XIII.—ON THE SCIENTIFIC INVESTIGATION OF THE BALTIC SEA AND THE GERMAN OCEAN.*

By G. Karsten.

The following lines are designed to call attention to the investigations of the Baltic Sea and German Ocean, which have been in progress several years, and which are of especial interest in opening up a new field of observation, to which hitherto but little attention has been paid. The extensive experiments of the Americans and Englishmen have increased our knowledge of the physics of the ocean and its organisms, but not being made with the view to continued systematic investigations, they have resulted only in discovering for the time being certain relations for given points; the variations, be they of a periodical or a non-periodical nature, for one and the same locality could not be ascertained during the rapid passages through the ocean. But just these variations are of special significance, since upon them depends our knowledge of the phenomena of the currents and of the relations between the physical conditions and the phenomena of life, as in meteorology, where the final conclusions are not drawn from a few isolated observations but from a knowledge of the limits between which the variations take place. With this view, Dr. H. A. Mayer made extensive investigations of the physical conditions of the western part of the Baltic, hoping thereby to gain information regarding the variable character of the organic world, a fact established by his own observations as well as by those of R. Möbius. The observations of Dr. Mayer have shown that the western portion of the Baltic offers fluctuations in all the physical elements—in the height of the water, its temperature, and the proportion of salt—fluctuations which vary with the seasons and likewise in different years. These observations gave a sufficient explanation of the character of the currents, but in order to properly fix the laws of these currents the co-operation of a number of savans was found necessary, since only by simultaneous observations at many points the enterprise could be made a success.

The impulse to make the present investigation was given by the German Society for Fish-culture, which, fully comprehending its importance, requested the Prussian Government to have the work established. The government acted in accordance with this petition, and entrusted

* Translated by Dr. Oscar Loew.

the work to a Commission stationed in Kiel. This Commission took into consideration the following points, viz:

(*a*) Depth, height of the water, condition of the bottom, quantity of salt and air of the water, and temperature.

(*b*) Flora and fauna of the sea.

(*c*) Distribution, propagation, and migration of the useful animals—problems which required for their proper discussion and settlement observations at numerous stations along the coast, as well as on the high sea. From the preliminary observations of Mayer it was known that in the western part of the Baltic the variations in the water are analogous to those of the climate; further, it was established as a fact that the physical conditions of the eastern and western portions differed—for instance, the variations in the amount of salt show smaller differences in the eastern than in the western part. This is in another relation also found in the German Ocean. The work was commenced by establishing a number of stations along the German as well as the foreign coast, one station being at Heligoland. Two expeditions have thus far been sent out, one in 1871, another in 1872, the former to the Baltic, the latter to the German Ocean. The following is a brief summary of the work of the Commission, the mode of observation, and the results, with the exception of the part relating to organisms, for which the reader is referred to the publications of the Commission.

The most important points for determination were the *amount of salt* and the *temperature*. As variations in these depend upon the currents, and these again upon various causes, as the height of the water, the direction and velocity of the wind, the duration of ice-formation, the amount of rain and snow in the drift regions, &c., it was evident that a thorough study would require a long series of observations. The amount of air contained in the water could not be well determined on account of the want of methods sufficiently simple for the several stations. The proportion of salt is important for several reasons:

First. The difference in the amount of the saline substance is one cause of the currents, the heavier salt water having the tendency to flow to the deepest place. In this manner two currents may be produced—a vertical one when from some cause or other the upper strata become more concentrated, and a horizontal one when two strata of different densities lie side by side. The latter currents predominate in the German Ocean as well as in the Baltic Sea.

Second. The strata in motion will also have temperature of their own. For the waters in question this can be easily shown. The under current of the heavier water of the German Ocean can readily be recognized by its temperature upon its entrance in the Baltic, and the same is the case with the light upper current issuing from the Baltic.

