expedition. Professor Otto Pettersson, however, proposed that the hydrographical work should be extended to »Svenska Djupet»; and this proposal was accepted. Hence it became necessary to equip ourselves for really deep-sea soundings. I resolved not to burden the budget of the expedition with a costly Lucas machine or any other up-to-date sounding apparatus with piano-wire, but to effect soundings, determinations of temperature and the bringing to the surface of samples of water with a hempen line provided with marks at every hundred meters in general accordance with the methods that had been employed by the great English »*Challenger*» expedition of 1872—1876, the German expedition with the »*Gazelle*» in 1874—1877, and the Norwegian Arctic Ocean investigation with the »*Vöringen*» in 1876—1878. The nature of the sounding-line, the plummet and the way in which the soundings were carried out have been described by me in the memoir »*Hydrographische Arbeiten der von A. G. Nathorst geleiteten schwedischen Polar-expedition 1898.*»<sup>1</sup>

Coming from Isfjord and Prince Charles Foreland, we approached with a certain excitement the place where the sounding of 1868 had taken place. We thought we were there when on 28 Juli at 8 p. m. we took a sounding. But this gave as its result only 2 750 m in depth, instead of the 4 720 m of the old expedition. We then supposed that our position was erroneous owing to the fact that, since we had left the Foreland, we had not been able to determine our position astronomically owing to the cloudiness of the weather, but had to determine our position by dead reckoning. This suspicion proved so far correct that an observation taken on the following day showed that we had driven about 65 km too far to the south-west. We then steamed somewhat towards the north-east, in order to come as exactly as possible to the site of the soundings in 1868. We there took a new sounding, but found the depth to be only 2 690 m. This place we afterwards found to be  $78^\circ 13'$  N. lat. and  $2^\circ 28'$  W. long. Thus this place also lay somewhat SW of the site of the 1868 sounding, though only 20 km from it. Evidently in these attempts the current caused by the Polar Drift had played its part, and in this last-named case had diminished the distance sailed by 20 km. But as in the great sea basins variations in depth at any considerable distance from the coastal banks are usually rather small, I considered it to be proved that the bathygraphical statement of the expedition of 1868 was erroneous, for a fall of 2 130 m in 20 km was extremely improbable in a region that is not known for any volcanic disturbances. Professor Nathorst also considered, like myself, that »Svenska

<sup>1</sup> K. Sv. Vetenskapsakademiens Handlingar, Bd. 41, No. 1, Stockholm 1906.

Djupet» in its quality of being a very marked abyss in the Polar basin, must be regarded as non-existent. We believed that the incident was closed. This, however, appears not to be the case, but the ghost of »Svenska Djupet» still walks.

At the request of Professor A. Penck, in his capacity of Direktor für Institut für Meereskunde in Berlin, M. Groll worked out new bathygraphical maps of the oceans. They came out in 1911 and 1912, and a description written by Groll to accompany them was published in the years mentioned in the »Veröffentlichungen» of the Institute. In a map of the Atlantic we there find »Svenska Djupet» very prominently marked and occupying a length of about 120 km and a breadth of about half as much. We find from the description that Groll considers that my sounding of 2 690 m in 78°13' N. lat. and 2°58' W. long. does not certainly show that the »Sofia» expedition depth of 4 720 m (or possibly 4 846 m) found in 78°26' N. lat. and 2°17' W. long. is mistaken, inasmuch as, as I myself state, the distance between the two points is 20 km and a difference in depth of 2 000 m at this distance is not so unusual that the result of the older expedition should be rejected off-hand. Nevertheless Groll expresses himself hesitatingly and has even provided the old depth figure with a question mark, which, however, owing to the small scale of the chart, is imperceptible without a magnifying glass.

In some later Swedish publications also I have found mention of »Svenska Djupet». In J. V. Eriksson's »Havet och Livet» (»The Sea and Life») »Svenska Djupet» is mentioned without reservation and it is said that opposite Spitzbergen there have been soundings of 4 846 m. Professor Gerard De Geer also mentions »Svenska Djupet» cursorily in an article »Spetsbergen som utgångspunkt för den arktiska forskningen» (»Spitzbergen as a Starting-Point for Arctic Research») printed in the first number of the new periodical »Jorden Runt» (Jan. 1929). Speaking of a more detailed investigation from various standpoints of the deep strait between Spitzbergen and Greenland, he says:» at the same time, of course, Svenska Djupet, discovered by the 'Sophia' expedition to the west of Spitzbergen and, its animal denizens should be more closely investigated». Neither Eriksson nor De Geer says a word as to the contribution of the Nathorst expedition and myself to the question of the existence of »Svenska Djupet».