An analogous difference is found in comparing the different strata of the German Ocean with the waters of the Atlantic. Furthermore, there is a certain relation between the amount of salt and carbonic acid contained in the water, and also between this and the organic life. The salt determinations are made with the hydrometer kept at the stations. It may be objectionable that the method used is not absolutely exact on account of the unequal composition of the salt in different parts of the sea. It is not necessary, however, to take this into consideration here, since the currents mainly depend upon the density of the water, which is indicated to a great degree of exactness by the hydrometer. At the stations there is no method simple enough for a trustworthy determination of the air contained in the water; the air collected from the water on expeditions, however, has been subjected to a chemical analysis.

The formula adopted by the Commission was well founded, being the result of the observation that an increase of the specific gravity of 0.0001 corresponded to an increase of 0.0131 per cent. of salt. The results thus far obtained are the following:

The specific gravity increases with the depth. In consequence of the German Ocean containing less salt than the Atlantic, and again the Baltic Sea less than the German Ocean, an under-current of heavier water can be traced flowing from west to east, and a lighter upper current flowing from east to west. This is shown by the current-meter as well as by the densities of the water and the difference in temperature. In very narrow straits, however, as, for instance, in the "Little Belt" and the "Alsensund," the different currents become turbulent and more or less mixed.

The intensity of the currents is variously changed by climatic influences, of which the wind is the most powerful. Prevailing westerly and southwesterly winds drive heavy currents from the Atlantic into the German Ocean and thence to the Baltic, at the same time retarding the light upper current. Easterly and northeasterly winds act reversely, diminishing the heavier under-current and increasing the lighter current on the surface. In accordance with the climatic conditions is the fact that the most salty water enters the Baltic in fall and winter, and the least in spring and summer. The amount of salt in the spring is reduced by the melting of the ice in the north and east; plentiful rains produce a like effect in summer. As the height of the water depends much upon the strength and direction of the wind, the percentage of salt will show a certain relation to the height. This relation, however, is not a simple one. Continuous west winds will not only increase the whole bulk of water in the Baltic, but also produce local differences between the height of the water on the eastern and western coasts, as above mentioned. We have then in the eastern part of the Baltic an increase of the mean level and a decrease of salt, while in the western part, the height of the water decreases and the amount of salt becomes greater.

Taking into consideration certain climatic relations, especially the wind, and the change of these relations in different years, it is clear that not only every stratum of water of a certain locality will show a difference in the amount of salt, but also that there will be deviations in different years; therefore only a prolonged period of observations can determine the average amount of salt of a certain locality. A glance at the following table will give an idea of the great variations taking place. Although the numbers are mere approximations, the differences are, nevertheless, considerable.

TABLE.—

Locality.	Surface.				Depth.				
	Maximum.		Minimum.		Fathoms.	Maximum.		Minimum.	
	Specific gravity at 63°.5, Fah.	Percentage of salt.	Specific gravity at 63°.5, Fah.	Percentage of salt.	1 fathom=6 feet.	Specific gravity at 63°.5, Fah.	Percentage of salt.	Specific gravity at 63°.5, Fah.	Percentage of salt.
I. BALTIC SEA.									
Helsingör*	1.0190	2.51	1.0062	0.81	16	1.0259	3.30	1.0086	1.16
Korsör*	1.0208	2.73	1.0088	1.19	20	1.0250	3.27	1.0154	2.02
Friedericia*	1.0203	2.66	1.0092	1.22	9	1.0220	2.88	1.0104	1.36
Svendborgsund*	1.0184	2.45	1.0085	1.15	7	1.0187	2.49	1.0095	1.26
Sonderbing	1.0211	2.76	1.0092	1.22	10	1.0243	3.20	1.0095	1.26
Eckern förde*	1.0174	2.30	1.0079	1.05	10	1.0204	2.67	1.0121	1.59
Friedrichs Ort	1.0201	2.63	1.0043	0.58	8	1.0219	2.87	1.0078	1.04
Kieler Hafen	1.0177	2.34	1.0000†	......	16	1.0196	2.58	1.0122	1.60
Fehmarnsund	1.0135	1.77	1.0072	0.96	6	1.0147	1.95	1.0090	1.20
Travemünde‡	1.0161	2.11	1.0093	1.24	5	1.0163	2.14	1.0093	1.24
Pöl‡	1.0160	2.10	1.0097	1.29	4	1.0169	2.22	1.0108	1.42
Warnemünde‡	1.0008	1.28	1.0063	0.83	5	1.0128	1.68	1.0072	0.96
Darser Ort	1.0133	1.74	1.0066	0.86	5	1.0152	1.99	1.0069	0.91
Lohme, Rügen	1.0094	1.25	1.0032	0.42	10	1.0095	1.26	1.0050	0.66
Neufahrwasser	1.0081	1.10	1.0019	0.25	3	1.0086	1.16	1.0035	0.46
Hela	1.0066	0.86	1.0014	0.19	....	....	.....	....	.....
II. GERMAN OCEAN.									
Ellenbogen, Sylt	1.0255	3.34	1.0208	2.73	7	1.0258	3.38	1.0215	2.82
Wilhelmshafen	1.0266	3.48	1.0220	2.88	8	1.0268	3.51	1.0222	2.91
Borkum	1.0276	3.63	1.0210	2.75	13	1.0277	3.65	1.0219	2.87
Heligoland§	1.0287	3.80	1.0244	3.22	4½	1.0288	3.81	1.0249	3.28

* Observed by A. H. Mayer.
† Consequence of ice.
‡ Not embracing a whole year.
§ Values probably too large in consequence of instrumental error.

With regard to the details of the currents and their relation to the wind the reader is referred to the publication of the Commission.

The temperatures.—Both bodies of water, the German Ocean and the Baltic Sea, show, in general, different relations as to temperature, but as they intercommunicate by way of the straits of Skagerak and the Kattegat, they exercise some reciprocal influence in this point of view. The condition of the Baltic with regard to climatic influences is almost that of an inland sea, owing to the insignificant extent of its junctions with the German Ocean and its greater outflow. Only in the vicinity of its junctions, and under certain circumstances at some distance from them also, there is a considerable influence brought to bear upon the temperature of the Baltic by the entering under-currents. The temperature of the Baltic varies greatly with the respective temperature of the air, the changes decreasing, of course, with the depth. The unequal temperatures of increasing latitudes will be equalized by the perpetual motions of the waters.

The German Ocean shows much smaller variations of temperatures, and undoubtedly will present different conditions at different points, being connected with the Atlantic in the North by a wide and in the South by a narrow channel, and again by a narrow channel with the Baltic in the East.

While throughout the year currents of but little variations enter the channels from the Atlantic, those from the Baltic are of various temperatures. This, together with the greater depth of the German Ocean, will suffice to show that it requires years of observation and prolonged study to determine the exact relations of temperature. The observations hitherto made for different strata can only be considered as initiating a closer study, the former investigations relating mainly to surface-temperatures. The observations along the coast not having to be made in great depths, the thermometer of the Commission could be of a simple construction. The thermometer for ascertaining the surface-temperature was very simple, reading to .2 of a degree; the temperature could be read either directly in the ocean or in a large quantity of water freshly drawn. For the observations of the temperature in deep water the thermometers were surrounded by a thick layer of India rubber, a poor conductor of heat. The instruments were compared, and the time necessary for each to indicate a change in temperature was noted, as well as that during which they marked the temperature of the water after being exposed to the air. An hour was ascertained to be the average time for each instrument to indicate the temperature of the depth, and fully five minutes that between the removal of the instrument from the water and any perceptible change. The thermometers always remained at the desired depth for one hour before the temperature was read.* During the expeditions upon the open sea this instrument could be used only when the ship or boat lay still or was anchored; in all other cases Casella's maximum and minimum thermometer was used. The results gained are the following:

The temperature of the surface-water of the Baltic, and with diminished extremes also that of the depths, varies with the temperature of the atmosphere. As an example the observations at two stations, Sonderburg and Kiel, are here given:

* These thermometers, surrounded by India rubber, can be had at Steger's in Kiel.