As I am still of the opinion that the depth figure in question taken from the year 1868 is due to a mistake, and as it would be regrettable if yet another Swedish expedition were to be equipped in order to investigate »Svenska Djupet» (which, in my opinion, has no existence in a limited meaning), I should like to take up the question for discussion.

In order to obtain more light, if possible, on the sounding method employed by the »Sofia» expedition, I have searched for the logbooks of the expedition and found them in the library of the Academy of Science. With the consent of Professor Baron Erland Nordenskiöld, they have been placed at my disposal. I have

not found any information of importance with regard to the sounding of 23 September in 78°26'.5 N. lat. and 2°16'.7 W. long., when the depth 2 650 fathoms was obtained. On the other hand, I made the noteworthy observation that on the following day, 24 September, in 78°32' N. lat. and 2°50'.5 W. long., a sounding was made from a row-boat which gave a depth of only 1 470 fathoms. This point lies only about 15 km NW of the previous sounding, that is to say still nearer than my sounding of 1898. It also shows that, if the sounding of »Svenska Djupet» (2 650 fathoms) is correct, it cannot in any event be a matter of the south-eastern end of a considerable basin or trough, but it must be a depression of very small extent, of about half the area of Lake Vänern and with a depth of about 2 000 m in relation to its surroundings. This makes the existence of the supposed »Svenska Djupet» still more improbable, for how should such a deep hole be formed? It cannot very well be an isolated tectonical »graben», nor can it be an explosion crater. The volcanic formations that come into existence on the floor of the sea — as, for instance, near the Canary Islands — have always the form of mountains, often with very steep sides, but volcanic depressions without surrounding heights would seem to be rare. Besides no volcanic formations are known from that part of the Arctic Ocean, the nearest — apart from the hot springs at Wijde Bay — being Jan Mayen, which is 8 000 km from »Svenska Djupet». This depth is improbable from the point of view also that in the whole of the Atlantic north of the Bay of Biscay no such great depth has so far been observed. However it must be confessed that the greater part of the Arctic Ocean is unexplored.

The cause of the mistake on the part of the Swedish expedition must have been the lack of any trustworthy method for soundings that exceeded 2 000 m. From the description given above (p. 150) one may surely draw the conclusion that they had not a continuous spliced sounding line rolled on a drum, but instead of that a considerable stock of short lines, which were tied together when required, and that they did not make any direct readings with a watch to determine the speed at which the line was paid out but endeavoured by computation to find out approximately when a diminution in the speed occurred in consequence of the plummet striking bottom. This determination, without the help of a watch, was bound to be highly subjective as soon as the depth became so great that the weight of the hanging sounding line by itself was still sufficient to keep the line lying on the deck taut and draw it out at a considerable pace.

The Swedish expedition of 1868 made yet another sounding that gave a depth which was surprisingly great in relation to the surroundings, namely that which was made on 24 August at 4 p. m. in 79°57'.1 N. lat. and 1°52'.3 E. long., where 2 100 fathoms was recorded. This sounding, like the previously mentioned one of 2 650 fathoms, is marked on the British Admiralty chart 2 282 »Arctic Ocean and

Greenland Sea», but quite close to it stands the figure 1 244, which hints that this sounding by the »Sofia» expedition is incorrect and excessively high.

By comparison with the logbook, however, we find that on the British chart a number of other soundings are taken from the Swedish expedition of 1868, and these seem to fit in very well with the surrounding depth figures. As examples of good concordance may here be cited the following soundings, made on almost the same spot, by the Swedish expedition of 1868 and the Norwegian North-Atlantic expedition of 1878.