Month.	Sonderburg.			Kiel.			
	Atmosphere.	Surface of water.	Ten fathoms.	Atmosphere.	Surface of water.	Five fathoms.	Ten fathoms.
1869.							
January	34.82	34.9	34.9	34.19	36.7	36.9	39.9
February	40.60	38.7	38.8	40.54	38.7	39.0	40.3
March	35.31	37.4	36.7	35.47	37.8	39.0	41.0
April	48.87	44.4	40.8	48.44	48.2	44.4	42.1
May	51.26	51.8	47.5	51.92	53.6	39.3	43.2
June	54.90	53.4	48.0	54.90	57.2	56.1	41.4
July	63.10	59.7	55.2	62.74	65.7	61.7	42.1
August	58.90	51.6	60.3	59.10	63.3	63.0	43.5
September	57.36	59.4	58.3	56.34	60.3	59.4	44.8
October	46.74	52.2	51.8	46.90	53.6	54.9	48.6
November	38.64	42.3	42.8	39.00	46.6	47.5	48.9
December	35.17	41.4	40.3	35.60	39.8	43.2	43.7
Year	47.23	48.2	46.2	46.92	50.2	49.7	43.2

The correspondence of the temperature of the surface-water with that of the atmosphere is evident at a glance. In Sonderburg, however, the periodicity can be traced to a depth of 10 fathoms, while in Kiel a marked decrease is noticeable at a depth of 5 fathoms, and at 16 fathoms a shifting of the seasons and a great diminishing of the extremes. The wider distribution of heat at Sonderburg is produced by the strong current of the Alsensund, mingling different strata, while at a depth of 16 fathoms at Kiel, motion is produced only by the inflow of heavy currents, or by strong winds.

The temperature of the surface-waters is greater than that of the atmosphere; for the temperature of the latter is taken in the shade, while the surface-waters are greatly influenced by solar radiation. As it is hardly possible to recognize the law of the changes in temperature in one year, the following average values of six years of observation in Kiel will give a clearer expression of the retardation of the heating influence of the season:

Kiel, average of six years. (*Degrees Fahrenheit.*)

Month.	Atmosphere.	Surface.	Five fathoms.	Sixteen fathoms.
January	31.40	34.08	36.12	37.60
February	32.20	34.02	34.80	37.23
March	37.17	35.98	35.76	36.27
April	44.62	43.60	40.55	36.80
May	51.70	51.50	47.44	40.18
June	58.00	60.80	55.07	41.96
July	62.60	65.59	61.80	43.60
August	62.58	65.30	62.90	47.45
September	55.42	55.74	59.58	52.70
October	47.87	53.10	54.34	54.24
November	39.44	45.39	47.07	49.44
December	35.40	38.52	40.55	43.02
Six years	46.54	48.67	48.00	43.40

The annual period here enters regularly into the greatest depth. In the air and on the surface July is the warmest month; at 5 fathoms the heat of August predominates, while at 16 fathoms October is the warmest and March the coldest month. The variations of the average values between this table and the previous one, for 1869, demonstrate the inequality of the course of the temperature during the isolated years, and, further, that in the water, as in the air, the climatical differences are represented. Herein the extreme values of the temperatures of the air play a significant part. The following numbers may give an idea how the cold year of 1871, with its low temperatures, influenced the temperatures of the water even at great depths:

Kiel.

Month.	Atmosphere.		Surface.		Five fathoms.		Sixteen fathoms.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1871.								
January	37.4	5.0	32.9	33.3	32.0	27.9	32.7	30.4
February	50.0	−6.7	34.2	32.0	32.4	31.5	34.2	32.0
March	56.3	25.2	42.1	35.4	38.3	34.9	35.4	34.2
April	55.8	29.7	46.8	38.7	39.8	37.1	37.2	34.9
May	74.3	34.9	54.5	45.5	51.1	41.0	41.0	37.6
June	79.2	41.4	65.7	53.4	59.0	51.1	43.9	41.0
July	76.8	51.8	68.0	59.0	61.2	55.6	43.9	42.1
August	81.5	50.0	73.6	61.2	64.6	59.0	54.5	44.3
September	77.0	40.1	65.7	56.7	61.2	57.4	56.7	55.6
October	61.2	30.4	54.5	47.7	55.6	50.0	56.7	54.5
November	45.3	23.4	47.7	39.8	50.0	41.0	54.5	47.7
December	39.2	5.7	37.6	34.2	38.7	35.4	46.6	38.7

The low temperatures of the air during a severe winter, therefore, reduce the temperatures of all strata considerably below the usual average. These lower temperatures are maintained in the depth for a long period; in the following autumn they again suddenly increase. If then a mild winter follows, the higher temperatures remain for a longer time and keep the lower strata above the average values. The lowering of the temperatures of all the strata below 32° F. finds an explanation in the fact that the maximum density of the water of 2 per cent. salt, as at Kiel, is in the region of the point indicating 29°.8 F., and, therefore, vertically descending currents of the heavier water will effect a rapid equalization of temperature. This will be the more easily possible when, like in the winter months, all water-strata have an increased percentage of salt, with little variation between the different strata. If, however, the lower strata are considerably richer in salt than the upper, then the communication of the lower temperature of the latter will be slow, since the increased densities of the cooler upper strata do not reach the densities of the lower strata, notwithstanding the higher temperature of the latter; violent winds, however, would soon cause a thorough intermingling. The above-mentioned sudden changes of temperature in August and in autumn may be attributed to two different causes: *either* the strata mingle thoroughly, whereby the percentage of salt of the lower strata will be diminished and the temperature of the upper strata communicated to them; as, for instance, in 16 fathoms at Kiel, September 8, 1870, the specific gravity was 1.0167; temperature, 50° F.; September 13, specific gravity was 1.0155; temperature, 61°.2 F.; *or* a sudden entry of heavy underwater from the German Ocean, with its own higher temperature, takes place, replacing the lower cold strata of the Baltic. In the latter case the increase of temperature is combined with an increase of specific gravity. This was observed at Kiel on the 16th of August, 1871, when the specific gravity was 1.0118; temperature, 50° F.; while on the 21st of the same month the specific gravity was 1.0140; temperature, 56°.75 F. These sudden variations are very singular, for the reason that usually the changes in the depths are very slow and gradual, and often for weeks are scarcely perceptible. Such simultaneous changes of temperature and percentage of salt have been noticed at all observing stations along the Baltic. Thus, for instance, at Sonderburg it was observed that the temperature, which from the 13th of December, 1872, to the 22d of January, 1873, at 10 fathoms was lower than 41° F., suddenly changed to 42°.1 F., while at the same time the specific gravity of 1.0195 increased to 1.0243, owing to a powerful current of warmer and heavier water from the German Ocean. If, on the one hand, the Baltic in summer furnishes an excess of heat to the German Ocean by the upper current, the latter in winter, on the other hand, by the under current effects a rise of temperature in the former. This source of heat for the winter is of especially good service in the western portion of the Baltic, and is certainly an important climatic element. It is not yet established with certainty how far to the east this under current extends. The smaller the percentage of salt the greater the maximum of density; hence it is probable that, notwithstanding the lower temperature of the winter in the north and east, the water in the greater depths never cools to the extent of that in the west. Experience, however, on this point is wanting.