»Sofia» Expedition, 1868.	Norwegian Expedition, 1878.
N. lat. .... 78°2'	78°1'
E. long. .... 6°44'	6°54'
Depth in fathoms 1 350	1 343

Thus there can be no question of expressing any distrust in the soundings of the »Sofia» expedition in general, but only of the two soundings mentioned, which yield unreasonable results. But almost all the older expeditions which have engaged in soundings in the open sea at great depths have been guilty of such mistakes.

A complaint might perhaps be lodged against the Nathorst expedition for not trying to reach more exactly the site of the »Swedish Deep».

But in the first place we thought this more or less in accordance with Mohn's bathymetrical chart as a basin with a cross-section of at least 100 kilometers; and in the second place it is not so very easy to reach a place exactly determined beforehand with a vessel not in touch with land. In this case the Arctic Current moving towards the south-west gave us difficulty: as we did not know beforehand its strength and extent, it made it really impossible in cloudy weather to keep an exact dead reckoning. Moreover the astronomical determination of a vessel's position is not very exact in itself. H. Mohn considers that, with regard to the determinations of position made by the Norwegian North-Atlantic expedition, we must allow for an error of  $\pm 1$  great circle minute in latitude and as much in longitude. Thus the probable error in every determination of position will be  $\pm 2.6$  km. Thus two separate attempts to reach one and the same place may diverge still more from one another. Obviously the determination of position on the sea, where no stable erection of instruments is possible and where it is necessary to confine oneself to such angle-measuring instruments as can be held in the hand, cannot possibly attain an exactitude comparable with determinations of position on land. The employment of a sensitive spirit-level is excluded, and instead of that use must be made of the dividing line between sky and sea to obtain the horizontal level, but this line is not always well defined and the refraction of rays of light on the horizon increases the uncertainty. But the greatest difficulties are

probably caused by the drifting of the vessel owing to wind and ocean currents, especially if cloudy weather intervenes, as is indeed shown by our attempts on the »Antarctic» to reach the site of the great depth-figures of the »Sofia» expedition. To reach a certain point, to a kilometer or so, under such circumstances would have been a veritable work of art, which could not possibly have been achieved without very special preparations. — Exactitude is also unfavourably affected by the fact that the determination of both the latitude and the longitude requires two separate sets of observations, made at an interval of about six hours.

With regard to my method of sounding, it would seem to have been somewhat superior to that which was used on the »Challenger» and the »Vöringen», in so far as I also determined the rate at which the line ran out after the plummet had touched bottom. The computation of the depth thus became what is known as a way problem, based on calculating the meeting-point on a way-length 100 m between two speeds moving in opposite directions (see the original treatise). I feel inclined to believe that this detail in the method is new. But nevertheless sounding with a hemp line certainly falls far short of modern sounding methods with piano-wire and an echo-sounding machine. Considerations of cost, however, put these methods out of the question for the Nathorst expedition.

The British Admiralty chart contains, in the tract in question, yet another depth-figure which strikes one as suspicious, that is to say the figure 2 187 fathoms' at 79°34' N. lat. and 2°40' E. long. Reduced to meters the figure becomes 4 000 m. This figure is found in De Gerlache's »Itinéraire de la *Belgica*» for the seventeenth station of the Belgian expedition on 12 July 1905, for which the latitude and longitude just now mentioned is given. If one turns up the tables on p. 171 in the report of that expedition<sup>1</sup> we find no sounding given. This circumstance seems to me to make the depth-figure mentioned dubious.

The most critically composed bathymographical map of those parts of the North Atlantic and the Arctic Ocean that are here in question which I know of — namely B. Helland Hansen and F. Nansen's »Bathymetrical chart of the Norwegian Sea», which accompanies their above-cited work — includes none of the great depth-figures criticized by me above. At the site of the »Swedish Deep» there are given, in addition to my sounding of 2 690 m, two others, namely 2 700 m and 2 107 m. Evidently these soundings are taken from stations 20 and 21 a of the Belgian expedition, for which the following geographical coordinates are given — 78°18' N. lat. 3°40' W. long. and 78°20' N. lat. and 4°27' W. long. respectively. The first of these two soundings in particular lies very near to the »Swedish Deep» and confirms the opinion that I have expressed above.

<sup>1</sup> Duc d'Orléans. Croisière Océanographique accomplie à bord de la *Belgica* dans la Mer du Grönland, 1905. Bruxelles 1907.