Regarding the relations of temperature in the German Ocean, but few observations have thus far been made. Stations were not established previous to 1872. The facts observed, however, are (1) the annual period of the temperature of the water decreases towards the west; (2) the difference of temperature between the strata of different depths is smaller than in the Baltic; and (3) a decrease to the freezing-point never occurs. During the expeditions currents from different sources could easily be traced by the thermometer and hydrometer; for instance, the currents of the Elbe and Baltic. The following table from Mayer's work contains some older observations on the average temperatures of the Baltic, Kattegat, and Irish coast, which show very distinctly the decrease of the differences in the annual periods:

Month.	Baltic.	Kattegat.	Irish coast.
January	35.8	....	46.6
February	36.3	....	45.7
March	36.9	36.3	45.9
April	44.6	42.6	48.4
May	52.7	49.5	51.8
June	59.0	54.7	55.4
July	64.6	60.8	58.7
August	64.8	62.1	60.1
September	59.9	57.8	59.4
October	53.4	52.0	55.2
November	44.6	42.8	49.1
December	39.9	....	48.2

But only by a long series of observations it can be determined to what extent these differences decrease at the different points of the German Ocean in contradistinction to the temperatures of the Baltic, what influence is brought to bear by the currents in different seasons, and what relations in greater depths the period of higher temperatures will show.

It will be seen from the following series of one year's observations at Heligoland that in the German Ocean, the temperatures of the waters of all strata are subjected to greater changes than the temperatures of the waters of the Irish coast although these changes are much smaller than those of the Baltic.

Month.	Air.			Surface.						Half fathoms.					
				High tide.			Low tide.			High tide.			Low tide.		
	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.
1872.															
September	59.02	76.10	45.50	62.64	64.6	58.5	62.51	64.6	58.5	63.20	65.1	59.0	63.10	65.0	59.0
October	51.13	61.47	46.85	55.90	58.3	54.0	55.88	58.1	54.0	56.81	59.0	54.9	56.78	59.0	54.9
November	45.25	54.50	32.67	50.74	54.0	49.1	50.74	54.0	49.1	51.30	54.9	49.5	51.30	54.9	49.5
December	37.20	47.75	25.47	44.61	48.6	41.9	44.61	48.6	41.9	45.00	49.1	42.1	45.00	49.1	42.1
1873.															
January	38.35	45.50	25.47	41.90	41.9	41.9	41.90	41.9	41.9	42.18	42.1	41.9	42.20	42.1	41.9
February	33.98	42.12	18.50	39.44	39.8	38.7	39.44	39.8	38.7	39.77	50.4	38.7	39.73	40.5	38.7
March	37.70	50.00	28.62	39.59	40.5	36.7	39.61	40.6	38.7	40.44	41.4	39.4	40.44	41.4	39.4
April	42.82	55.62	32.90	43.10	44.6	41.0	43.05	44.4	40.7	44.10	46.8	41.7	41.10	46.8	41.7
May	48.42	58.55	40.77	46.71	48.6	44.6	46.71	48.6	44.6	47.47	48.6	46.8	47.45	48.6	46.8
June	59.02	72.72	48.20	53.90	57.2	48.9	53.90	57.2	48.9	53.23	55.4	49.3	53.21	55.4	49.3
July	63.14	74.07	52.70	61.37	64.4	57.2	61.37	64.4	57.2	60.82	63.9	55.4	60.84	63.9	55.4
August	62.39	72.95	54.30	64.85	65.1	62.6	64.85	65.1	62.4	63.95	64.8	62.4	63.99	64.85	63.0
Year	48.2	....	....	50.3	....	....	50.3	....	....	50.7	....	....	50.7	....	....

The difference of 29° in the temperature of the atmosphere between the coldest and the warmest month is lowered to 24°.5 in the surface-water, and at a depth of 4½ fathoms to 24°. The absolute extremes, however, are as follows: In the air, 57°.6 F.; in the surface-water, 26°.1, and in deep water, 24°.3. The average volume of the heat of the water in all strata exceeds that of the heat of the air, and it is therefore probable for Heligoland that a source of heat must be looked for in the entering heavier under-current of ocean water. Although the temperature of the air falls considerably below the freezing-point, the temperature of the water at Heligoland in all the strata remains above this point, and, without doubt, this difference causes one of the principal differences in the development of organisms which cannot be explained by the differences in the percentage of salt.

For further information the reader is referred to the report of the Commission.

AUXILIARY APPARATUS.

For the various observations many auxiliary implements are required, such as lead-lines, hoisting-apparatus, sounding-cups, water-bottles, &c. A few words may be said in relation to these, since the usefulness of areometric determinations depends upon the well-working of the machinery.

To secure specimens of bottom water a simple arrangement, first used by Dr. H. A. Mayer, is employed. A strong, well-corked flask is lowered to the desired depth, when it is uncorked by a sudden jerk of the line; the drawing up may be easily done, as experience has shown, without a noticeable change in the quality of the water. This arrangement, however, cannot be used for any but moderate depths, having, like all other means for this purpose, the disadvantage of not permitting a gas-analysis, the air of the bottle becoming partially absorbed by the entering water. An examination of waters thus obtained shows the presence of irregular quantities of the permanent gases, partially derived from the air of the bottle. With the view of exact areometric determinations and gas analyses the Commission has made use of various instruments, those of Professor Dr. Jacobsen, in Rostock, and of Dr. H. A. Mayer proving the best. The apparatus of Jacobsen consists of an India-rubber bag partially filled with mercury and freed from air by pressure. The cork is self-regulating, opening as soon as the bottom is reached and closing again when the bag is drawn up. The apparatus of Mayer consists of a wide, open metallic cylinder, with bottom valves, and permits the bringing up of water from any depth. For further details, especially regarding the amount of carbonic acid, reference is made to the annual reports of the Commission.

Of the other apparatus used during the investigation we only mention the current-meter. The instruments permitting of determination of the direction and intensity of the currents are very defective. From an anchored ship it is comparatively easy to determine the surface-current, but not when the vessel is in motion, especially as regards the determination of the under current. On a firm position or from an anchored ship, the Commission made use of a simple apparatus consisting of two metallic plates combined crosswise and fastened by a fine wire. The current pressing against the plates shifts them from a horizontal position, and thus the strength of the current is approximately determined by angle of deviation. This instrument, however, is not sufficiently sensitive for a weak current, and does not admit of an exact determination of the velocity. Floating bodies combined with the plates also worked unsatisfactorily for the under currents, the upper currents interfering with the indication of the instrument; it was found to be perfectly useless when the ship was in motion or when drifting with the current. As the determinations of velocity and direction of these currents are of great importance, the invention of a good current-meter is very desirable.

Deep-sea investigations proper have been made by the Commission only in a limited sense; the greatest depths investigated were in the Baltic amounting to less than 200, and in the German Ocean to less than 400 fathoms. In such depths it is not difficult to manipulate the instruments. The determination of depth can be made by simple means; the bringing up of bottom may be done by dredging. Should the Commission have occasion to make more extended investigations of the German Ocean currents, or the Navy enter upon such scientific labors, it would be desirable to introduce improvements in the measurement of depths, the apparatus thus far employed not being sufficiently accurate. For trustworthy determinations an apparatus operated by the pressure of the water is required. Some instruments have been constructed upon the principle of Mariotte's law of compressed air, but they are not sufficiently sensitive. It would probably be best to make use of spring-manometers constructed for high pressures of the ocean depths. The knowledge of temperatures and percentage of salt will be highly valuable only in connection with exact measurement of depth.

The Commission hopes that the government will continue the means for carrying on the investigation in question. When the expeditions become more frequent and numerous, and the Navy and commercial ships participate, science cannot fail to be considerably enriched by important results. There will then be occasion to solve many more interesting problems not thus far studied, for instance the changes in the mean level of the ocean, or the secular changes in the level of the coast, the question of the intensity of light in various depths of the water, etc., etc.